BBC

SCIENCE • HISTORY • NATURE • FOR THE CURIOUS MIND

earth

INCORPORATING BBC SCIENCE WORLD

ASIA EDITION | **VOL** 9 **ISSUE** 3

GRAVITATIONAL WAVES DETECTED p24

UNSOLVED MYSTERIES OF THE DINOSAURS

Advanced discoveries that might change what we know p30

IS THIS **THE END OF FISH** AS FOOD? p38

THE **KILLING** OF **LADY JANE GREY** p44

SECRETS OF THE **HAPPIEST PEOPLE** IN THE WORLD p66

PPS 1875/01/2016 (025609)
MCI (P) 072/09/2016 ISSN1793-9836

9 771793 983016 03

SGD 7.50 | THB 240 | NT 200 | RM 18

Regent Media

Access to clean and pure drinking water, ensures a better tomorrow.

For centuries, women in India like Chandni,
have had to walk miles to collect potable water.

Thankfully this is no longer necessary.

To find out more, visit www.me-peii.com

CDP A LIST 2016 WATER

Mitsubishi Electric water treatment systems.
Helping communities across Asia.

eco Changes for a greener tomorrow

www.mitsubishielectric.com.sg

MITSUBISHI ELECTRIC
Changes for the Better

Proud sponsor of PLANET EARTH II on BBC earth

A WALK IN THE PARK

No, it does not refer to any neighbourhood parks. I am talking about Jurassic Park, the 1993 American science-fiction adventure film made famous worldwide by Steven Spielberg. Whether it was the original film made 24 years ago, or the latest instalment – Jurassic World – released in 2015, dinosaurs are often painted as reptilian and full of loud roars. You might think that palaeontologists are pleased with the increased number of fossil discoveries in recent years, but instead of adding on to existing theories, it seemed like a whole new discovery is made and things just isn't what they seem to be. Flip the pages to learn more about the latest puzzles solved in the world of dinosaur research (p30).

In other news, 31 January may be a bad day for salmon-lovers as they learn about the decline in farmed salmon production. Norway and Scotland salmon farms (two of the world's biggest exporters) have been decimated by sea lice, while a toxic algae bloom killed enough fish in Chile to fill several Olympic swimming pools. With that being said, poor fishing practices for decades also add on to the drastically decreasing population of edible fish and it may spell the end of fish as food. We got in touch with a marine biologist; writer and keen scuba diver to reveal new innovations that could help reverse the damage (p38).

Enjoy the issue!

Josmin Ong
josmin@regentmedia.sg

"LIKE" US ON FACEBOOK! **www.facebook.com/earthmagazine**

✉ We welcome your letters, while reserving the right to edit them for length and clarity. By sending us your letter you permit us to publish it in the magazine and/or on our website. We regret that we cannot always reply personally to letters.

BBC earth

BBC Earth Magazine

Includes selected articles from other BBC specialist magazines, including *Focus, BBC History Magazine and BBC Wildlife Magazine.*

FOCUS www.sciencefocus.com

History www.historyextra.com

Wildlife MAGAZINE www.discoverwildlife.com

IMPORTANT CHANGE:

The licence to publish this magazine was acquired from BBC Worldwide by Immediate Media Company on 1 November 2011. We remain committed to making a magazine of the highest editorial quality, one that complies with BBC editorial and commercial guidelines and connects with BBC programmes.

The BBC Earth television channel is available in the following regions: Asia (Cambodia, Hong Kong, Indonesia, Malaysia, Singapore, South Korea, Thailand, Taiwan)

SCIENCE • HISTORY • NATURE
FOR THE CURIOUS MIND
Know more. Anywhere.

BBC Earth Magazine provides trusted, independent advice and information that has been gathered without fear or favour. When receiving assistance or sample products from suppliers, we ensure our editorial integrity and independence are not compromised by never offering anything in return, such as positive coverage, and by including a brief credit where appropriate.

Experts in this issue…

DR STEPHEN BRUSATTE

Dr Stephen Brusatte is a palaeontologist and evolutionary biologist at the University of Edinburgh. He reveals the enduring mysteries that are baffling dinosaur experts today. p30

HELEN SCALES

Helen is a marine biologist, broadcaster and writer. She reveals the detrimental results of poor fishing habits over the past decades and what can be done to reverse the damage. p38

NICOLA TALLIS

Nicola is a Historian who graduated from Bath Spa University with a first class BA Honours degree in History. Here, she explains why Lady Jane Grey was doomed by her father's foolishness. p44

JHENI OSMAN

Former BBC Focus editor Jheni is a science writer and presenter. She finds out how the world's happiest people keep smiling through winter. Maybe we can pick up a tip or two from her. p66

CONTENTS VOL. 9 ISSUE 3

FEATURES

28 Adventures in Victoria, Australia
Extend learning beyond the classroom with an educational trip down to Victoria

30 Unsolved Mysteries of the Dinosaurs
What colour were they? Did they have feathers? And what's the story behind T.rex's short arms and large head?

38 There aren't plenty more Fish in the Sea
Stocks of fish in our oceans are declining rapidly. So what can we do about it?

44 The Curse of the Nine-day Queen
Lady Jane Grey was put on the English throne by her scheming father-in-law and condemned to death by her own father...

50 Meet your second Brain
Britain's freshwater fish are often overlooked by naturalist, thus Jack Perks wishes to film every species of freshwater fish in the UK

56 Bouncing Back
African wild dogs were once on the brink of extinction. Here's a good piece of news where certain environments allowed the predator to flourish

62 Winston Churchill: Atomic Warrior, Nuclear Peacemaker
At the dawn of the Cold War, Churchill was one of the west's leading champions of the atomic bomb. What changed his attitude to nuclear weapons?

66 Secrets of the Happiest People in the World
Denmark is the happiest country on Earth, apparently. What do the Danes know that the rest of the world doesn't?

72 Understand De-Extinction
Extinct animals may have a chance of being brought back to life, thanks to intriguing advances in cloning and gene editing. But would it be the real deal?

UPDATE

12 The Latest Intelligence
Scientist reverse signs of ageing, dinosaur tail found trapped in amber, robot given the human touch, 2016 best scientific breakthroughs

81 Q&A
How do fish sleep, why does rubber have high friction, could we make shoes that walk on water, what colour is the sky on an exoplanet...

REGULARS

3 Welcome
A note from the editor sharing her thoughts on the issue and other ramblings

6 Snapshot
Stunning images from the fields of science, nature or history

24 Comment & Analysis
Helen Czerski explains why Rice Krispies make so much noise in milk

96 Witty Viewpoints
Robin Ince mentioned it takes an average of 66 days to form a new habit

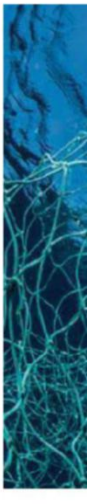
97 My Life Scientific
Meet Prof Danielle George, a professor of radio frequency engineering

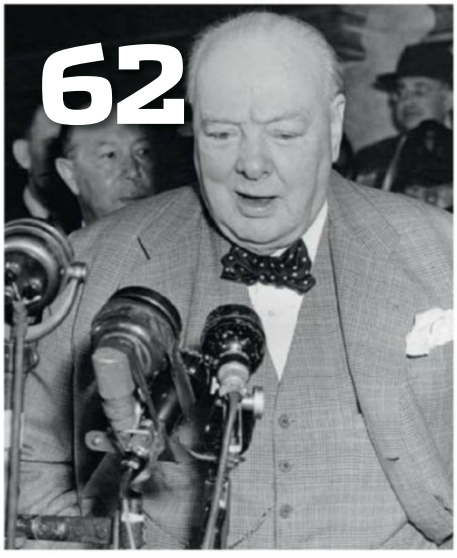
98 The Last Word
Robert Matthews discusses about closure and letting theories go

RESOURCE

90 Show & Book Review
Q&A with Rob Pilley and a study of the brain

95 Time Out
Crossword puzzles to stimulate your brain





BBC earth

SEND US YOUR LETTERS

Has something you've read in BBC Earth Magazine intrigued or excited you? Write in and share it with us. We'd love to hear from you and we'll publish a selection of your comments in forthcoming issues.

EMAIL US AT:

editorial-bbcearth@regentmedia.sg

We welcome your letters, while reserving the right to edit them for length and clarity. By sending us your letter you permit us to publish it in the magazine and/or on our website. We regret that we cannot always reply personally to letters.

BULK SUBSCRIPTION

Having just one copy of BBC Earth Magazine isn't enough to go around? Not to worry – Discounts on bulk subscriptions are now available for schools, libraries and organisations who are keen to order more than 50 copies per issue.

For enquiries or to place an order, email to subscription@regentmedia.sg or call us at +65 6446 6888 today!

BBC earth

BBC Earth Magazine, MCI(P) 072/09/2016, ISSN 1793-9836, PPS 1875/01/2016 (025609), is published by Regent Media Pte Ltd under license from Immediate Media Company Bristol Limited. Printer: KHL Printing Co Pte Ltd (197801823M) Address: 57 Loyang Drive Singapore 508968.

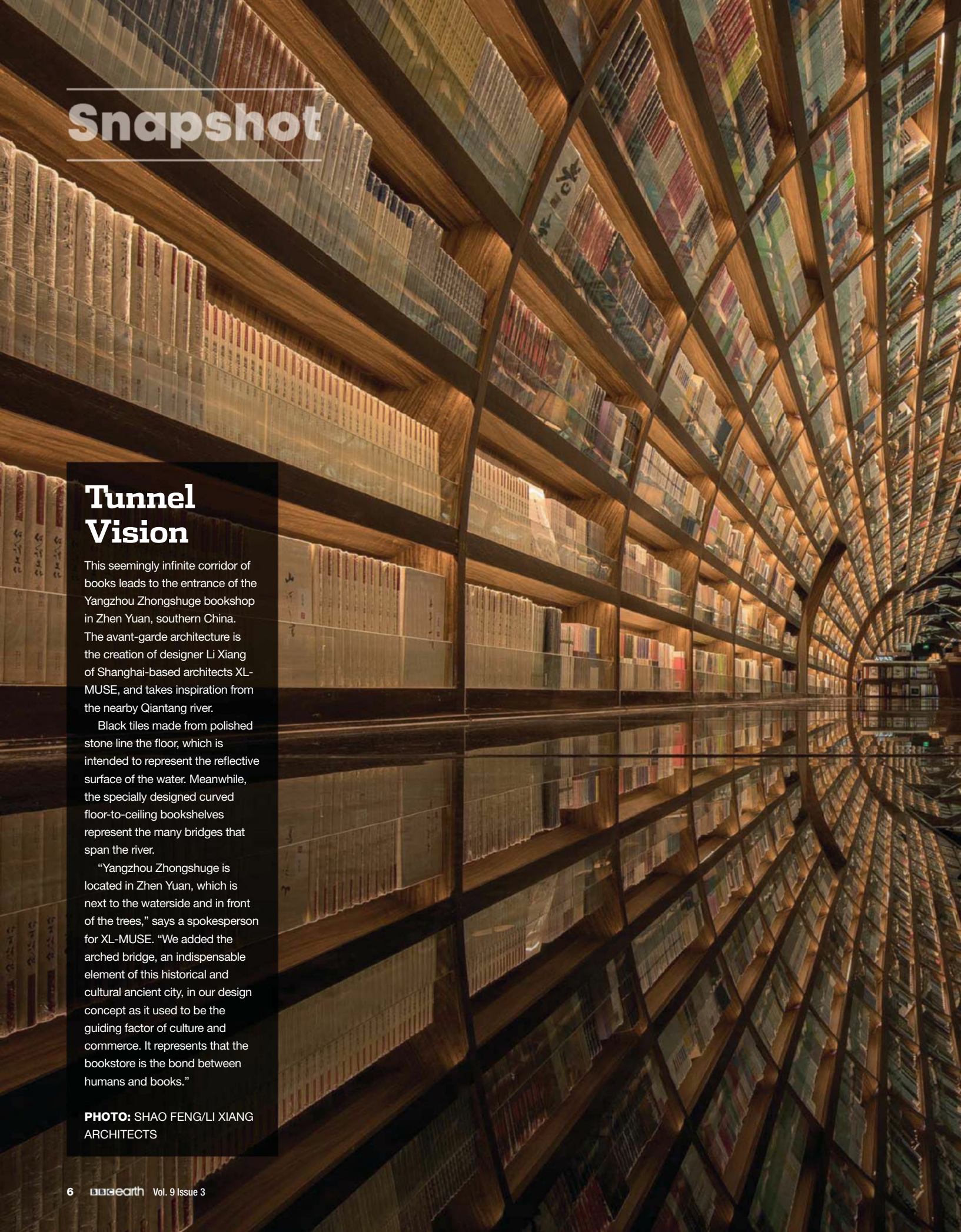
HERE'S HOW TO GET IN TOUCH

PHONE **Subscription, editorial and advertising enquiries**
Tel: 6446 6888 **Fax:** 6449 9945

EMAIL **Advertising enquiries**
sales@regentmedia.sg

Subscription enquiries
subscription@regentmedia.sg

POST **Subscription, editorial and advertising enquiries**
Regent Media Pte Ltd
20 Bedok South Road, Singapore 469277



Tunnel Vision

This seemingly infinite corridor of books leads to the entrance of the Yangzhou Zhongshuge bookshop in Zhen Yuan, southern China. The avant-garde architecture is the creation of designer Li Xiang of Shanghai-based architects XL-MUSE, and takes inspiration from the nearby Qiantang river.

Black tiles made from polished stone line the floor, which is intended to represent the reflective surface of the water. Meanwhile, the specially designed curved floor-to-ceiling bookshelves represent the many bridges that span the river.

"Yangzhou Zhongshuge is located in Zhen Yuan, which is next to the waterside and in front of the trees," says a spokesperson for XL-MUSE. "We added the arched bridge, an indispensable element of this historical and cultural ancient city, in our design concept as it used to be the guiding factor of culture and commerce. It represents that the bookstore is the bond between humans and books."

PHOTO: SHAO FENG/LI XIANG ARCHITECTS

Snapshot

Harsh Climes

Seen here is the Dallol salt dome. It rises from the floor of the Danakil Depression – part of the East African Rift, and one of the hottest places on Earth – in northern Ethiopia. The Dallol salt dome lies at the heart of a system of hot springs, geysers, salt flows and oily lakes that give off acidic gas and smoke. The dome forms as briny water from springs evaporates when it reaches the surface, leaving the salts behind.

As conditions here are thought to be similar to those that prevailed on our planet when life first emerged, the area is of great interest to those studying 'extremophile' life forms. Until recently, scientific research in the area has been limited, due to the war between Ethiopia and neighbouring Eritrea. But January 2016 saw a team of ecologists, microbiologists, geologists and crystallographers spend two weeks gathering samples under military protection.

Since then, they've been busy analysing all the specimens they collected. All we know so far is that they can "confirm the presence of extremophilic microorganisms," but astrobiologists, in particular, will be waiting to read their findings with great interest.

PHOTO: OLIVIER GRUNEWALD

Snapshot

Election Day 2016

An American flag is visible in the windows of the cupola aboard the International Space Station. Thanks to a bill passed by Texas legislators in 1997 that put in place technical voting procedure for astronauts – nearly all of whom live in Texas – they have the ability to vote from space through specially designed absentee ballots. To preserve the integrity of the secret vote, the ballot is encrypted and only accessible by the astronaut and the county clerk responsible for casting the ballot.

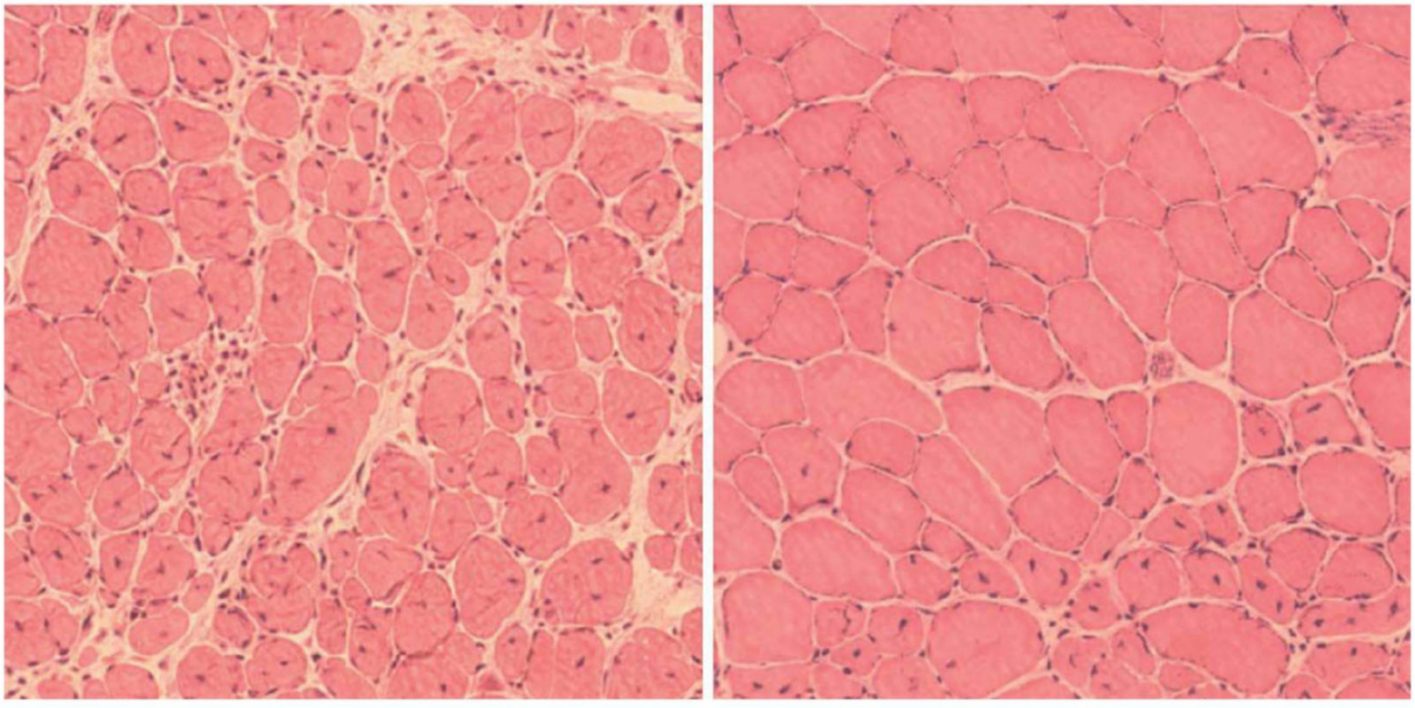
PHOTO & TEXT: NASA

GENETICS

SCIENTISTS REVERSE SIGNS OF AGEING

New genetic treatment using stem cells suggests we can turn back the clock on old age

PHOTO: SCIENCE PHOTO LIBRARY



It has long been known that manipulating certain genes in an organism can slow ageing and extend its lifespan – but the creation of genetic techniques to safely halt or reverse age-related conditions in humans has so far proved elusive.

However, researchers at the Salk Institute of Biology in California have developed a new technique that could be a first step towards the medical world's fabled 'elixir of youth'.

The method, recently outlined in the journal *Cell*, involved 'switching on' four genes associated with stem cells. It appeared to reverse some signs of ageing in both human skin cells and live mice. The four genes, known as 'the Yamanaka factors', are often used by researchers wanting to turn any type of cell into unspecialised cells known as induced pluripotent stem cells (iPSCs). These cells are capable of dividing indefinitely and becoming any cell type present in the body.

Previous studies found that when cells are made to express Yamanaka genes and turn into iPSCs, they appear younger, having been stripped of the cellular markers of ageing as they revert back to a more fundamental cell type. Yet to induce cells to turn into iPSCs en masse in a live animal would mean many cells cease to function in the way organs need them to, causing organ failure and ultimately death.

However, researchers at the Salk Institute decided to try making cells express the Yamanaka factors cyclically, in bursts. The hope was that the cells would begin to experience some of the age-defying effects of the Yamanaka genes without actually turning into stem cells.

"THIS STUDY SHOWS THAT AGEING IS A VERY DYNAMIC AND PLASTIC PROCESS"

The researchers first tested this idea with skin cells from mice and humans. When they applied their method of cyclically turning on the expression of Yamanaka factors, the cells showed reversal of multiple ageing hallmarks, but did not lose their identity as skin cells.

Next, the researchers used the technique in live mice affected by progeria, a disease that causes accelerated ageing. After inducing the animals to express the genes in short bursts, their cardiovascular performance improved, as did the function of other organs, and the animals lived 30 per cent longer.

Crucially, the mice were not more likely to develop cancer, which is a fundamental drawback of many stem cell-based techniques.

Finally, the scientists turned their efforts to old but otherwise normal mice. In these animals, the technique led to an improvement in the ability of the pancreas and muscles to repair themselves, a key process that deteriorates with age.

"Obviously, mice are not humans and we know it will be much more complex to rejuvenate a person," says Izpisua Belmonte, one of the study's co-authors. "But this study shows that ageing is a very dynamic and plastic process, and therefore will be more amenable to therapeutic interventions than what we previously thought."

PHOTOS: ESO, GETTY

SPACE

SUN-LIKE STAR EATS PLANETS FOR BREAKFAST

It seems that planet-destroying Death Stars aren't just confined to *Star Wars* movies. Astronomers have discovered a solar system with a host star a lot like the Sun, and it appears to have swallowed up some of its planets.

The study, which was published in *Astronomy & Astrophysics*, focused on HIP 68468, a star about 300 light-years away with a mass roughly that of our Sun. These 'solar twins' are of great interest to astronomers because they can tell us more about the likely past, and future, of our own planetary neighbourhood.

Using the 3.6m telescope at La Silla Observatory in Chile, the international team of scientists discovered two potential exoplanets orbiting HIP 68468: a giant planet that's 50 per cent more massive than Neptune and a 'super-Earth', three times the mass of our own. Even more intriguingly, analysis of the star's chemical composition revealed that it contains four times more lithium than would be expected for its age, as well as a high level of 'refractory elements' – heat-resistant metals that are abundant in rocky planets.

The most likely explanation for these unexpected elements is that the star has a history of ingesting planets, which would have deposited lithium and other metals in the stellar atmosphere. Taken together, the star's extra material is equivalent to the mass of six Earths.

So could the same thing happen in our own Solar System? "It doesn't mean that the Sun will 'eat' the Earth any time soon," explained Prof Jacob Bean, a co-author of the study. "But our discovery provides an indication that violent histories may be common for planetary systems, including our own."

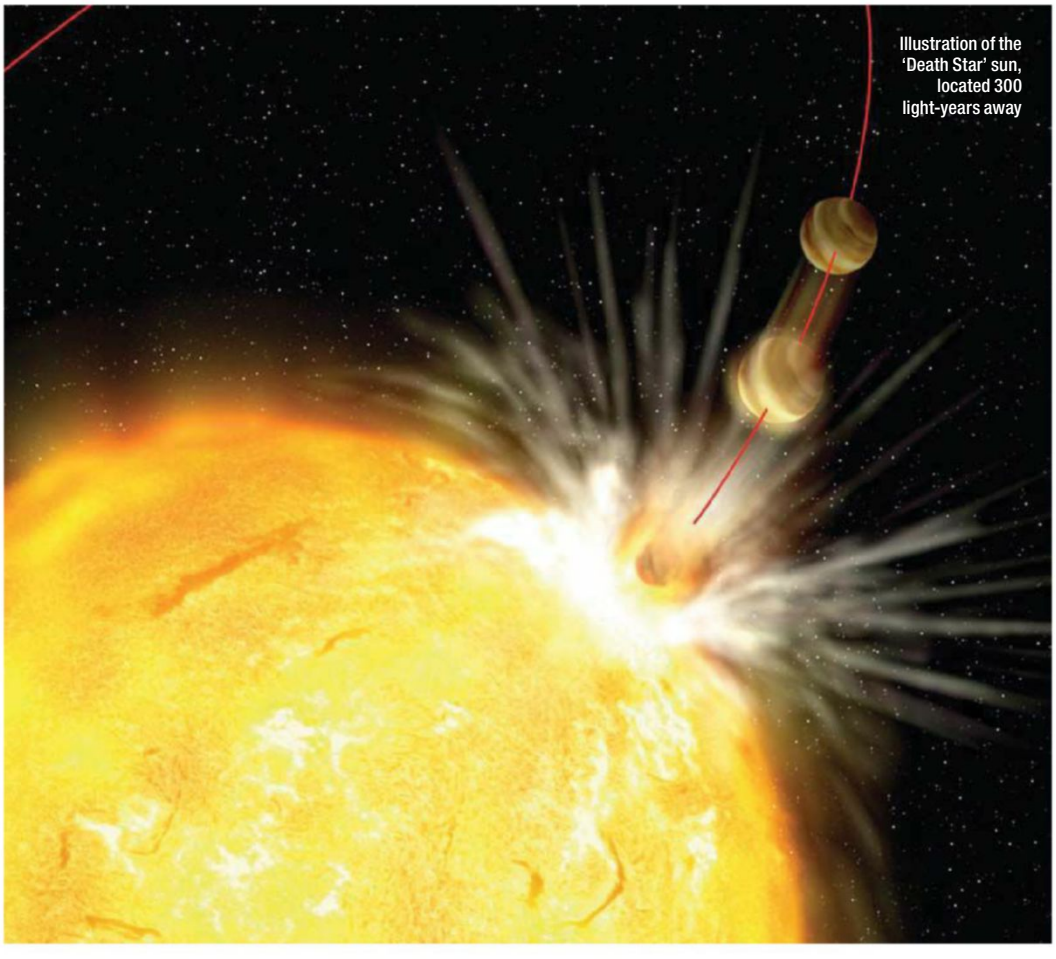


Illustration of the 'Death Star' sun, located 300 light-years away

PHOTOS: ESO, GETTY

IN NUMBERS

136

The number of different dance moves used by male flamingoes to woo females, as discovered by researchers in the south of France.

4kg

The average amount of weight gained by students during their time at university, as reported by researchers at the University of Vermont. The effect is due to poor diets and high rates of alcohol consumption, they say. No surprise there, then.

19m

The height of the biggest wave ever recorded. It was clocked by a buoy set up by the World Meteorological Organisation in the North Atlantic in February 2013 but was only recently officially recognised.

DINOSAURS

DINOSAUR TAIL FOUND TRAPPED IN AMBER

This really is a telling tail: researchers from China, Canada and the UK have discovered a dinosaur tail, complete with its feathers, trapped in a piece of amber.

The tail, consisting of eight vertebrae surrounded by feathers, belonged to a juvenile bipedal dinosaur that was preserved in mid-Cretaceous amber about 99 million years ago. While dinosaur feathers have been found in amber before, earlier examples have been difficult to link to their source animal.

"We can be sure of the source because the vertebrae are not fused into a rod or pygostyle [a triangular plate that supports the tail feathers] as in modern birds and their closest relatives," said researcher Ryan McKellar. "Instead, the tail is long and flexible, with keels of feathers running down each side. In other words, the feathers are definitely those of a dinosaur, not those of a prehistoric bird."

After investigating the sample with microscopes and CT scanners, the researchers found that the tail probably had a chestnut-brown upper surface and a pale underside. Layers of soft tissue layer around the bones contain traces of ferrous iron, a relic left over from red blood cells trapped in the sample.

"Amber pieces preserve tiny snapshots of ancient ecosystems, but they record microscopic details, three-dimensional arrangements, and labile tissues that are difficult to study in other settings," said researcher Ryan McKellar. "This is a new source of information that is worth researching with intensity, and protecting as a fossil resource."

PHOTOS: RYAN MCKELLAR, ERIC GUTIERREZ/STANFORD UNIVERSITY

DINOSAURS

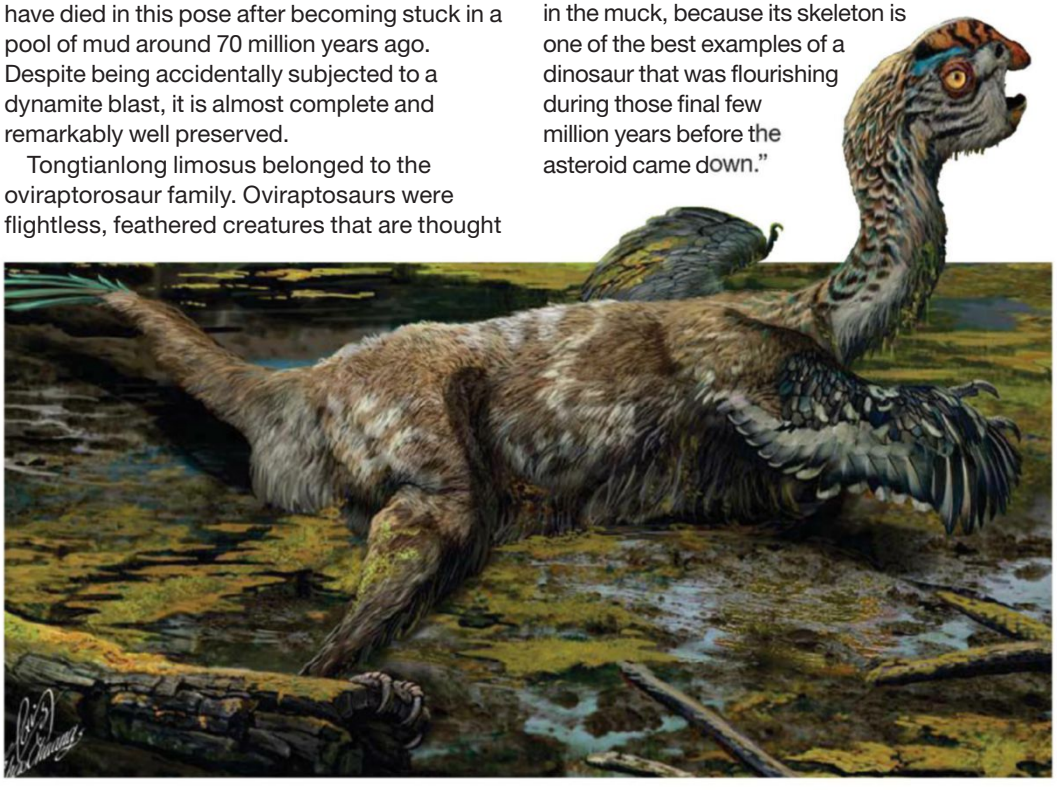
‘MUD DRAGON’ FOSSIL DATES BACK TO DINOSAURS’ LAST DAYS

This is Tongtianlong limosus, or ‘muddy dragon on the road to heaven’ – a new species of feathered dinosaur that was recently unearthed near Ganzhou in southern China.

The fossil was found by researchers from the University of Edinburgh and the Chinese Academy of Geological Sciences on a construction site where a new school was being built, lying on its front with its wings and neck outstretched. It’s believed the dinosaur may have died in this pose after becoming stuck in a pool of mud around 70 million years ago. Despite being accidentally subjected to a dynamite blast, it is almost complete and remarkably well preserved.

Tongtianlong limosus belonged to the oviraptorosaur family. Oviraptosaurs were flightless, feathered creatures that are thought to have been one of the last groups to flourish before an asteroid impact killed off all the non-bird dinosaurs, some 66 million years ago. It walked on two legs and had a prominent crest of bone on its head, much like that seen on modern-day cassowaries.

“This new dinosaur is one of the most beautiful, but saddest fossils I’ve ever seen,” said the University of Edinburgh’s Steve Brusatte. “But we’re lucky that the Mud Dragon got stuck in the muck, because its skeleton is one of the best examples of a dinosaur that was flourishing during those final few million years before the asteroid came down.”



ABOVE: The Mud Dragon, as it’s been nicknamed, was covered in feathers but couldn’t fly
BELOW: The *Tongtianlong limosus* specimen is remarkably well preserved

WHAT WE LEARNED THIS MONTH

FOOTBALL REFS HAVE SUPER VISION

Belgian researchers have found that top-level football referees have enhanced visual perception that makes them better at spotting foul play. It seems that the ref doesn’t need glasses after all.

CATCHY SONGS SHARE COMMON MELODIES

A team at Durham University has found the catchiest pop songs feature motifs that rise then fall in pitch, unusual melodic leaps, and lots of repetition. Topping their list of songs that fit the bill was Bad Romance by Lady Gaga. Rah rah, ah-ah-ah…

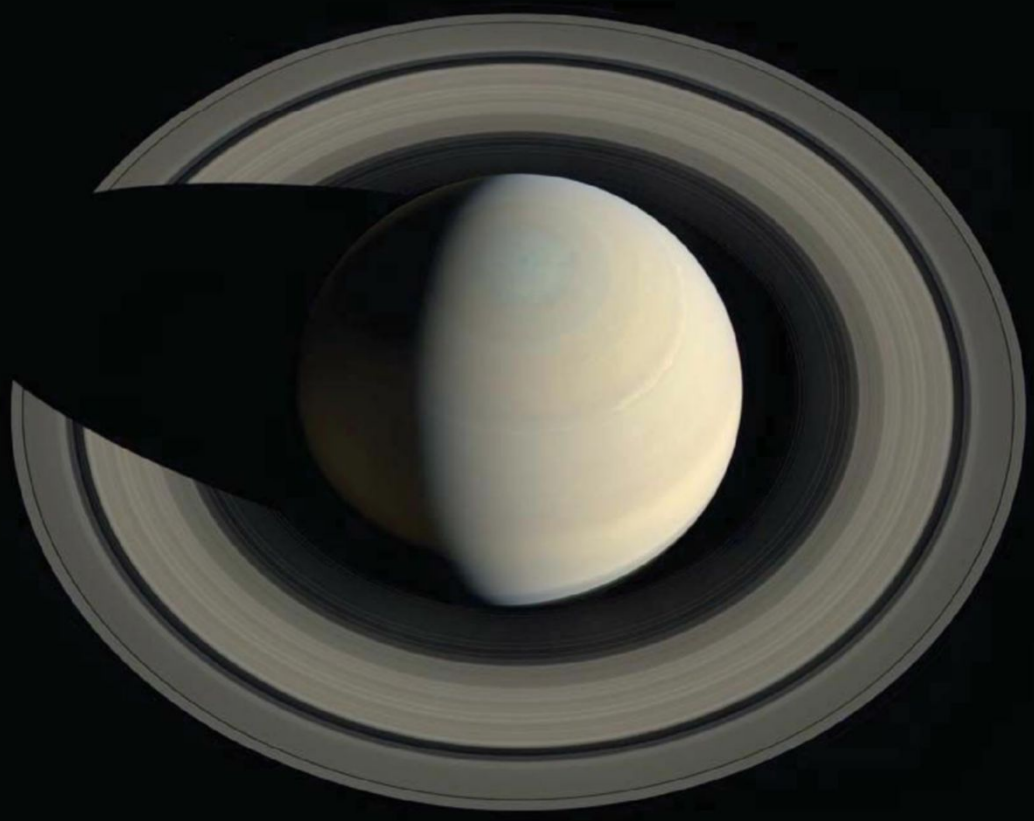
SWIFTS SPEND MOST OF THEIR LIVES IN THE AIR

The common species of swift flies for 10 full months of the year, landing only to breed, a team of Swedish researchers has found. It’s the longest known time spent on the wing by any bird.

WE ARE HARD-WIRED TO PREFER RED FOOD

It looks like all those hours spent unsuccessfully trying to convince your little ones to eat their greens might have been a waste of time. A team in Trieste, Italy has found we have a natural preference for red food due to its higher calorific content.

PHOTOS: NASA X2, JUNCHANG LU, ZHAO CHUANG



SPACE

DID SATURN STEAL ITS RINGS FROM INTRUDING DWARF PLANETS?

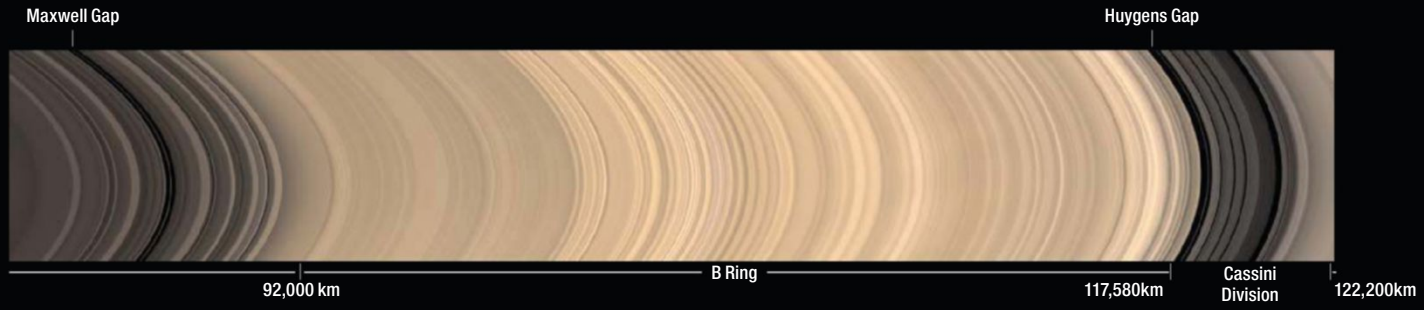
Thanks to its distinctive pattern of rings, Saturn is one of the most recognisable and spectacular sights in the Solar System. But exactly how the gas giant's signature halo got there has always been something of a mystery.

Now, researchers from Japanese and French universities have found that the chunks of ice and rock that make it up may have come from collisions with thousands of Pluto-like bodies.

Around four billion years ago, the orbits of the giant planets in the Solar System – Jupiter, Saturn, Uranus and Neptune – became unstable. It is thought that this created a change in the gravitational pull on thousands of Pluto-sized bodies in distant orbit around the Sun, drawing them into the deeper into the Solar System where they collided with the planets. This could explain why there are so many craters on the surface of the moon.

By modelling this event using supercomputers at the National Astronomical Observatory of Japan, the researchers found that the fragments broken off from these planetary collisions may have been captured by the giant planets and drawn into orbit around them. Further collisions between these fragments could then have broken them down even more, leading to the formation of the rings we see today.

BELOW: Saturn's rings consist of 99.9 per cent pure water ice, with a total mass of 3×10^{19}kg



PHOTOS: NASA, LORI SANDERS/HARVARD

ROBOTICS

ROBOT GIVEN THE HUMAN TOUCH

Artificial hands with an almost human-like sense of touch could be on their way.

Although some modern robots do have 'fingers' and are able to pick up delicate objects, they usually rely on cameras and proximity sensors to determine where an object is – the robot doesn't actually 'feel' anything. Now, a team at Cornell University's Organic Robotics Lab has managed to give a soft prosthetic hand a refined sense of touch. The robot was so sensitive that it could identify which tomato out of a group of three was the ripest, simply by pressing its finger onto the surface of each piece of fruit.

To give the robot a sense of 'touch', the team embedded an LED light source and a system of stretchable optical waveguides – structures that steer waves of light in a particular direction – below the surface of the robot's 'skin'. When nothing is being touched, the waveguides steer light from the LED straight to a sensor, but when the hand comes into contact with an object, the waveguides become deformed, and hence steer less of the LED light towards the sensor.

"Most robots today have sensors on the outside of the body that detect things from the surface," said researcher Huichan Zhao. "Our sensors are integrated within the body, so they can actually detect forces being transmitted through the thickness of the robot, a lot like we and all organisms do when we feel pain, for example."

Optical waveguides have been used in sensing systems for years, but this new development has been made possible by advances in lithography and 3D printing, which have enabled the production of waveguides that are sufficiently small and flexible at a reasonable cost.

PHOTOS: GETTY, ALAMY ILLUSTRATION: RAJA LOCKEY

NATURE

BUTTOCKS ARE TO CHIMPS WHAT FACES ARE TO HUMANS

These guys definitely don't judge things at face value. Chimpanzees can recognise each other instantly simply by looking at each others' buttocks, in the same way that humans recognise each other by looking at faces.

Working at the Kyoto University Primate Research Institute in Japan, a team of researchers led by neuropsychologist Mariska Kret from the University of Leiden compared how rapidly humans could recognise faces, and how quickly chimps could recognise buttocks, compared to other objects. Their research found that while humans are better at recognising faces, chimpanzees are better at recognising buttocks.

"Faces are enormously important for people, and all the features of our faces are optimally arranged to be seen and to communicate," explained Kret. "Over the course of evolution, our faces have acquired more contrast: red lips, the whites of our eyes, eyebrows and a smooth skin that makes everything more visible."

These are all signs of good health and play a key role in sexual arousal. In chimps, however, such 'signals' tend to be found in the nether regions. "It is not without reason that it's the face and buttocks of female primates that are free of hair, which makes the skin and colour all the more visible," said Kret.

What's more, in humans the 'face inversion effect' means that faces shown upside-down are recognised more slowly, whereas inverting pictures of other objects has no effect on recognition time. The same applies to chimps and buttocks, further suggesting that chimps' brains prioritise buttocks in the same way ours prioritise faces.

As humans and chimps are so closely related, the study sheds new light on how the ways our brains process visual information may change over time as a result of evolution.

Chimpanzees recognise each other by their buttocks, just like we recognise each other by our faces

THEY DID WHAT?!

ATHLETES TOLD TO TAKE UP SWINGING

They did what?!
A group of parkour athletes were asked to swing through trees like orangutans.

What did they do?
Researchers at the University of Roehampton set up an artificial canopy imitating the high branches of trees in a jungle, and monitored the energy use of parkourists – athletes who traverse urban environments – as they jumped, climbed and swung around it.

Why did they do that?
They wanted to investigate how different approaches to moving around in trees affected apes' energy expenditure, to shed light on why some apes live on the ground and others in the trees. Doing this with real apes in the wild is difficult, so parkourists were the next best thing.

What did they find?
Climbing was found to consume the most energy. However, energy consumption when jumping and swinging varied according to branch stiffness, gap distance and the athlete's size and weight. Further research is needed to determine what makes the orangutan 'king of the swingers'…

CLIMATE CHANGE

"IT'S NOW POSSIBLE TO SEQUENCE THE GENES THAT ARE ACTIVE IN THOUSANDS OF INDIVIDUAL CELLS IN A SINGLE EXPERIMENT"

Climate change is driving animals out of their natural ranges. Prof John Wiens has been studying just how bad these 'local extinctions' are becoming

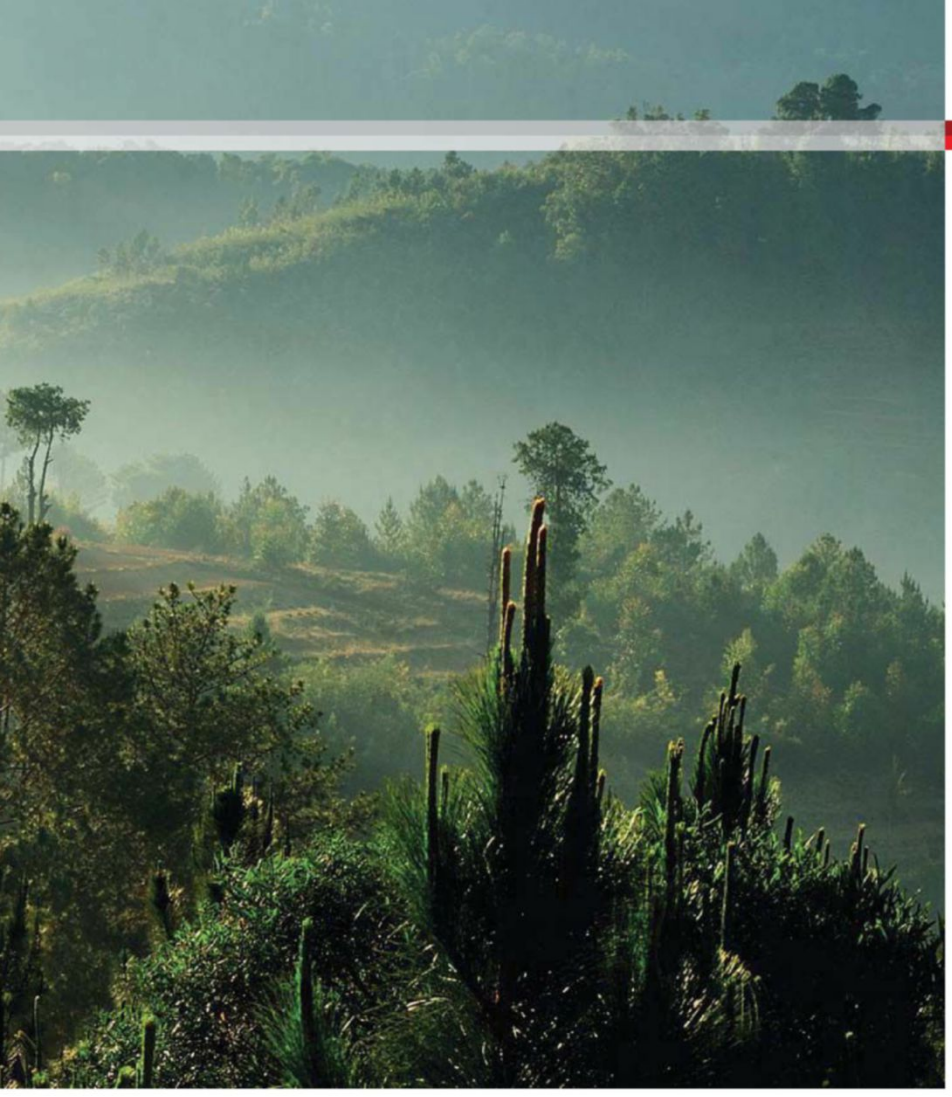
How might species respond to warmer temperatures?
They could stay and change themselves: maybe spend more time in the shade, where their tolerances expand. We call that a 'niche shift'. Or they can adapt evolutionarily. But my study shows that doesn't seem to be happening. Instead they're tracking the suitable climate over space.

How does climate affect a species' geographic range?
Temperatures get cooler as you move higher in elevation, towards the top of a mountain, or higher in latitude, towards the North or South Pole. Every single species has a sort of elevational range and a latitudinal range. We call the lowest latitudes and elevations the 'warm edge' of a range because they have the highest temperatures. That's where we expect to see species affected by climate change.

RIGHT: A lemur in Madagascar. Climate change is expected to have devastating effects on wildlife in tropical regions

What are 'local extinctions'?
Local extinction means that in one place, all the individuals are gone. So it's not necessarily the whole species' range, but in that particular place, people can't find it anymore. Maybe 50 or 60 years ago, they looked at a bunch of species along a mountain slope and documented what species were there, then in the past 10 to 15 years they've found it's different.

So how many species have gone locally extinct?
In one or more parts of their ranges, 47 per cent out of 976 [surveyed]. The other 53 per cent were able to stay at their 'warm edges'. This is the climate change that has happened so far which, relative to what's expected, is actually really small. So there's been less than a 1°C increase [in average global temperature] but still there's these local extinctions across the whole planet in about



ABOVE: Madagascar, one of the regions that was looked at in Prof Wiens' study

BELOW: Prof John Wiens of the University of Arizona

half the species that anybody has looked at. It's going to get worse. We think there's going to be an additional increase of between 1°C and 5°C, so I think that a lot of species are going to lose most or all of their ranges, and a lot of them will go extinct.

You found that extinction is greater in tropical zones. Why is that?

It's almost a two-fold difference. That has an intuitive explanation: in the tropics there's much less seasonality. At low elevations it's warm all year long, and at higher elevations it's cool all year long. Whereas in temperate zones, it's hot in the summer and cold in the winter. So if you're in the temperate zone, you have to be able to tolerate a broad range of conditions, and that's not so in the tropics. We think most species on Earth are in the tropics, so it's vital to note that there could be more loss of species.

Will local extinctions affect humans?

Particularly in the developing world, 50 per cent of humans' diet is coming from grasses. If you have a bad crop year, people will die. Those are places where, instead of the plants being irrigated, they depend a lot on local climatic conditions. It's very bad. It doesn't have to be extinction of the entire species, because even a local extinction will be devastating for people.

CURVY WOMEN

Researchers at the University of Oxford have found ladies with plump posteriors are healthier and more intelligent than their counterparts. The effect is due to the increased storage of Omega 3 fats, they say.

THE HAPPILY MARRIED

Forget fame and fortune – all you really need to lead a happy, fulfilling life is a loving partner. Researchers at the London School of Economics have found having a partner boosts our happiness three times more than doubling our salaries does.

GOOD MONTH

BAD MONTH

FISH AND CHIP SHOPS

Anyone for squid and chips? The increasing temperature of the North Sea is forcing cod out of UK waters, says the Centre for Environment, Fisheries and Aquaculture Science. They will be replaced by warmer water species such as squid.

EXAM CRAMMERS

It's the night before a test and you haven't done any revision. But last-minute cramming is unlikely to work. Researchers at Tufts University have found that the extra stress it causes leads to more information being lost from your memory.

2016 WASN'T ALL BAD

Thanks to outbreaks of Zika and MERS, the deaths of David Bowie, Prince and Harambe, and other untold tragedies, 2016 has been a bit of a stinker. But keep your chin up, here's our pick of the five biggest breakthroughs made last year

SPACE

JUNO MADE IT TO JUPITER

In July, NASA's Juno space probe completed its five-year journey to Jupiter. A month later the probe successfully executed its first flyby of the gas giant, travelling at more than 200,000km/h and passing within 4,200km of the planet's swirling clouds.

Scientific instruments onboard the space probe are designed to measure the planet's magnetic field, atmospheric composition and landscape. At the time of writing, Juno has so far beamed back stunning pictures of Jupiter's poles, aurorae, and violent atmospheric storms.

The probe is scheduled to complete a total of 36 flybys before finally plummeting into the planet's surface at the end of its mission in February 2018.

This image of Jupiter's swirly atmosphere was created using photographs taken by Juno

NEUROSCIENCE

PARAPLEGICS TRAINED TO WALK AGAIN

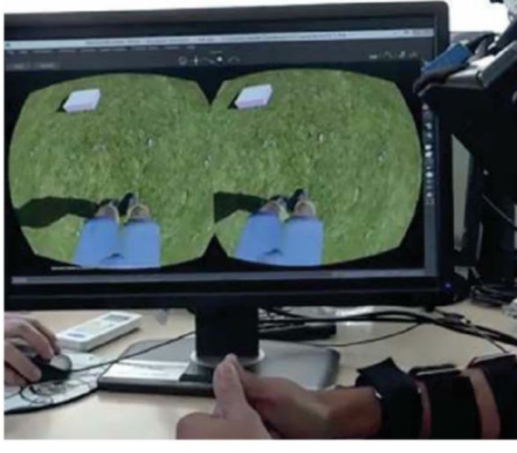
Scientists based at the Walk Again Project, in São Paulo, Brazil, announced in August that they were able to train eight patients with spinal cord injuries how to move their legs using robotics and virtual reality.

The team fitted the patients with electrode caps that could read the motor commands produced by their brains. They found that when they asked the patients to think about moving their legs no signals were produced. But by hooking them up to a VR walking simulator, the team was able to retrain the patients' brains to 'remember' how to use their legs, despite some of them being paralysed for more than 10 years. The most successful patient is now able to drive, and can walk using a frame.

The effect is likely to be due to the brain reorganising itself during the training and generating new electrical commands to send to the remaining nerves in the legs, the researchers say.

The team is now planning to conduct a new trial on patients who have suffered recent spinal cord injuries to see whether quicker treatment can lead to faster or better results.

VR isn't just for gaming – it has helped paraplegics learn how to walk again



PHYSICS

LIGO DETECTS GRAVITATIONAL WAVES

One hundred years after they were first predicted by Albert Einstein's General Relativity, gravitational waves were directly detected for the first time ever by researchers at LIGO (Laser Interferometer Gravitational-Wave Observatory) in February.

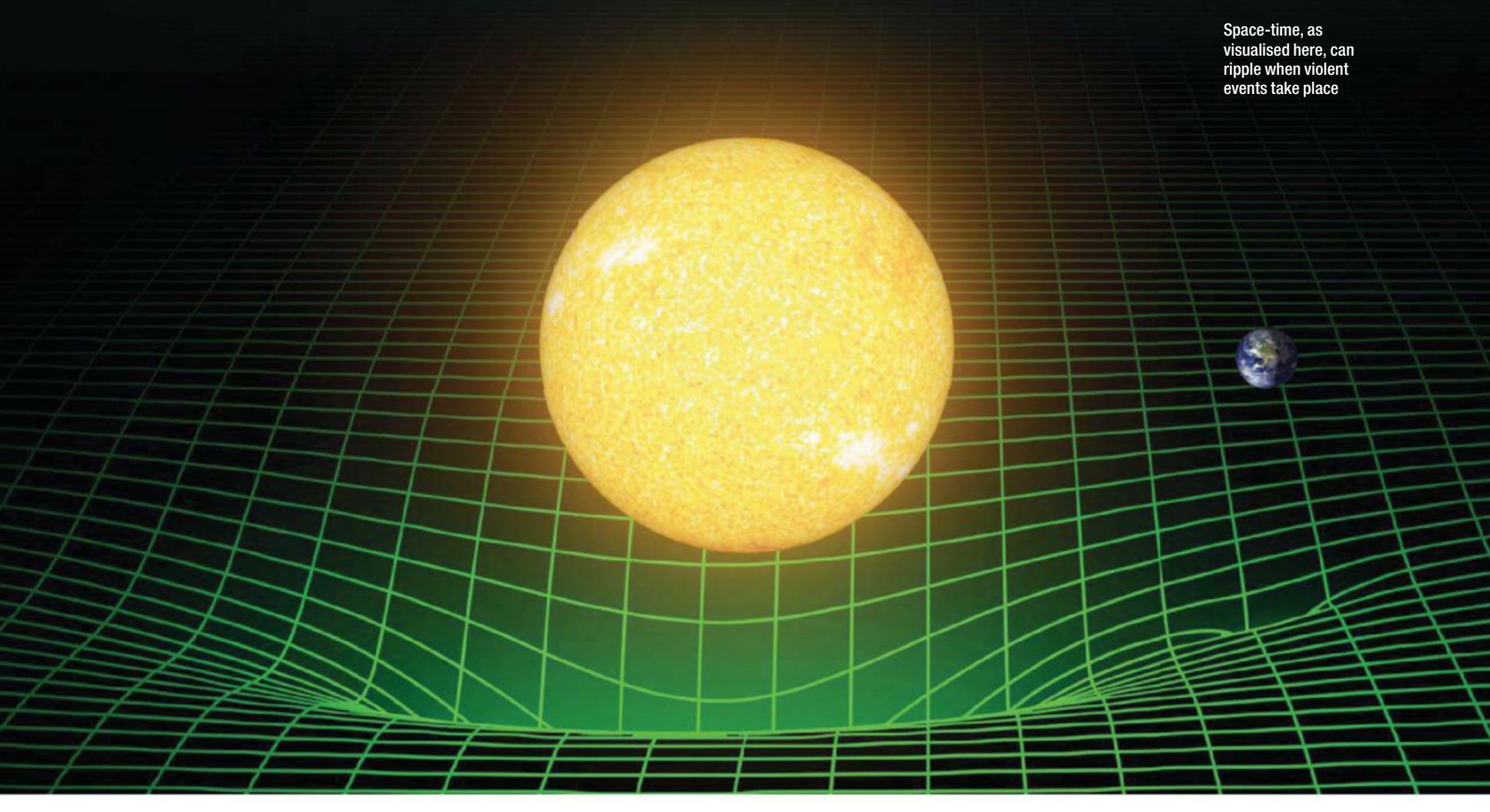
Gravitational waves are ripples in the fabric of space-time generated by violent events such as the collision of massive objects like black holes. They travel across the Universe stretching and squeezing space-time as they go. It took so long to find them because their effect is so weak – even Einstein doubted we would ever be able make an instrument sensitive enough to pick them up.

The waves observed by the team were generated by the collision of two black holes, about 29 and 36 times the mass of the Sun, which occurred 1.3 billion light-years away, meaning they have taken 1.3 billion years to reach as gravitational waves travel at the speed of light.

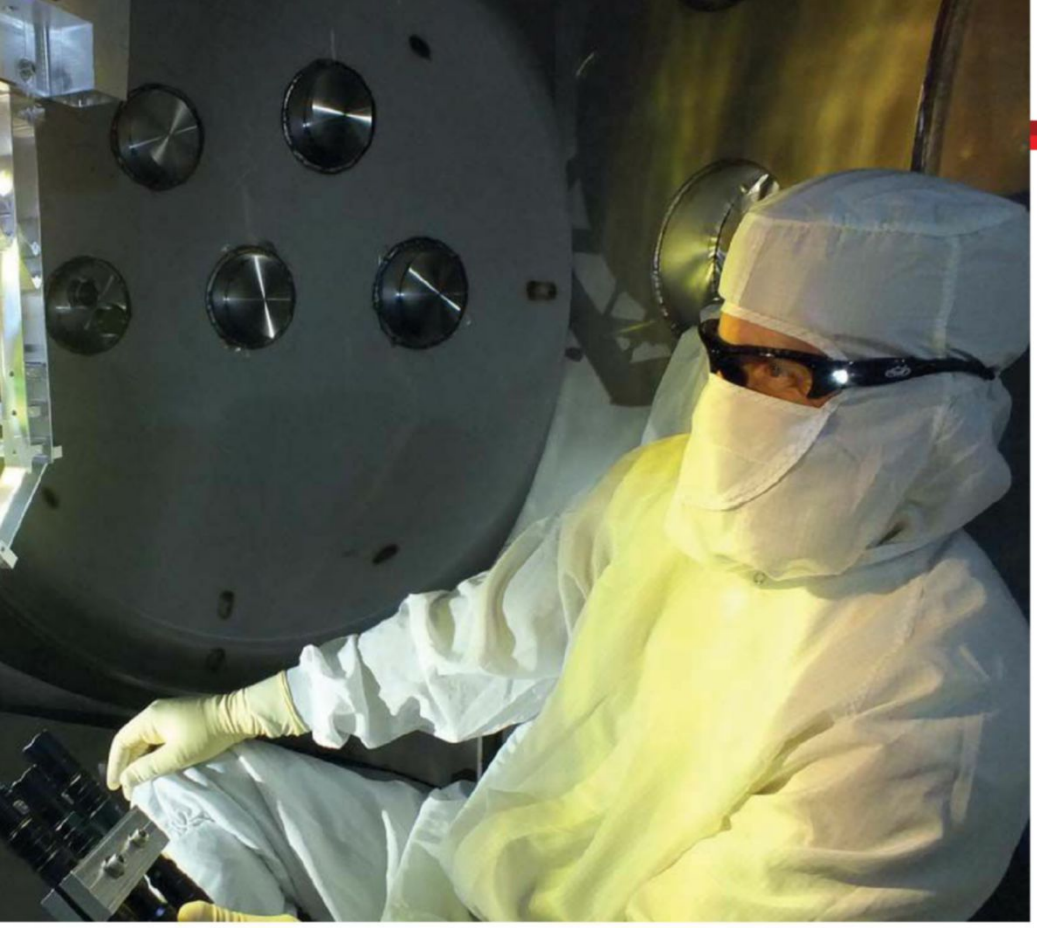
In June, the team announced they had observed gravitational waves for a second time, resulting from a collision between another pair of black holes. These ones were smaller, at 8 and 14 times the mass of the Sun, and located 1.4 billion light-years away.

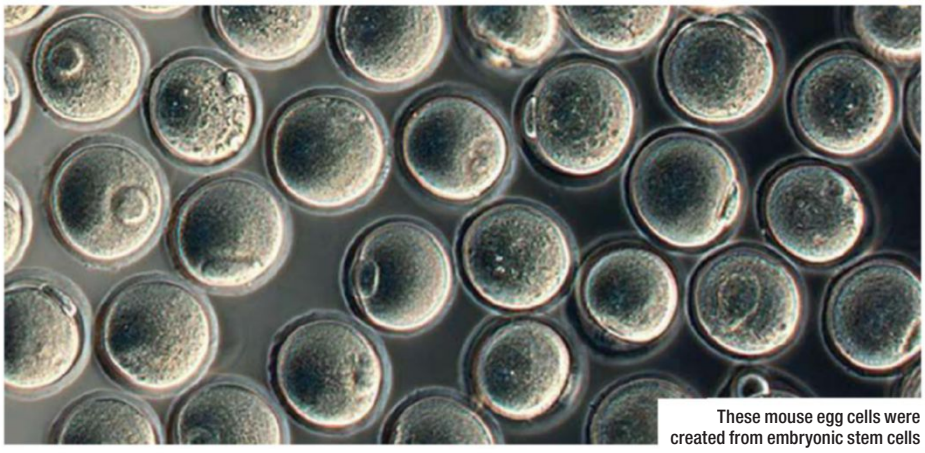
The observatory is currently partway through a second, more sensitive run, looking for gravitational waves generated by the mergers of neutron stars, the incredibly dense cores of collapsed massive stars.

A researcher checks LIGO's equipment



Space-time, as visualised here, can ripple when violent events take place





These mouse egg cells were created from embryonic stem cells

BIOLOGY

HEALTHY MICE BORN FROM LAB-GROWN EGGS

Another world first was announced in October, when Japanese researchers reported that they were able to raise healthy mouse pups from eggs created in the laboratory using stem cells.

The team, led by Katsuhiko Hayashi at Kyushu University, took skin cells from the tails of adult mice and transformed them into induced pluripotent stem cells. These are cells that have been genetically modified to behave like embryonic stem cells, which are capable of forming any adult cell type.

The team then treated these stem cells with growth factors and hormones taken from mouse ovaries to coax them into growing into eggs, before fertilising them using IVF and implanting them into the wombs of living mice.

Though the method has so far only been proven in mice, and even then only 11 of the 300 embryos implanted resulted in successful births, it could one day help infertile human couples to have kids without the need for egg donors, the researchers said.

PHOTOS: LIGO X2, GETTY, K HAYASHI/KYUSHU UNIVERSITY

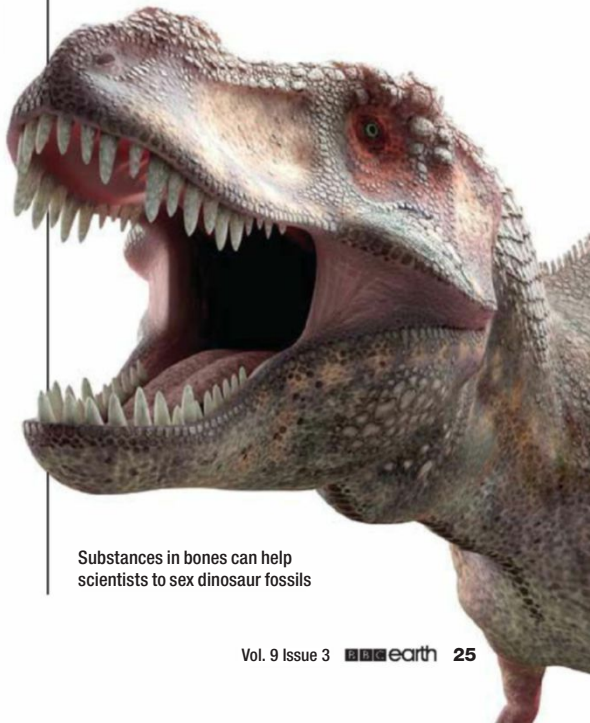
PALAEONTOLOGY

PREGNANT *T. REX* FOSSIL IDENTIFIED

Determining the sex of a dinosaur fossil is incredibly difficult as bones tell us very little about the animals' sexual characteristics. However, last year, a 68-million-year-old *T. rex* fossil became one of the first to be definitively identified as female thanks to the discovery of its medullary tissue – material found within a bone that supplies the calcium to create eggshells in pregnant females.

The fossil was originally excavated from Montana's Fort Peck Lake in 2003. Researchers suspected that the specimen's femur contained medullary bone but they were unable to send it for chemical analysis. But a tissue analysis carried out in March found that the sample contained keratin sulphate, a substance not found in other types of bone. The researchers also compared the sample to medullary tissue taken from modern ostriches and chickens and found similarities in composition and structure.

Identifying the dino as female will help the scientists to identify further characteristics that differ between sexes, and may even offer an insight into the evolution of egg-laying in modern birds.



Substances in bones can help scientists to sex dinosaur fossils

HELEN CZERSKI ON...

WHY DO RICE KRISPIES GO SNAP, CRACKLE AND POP?

"FOR ME, THE MOST ASTONISHING THING ABOUT THIS MECHANISM IS THAT SO MUCH SOUND GETS OUT"

It's one of those sounds that's so familiar, we've almost forgotten to hear it. You pour milk into your bowl of Rice Krispies and immediately there's a jolly, crackling noise that sounds like a log fire with the volume turned down, or perhaps like mice running around on tiny bubble wrap. It would be completely weird if we weren't so used to it – how can starch so fragile that it's barely there make such a loud noise? I was set the task of finding out.

Each little Rice Krispie has the structure of a sponge. If you cut one in half, you can see that it's full of tiny air pockets surrounded by very thin walls. Sometimes the starch walls are so thin that they're transparent, and quite often the outside of a Rice Krispie has got holes in it where an expanding bubble of gas on the inside burst through. The walls are made of a mixture of long carbohydrate molecules (that's the starch) and sugar, and together they form a material a bit like glass. It's brittle, so if you crush it, you hear sharp snaps as the thin layers shatter. That makes sense when it's dry, but surely wet starch is soggy, and is much more likely to squish than shatter!

There's quite a lot of variety in the popping sound that you get. If you try putting water rather than milk on your Rice Krispies, the crackling is loud and immediate. And you can see bubbles of air being expelled from the insides of the cereal. Skimmed milk produces quieter crackling than water, and full fat milk is quieter still. I also tried different temperatures, and found that hot milk is much noisier than cold milk. So I suspect that the speed and loudness of popping is dependent on the viscosity of the milk – when it's straight from the fridge it's twice as viscous as it is at body temperature. And whole milk is about twice as viscous as water. Viscosity is important for how fluids flow – a more viscous liquid tends to flow more slowly because the fluid is resisting the flow. So that gets us to what's happening inside the Rice Krispies. The appearance of bubbles tells us that the milk is seeping slowly into the air spaces. The sound isn't coming from the bubbles, so it must be coming from the inside. What's going on in there?

The least viscous liquid of all, hot water, will rush in to fill the air pockets pretty quickly. Water is attracted to starch, and so it will crawl inside through the gaps, creeping along the walls and dragging other water behind it. The problem is that those pockets are already full of air. So the best explanation seems to be that as the air gets squeezed by milk advancing on one side of the pocket, the pressure in each pocket goes up until eventually it bursts the fragile starch wall on the other side. That's what makes the snap that we hear. The milk keeps creeping in, pushing up the pressure pocket by pocket and cracking each one as it goes. The faster the milk advances, the louder and more frequent the crackling, which is why less viscous milk gives you noisier popping sounds.

For me, the most astonishing thing about this mechanism is that so much sound gets out. Sound doesn't travel well through mixtures of air and water, which suggests that the original crack must be extremely loud. But it's nice to think that even a breakfast cereal contains a few hidden mysteries – the subtlety and sophistication of the everyday world is not to be underestimated!

Dr Helen Czerski is a physicist and BBC science presenter Her book, *The Storm In A Teacup*, is out now

ILLUSTRATION: DARIA SKRYBCHENKO


BBC earth
SCHOOL CHALLENGE 2017
EXCITING EDUCATIONAL TOURS AND MANY OTHER ATTRACTIVE PRIZES TO BE WON!
COMING SOON IN
MAY 2017
- NEW FORMAT -
To register, please visit: regentmedia.sg/events
For more enquiries, please email to bbcearthchallenge@regentmedia.sg or call +65 6446 6888
Organised by
Regent Media

LEARNING THROUGH ADVENTURES IN VICTORIA

Extend learning beyond the classroom with an educational trip down to Victoria

Under the canopy of blue skies, a boundless world await to be explored to no end. If you are thinking of taking learning outside the classroom, venture to Victoria where a myriad of educational attractions lie in abundance. Reinvigorate your learning spirits by taking a trip to the various attractions available including an adventurous tour of an African safari as well as an exquisite gold exhibition in a historical town that highlights the glorious days of Australian gold rushes.

PUFFING BILLY STEAM RAILWAY

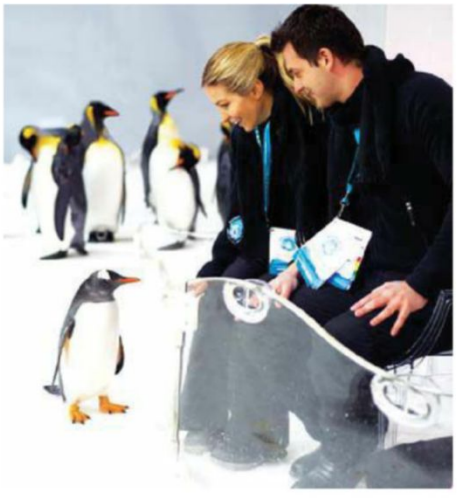
Hop on a 100-year-old steam train that runs on one of the most well-preserved steam railways in the world – the Puffing Billy Steam Railway. Passengers are given the options of either travelling first class in luxurious private carriages on board selected departures where a sumptuous dining experience is well prepared, or board a open-sided carriages where one can get to take in the view of the picturesque forests and fern gullies of the Dandenong Ranges. You may also board night trains which feature various themes such as the Murder on the Puffing Billy Express as well as Rhythm and Blues on Puffing Billy.

SOVEREIGN HILL

Step into a completely different world in Sovereign Hill where visitors get to walk in the shoes of gold miners back in the glorious days of Australian gold rushes. Having won the title of Australia's best 'Major Tourist Attraction' three times, the massive attraction features a creek where visitors get to pan for real gold, historical streets that are similar to those in the 1850s and a Gold Museum that houses the most ethereal exhibition of gold and Ballarat history. Visitors should also seize the opportunity to catch the spectacular $150,000 gold pour as well as a multi-million dollar sound-and-light show called 'Blood on the Southern Cross'.

PHILLIP ISLAND NATURE PARKS

Take a short 90-minute drive down from Melbourne to Phillip Island where a host of natural and wildlife attractions are waiting to be explored including the world-famous Penguin Parade and Koala Conservation Centre. The Penguin Parade offers tours such as self-guided tours, a variety of ranger-guided tours as well as exclusive Underground Viewing where visitors get to witness



penguins return to one of the largest penguin colonies in Australia at sunset. Thrill-seekers should also not miss the opportunity to take a 'fast-boat' ride on the Wild Ocean EcoBoat Tour which takes visitors to Australia's largest fur seal colony to get up close to the seals in its natural setting.

SEA LIFE MELBOURNE AQUARIUM

Designed to resemble a ship docked by the river, the SEA LIFE Melbourne Aquarium encompasses a total of 12 zones of discovery and serves as home to thousands of aquatic animals including the Gentoo Penguins and Elephant Sharks. In collaboration with Disney Pixar, the SEA LIFE Melbourne Aquarium recreates the amazing underwater world featured in the box-office hit 'Finding Dory' where devoted fans from all over the world get to take on the roles of underwater explorers and learn about marine conservation through an interactive quiz trail.

WERRIBEE OPEN RANGE ZOO

Inspired by an African safari, the Werribee Open Range Zoo spans across a 225 hectares of wide open savannah where wild animals such as rhinoceros, giraffes and zebras roam freely. Visitors may explore the picturesque attraction by taking a leisurely walk on either the Pula Reserve Walking Trail which features gorillas, lions, monkeys and cheetahs or the Australian Journey Walk where Australian animals like koala, emu and kangaroo reside. For those who like to get up close and personal with the wildlife, join in Wild Encounters where you get to feed giraffes, stroke a serval and observe wild animals on the savannah from an open vehicle.

UNSOLVED MYSTERIES OF THE DINOSAURS

WE ALL KNOW THAT *BRONTOSAURUS* HAD A LONG NECK AND *TRICERATOPS* HAD A HORNED HEAD. BUT THERE ARE STILL MANY THINGS ABOUT PREHISTORIC BEASTIES THAT PERPLEX THE WORLD'S BEST PALAEONTOLOGISTS...

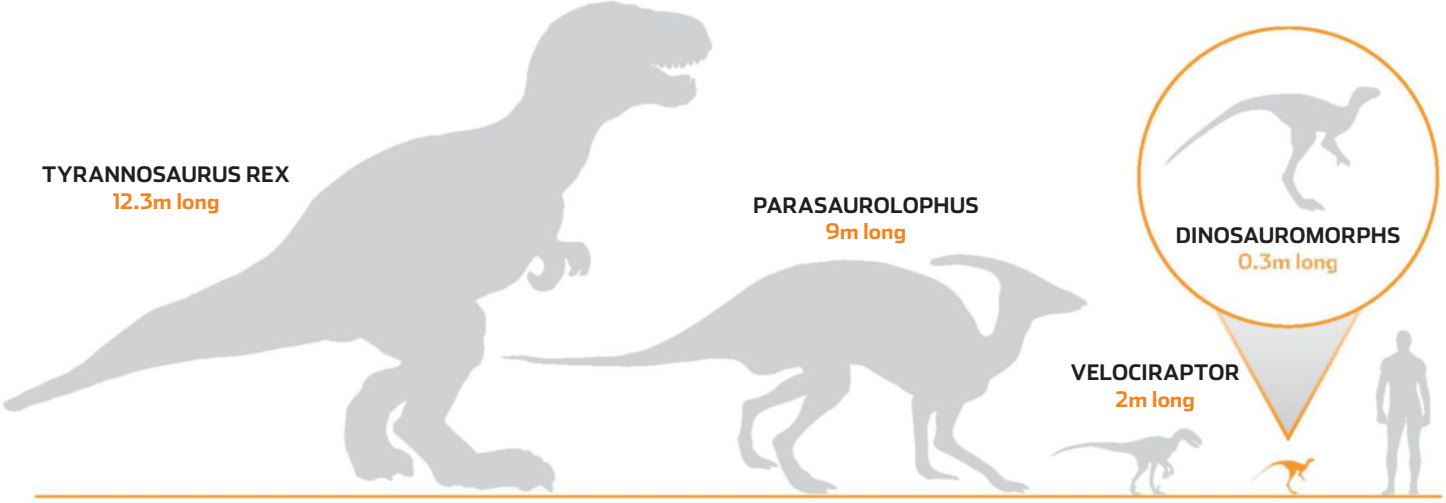
WORDS: **STEVE BRUSATTE**

Scan this QR Code for the audio reader

Back in November, I was part of a team that described a new dinosaur (pictured). Hailing from southern China and living just a few million years before dinosaurs disappeared, the species would have looked like a deranged bird. It was about the size of a sheep and covered in feathers, with a sharp beak that it probably used to crack open nuts and shellfish. We called it Tongtianlong in formal scientific parlance, but gave it the nickname 'Mud Dragon' because its skeleton was found suspended in rock that hardened from ancient mud. It seems like this poor dinosaur got trapped in the muck and died. Then, some 68 million years or so later, its corpse was exhumed by dumb luck as workmen dynamited bedrock while building a school.

It's one of those things that every dinosaur-obsessed child dreams of: getting the chance to discover and name a completely new species. But I'll let you in on one of the dirty little secrets of modern palaeontology. What my Chinese colleagues and I did wasn't that unusual. New dinosaurs are appearing everywhere these days – about 50 new species each year, an average of almost one per week. And this pace shows no signs of slowing, as parts of the world continue to open up to fossil hunters and a fresh generation of scientists, born in the Jurassic Park era, come of age. Because of this bounty of new fossils, we now know more about dinosaurs than we do about many modern animals.

But that's not to say that we know everything. Palaeontology is still adventure driven by mystery, and these are some of the biggest riddles that dinosaur hunters are working on today.



WHAT WAS THE FIRST DINOSAUR?

Dinosaurs didn't start out as brutish monsters like Tyrannosaurus or behemoths like Brontosaurus. They evolved from a group of gangly, cat-sized reptiles called dinosauromorphs, which scuttered around on all-fours in fear of giant amphibians and primitive crocodile relatives called rauisuchians that lorded over the food chain. The first dinosauromorphs started leaving their tracks along the shores of Polish lakes about 250 million years ago, just 1-2 million years after the worst mass extinction in Earth history, when perhaps up to 95 per cent of all species perished in a volcanic hellscape at the boundary between the Permian and Triassic periods.

These dinosauromorphs remained small and rare for many millions of years, then sometime after the volcanoes stopped and the world started to heal, they gave rise to the dinosaurs. The oldest dinosaur fossils come from Argentina and Brazil, and are about 231 million years old. Yet the first dinosaurs probably entered the scene earlier – maybe many millions of years earlier if some scrappy fossils from Africa turn out to be early dinosaurs and not just very advanced dinosauromorphs with similar anatomies and behaviours. The boundary between 'dinosauromorph' and 'dinosaur' is becoming blurrier with each new discovery, but what is becoming clear is that it took tens of millions of years for these first dinosaurs to spread around the world, grow to huge sizes, and become truly dominant. More fossils will surely help, but there isn't a single Rosetta-stone type fossil that could solve the mystery of exactly how dinosaurs rose to power.

Were dinosaurs warm-blooded or cold-blooded?

The old-school image of dinosaurs was not very flattering: crack open a book from the 1950s or 1960s and you'll see drab, scaly, plodding reptiles that look like they're just waiting to go extinct.

That concept went out of favour in the 1970s, as new discoveries like the agile and shockingly bird-like *Deinonychus* proved that dinosaurs were far more dynamic and intelligent than we used to think. Some mavericks even proposed that dinosaurs were warm-blooded like modern birds: they had a constant, high body temperature that they controlled internally through their metabolism, not by basking in the sunshine like an iguana. A few decades later, the evidence is still mixed. The problem is that dinosaurs cannot be observed, so palaeontologists must rely on evidence. Some of it seems convincing: we know from studying their bones that dinos had rapid growth rates, just like modern, warm-blooded animals. But other scientists look at the same evidence and disagree, and some have proposed that dinosaurs had 'mesothermic' metabolisms, somewhere between cold-blooded reptiles and warm-blooded birds. The more we know about how dinosaurs grew, and the more chemical studies of their bones can tell us about their internal body temperatures, the more clarity we will have.

Fast, powerful dinosaurs like *Velociraptor* may have been warm-blooded

PHOTOS: GETTY X4, GETTY/DK IMAGES, ZHAO CHUANG, JUNCHANG LU

WHY DID DINOSAURS HAVE FEATHERS?

In the 1960s, the discovery of *Deinonychus* – long arms, skinny legs, head perched on an arched neck, big claws on the feet – helped solidify the theory that birds evolved from dinosaurs. In the late 1990s, the discovery of thousands of feather-covered dinosaurs in China sealed the deal.

But these stunning fossils raised another question: why did feathers first develop in dinosaurs?

Feathers started out as simple, hair-like strands, which probably evolved in some of the most primitive dinosaurs as a way to keep warm. Many dinosaurs retained this basic fluffy coat, but one group of small meat-eaters modified their feathers even further. They got bigger, started to branch, flattened out, and morphed into quill pen feathers like those found on modern birds. These structures lined the arms, and sometimes the legs, forming wings. The reason that some meat-eaters elaborated their feathers was probably for display: to attract mates or intimidate rivals. But with wings, came flight...

DINOSAUR DIVERSITY THROUGH THE AGES

Dinosaurs owned the planet for millennia, evolving into some incredibly iconic species

HERRERASAURUS
Late Triassic
(c. 230 million years ago)

One of the oldest dinosaurs, *Herrerasaurus* was a fierce predator about the size of a horse. It terrorised other primitive dinosaurs with its sharp claws and teeth.

STEGOSAURUS
Late Jurassic
(c. 150 million years ago)

Stegosaurus has one of the most recognisable profiles of any dinosaur. It probably used the plates on its back as display billboards, and the sharp spikes on its tail to ward off predators.

BRONTOSAURUS
Late Jurassic
(c. 150 million years ago)

The iconic 'thunder lizard', Brontosaurus, used its long neck to pluck leaves from high up in the canopy. It must have eaten hundreds of kilograms of plants every day, to fuel its huge body.

MICRORAPTOR
Early Cretaceous
(c. 125 million years ago)

With wings stretching out from its arms and legs, the tiny Microraptor looks like a strange species of bird. It is actually a dromaeosaurid, a 'raptor' dinosaur closely related to Velociraptor.

PARASAUROLOPHUS
Late Cretaceous
(c. 75 million years ago)

The Late Cretaceous valleys and plains of western North America would have been alive with the bellows of Parasaurolophus, a duck-billed dinosaur that used its gaudy head crest to make sounds.

Flight in small, winged dinosaurs might have evolved **by accident**

PHOTOS: GETTY X3, ALAMY, SCIENCE PHOTO LIBRARY X2, AMNH/M ELLISON, RANDY IRMIS

HOW DID THE DINOSAURS LEARN TO FLY?

It all has to do with the wings: no wings, no way an animal can fly. For a long time scientists assumed that wings must have evolved specifically for flight. Evolution must have driven some dinosaurs to turn their hair-like filaments into the more familiar feathers that make a wing, in order for that dinosaur to move through the air. Yet new research suggests that this probably wasn't what happened.

Wings do not show up in the first dinosaurs that started flying. Instead, wings appear in fairly large, ground-dwelling dinosaurs such as the ostrich-like Ornithomimosaurs and beaked omnivores like our Mud Dragon. These dinosaurs were too large and cumbersome to fly. So a new theory is that wings actually originated as display structures – advertising billboards if you like – and only later were repurposed as airfoils. Flight may have evolved by accident as some of these small, winged dinosaurs began jumping between branches or leaping in the air, and suddenly found that their billboards had aerodynamic properties. It is one of the most exciting new hypotheses about dinosaurs.

TRICERATOPS
Late Cretaceous
(c. 68-66 million years ago)

Triceratops is famous for its horns, with one sticking up from the nose and one from above each eye. These plant-eaters probably used their horns to wrestle rivals and attract mates.

PACHYCEPHALOSAURUS
Late Cretaceous
(c. 68-66 million years ago)

Pachycephalosaurus had a thick dome of bone on the top of its head. There is debate about what this was for. Was it for display? Or did these plant-eaters butt heads in fights over mates and territory?

TYRANNOSAURUS
Late Cretaceous
(c. 68-66 million years ago)

There is no mistaking the king of dinosaurs, the biggest predator to ever live on land. T. rex was a monster: 13m-long, with jaws so strong that it could literally crush through the bones of its prey.

Anchiornis huxleyi was a small, bird-like dinosaur that may have used its feathers to help it glide

The early bird *Vegavis*, seen here with its voice box highlighted, probably sounded similar to its modern counterparts

WHAT DID DINOSAURS SOUND LIKE?

In films and documentaries, dinosaurs always seem to be roaring. But we don't really know what noises they made, although there are plenty of guesses. What we do know is that some of the first birds that existed alongside dinosaurs probably sounded like today's birds. One spectacular fossil of *Vegavis* (a member of the duck/geese group of birds) includes a voice box that's almost identical to that of modern birds, even though it lived during the Cretaceous. Other scientists have attempted to recreate the sounds of duck-billed dinosaurs by scanning their skulls, building a digital model, and using software from the instrument-making industry to simulate what kind of noises these animals could make. One of these dinosaurs, *Parasaurolophus*, could have passed air through meandering chambers in its gaudy head crest. Simulations show that this air would have been emitted from the nose and mouth as a low frequency rumbling that could change in pitch. In other words, more of a bellow than a roar.

WHAT COLOUR WERE DINOSAURS?

There's something else that feathers can tell us. They unlock the potential to determine what colour dinosaurs were. If you look at modern bird feathers under a high-powered scanning electron microscope, you can see tiny blobs called melanosomes. These are little bag-like structures that hold melanin, one of the main colour-producing pigments in animals. Some melanosomes are globular, others are egg-shaped, and so on. And that's important, because different shapes hold different colour pigments. So if you can identify the shape, you can identify the colour. A few years ago some brilliant palaeontologists realised that you could find melanosomes in particularly well-preserved fossil feathers, like those found coating many of the famous Chinese 'feathered dinosaurs', which were buried rapidly by volcanoes and locked in stone. It turns out that different dinosaurs had all sorts of different melanosomes, which meant they had a variety of different colours. Some were iridescent black like crows, others had ginger feathers, some had rings of colour on their tails like raccoons, and yet others had splotchy colours. Dinosaurs, therefore, had a whole rainbow of hues, just like modern birds.

Perhaps T. rex did push-ups to lift itself from the ground **after it slept**

WHY DID T. REX HAVE SUCH TINY ARMS?

Poor *T. rex*, it's the butt of so many jokes about its tiny arms. Its body cries out Arnold Schwarzenegger, but its arms scream Woody Allen. The king of dinosaurs was a 13m-long, meat-crunching machine as an adult, but its arms were no bigger than mine. This has amused, and confused, palaeontologists for decades. But what's important to realise is that while its arms were incredibly short, they were also very muscular. So they must have been doing something. Otherwise, evolution would have just got rid of them, the same way that the hindlimbs of whales disappeared when they were no longer needed. There are many ideas floating around: perhaps *T. rex* did push-ups to lift itself from the ground after it slept, or used its arms as claspers when mating, or simply braced itself against its prey while feeding, for a little extra stability. We still don't know the answer. However, exciting developments in cutting-edge computer modelling software could help us come up with a solution before too long.

No wonder *T. rex* was angry: he couldn't even scratch his belly!

WHY DID DINOSAURS DIE OUT?

And we end with the most enduring mystery of all, the one that has been bickered about ever since the first fossils of giant, extinct reptiles were found in England in the 1820s. Why aren't dinosaurs around today?

Of course, we now know that birds evolved from dinosaurs, so some dinosaurs do persist, but the spirit of the question remains. There is nothing like a *T. rex*, *Triceratops*, or *Brontosaurus* in today's world. They dominated the planet for over 150 million years, but suddenly disappeared from the fossil record 66 million years ago, at the end of the Cretaceous. That's exactly the same time that a 10km-wide asteroid struck what is now Mexico, impacting with the force of over a billion Hiroshima bombs and unleashing an instantaneous apocalypse of earthquakes, tidal waves, wildfires, and hurricane-force winds.

Although palaeontologists still like to argue about what role the asteroid played in the dinosaur extinction, there really isn't much of a mystery left. The asteroid did it, and did it quickly. There are few signs that dinosaurs were struggling before that one fateful moment, when the course of prehistory was changed forever. No dinosaurs, save a few birds, were able to endure the devastation. But some small, omnivorous, furry mammals did. These plucky survivors found themselves in an empty world, and as the planet started to mend, they rapidly evolved into all sorts of new creatures, including the first primates. It was in the ashes of the dinosaurs that our ancestors began their long march.

Dr Steve Brusatte is a palaeontologist at the University of Edinburgh and the author of many books on dinosaurs. He is currently writing *The Rise And Fall Of The Dinosaurs*, to be published in 2018

PHOTOS: GETTY X2, SCIENCE PHOTO LIBRARY, NICOLE FULLER/SAYO ART/UT AUSTIN

THERE *AREN'T* PLENTY MORE FISH IN THE SEA

Decades of poor fishing practices may spell the end of fish as food. But it's not the end of the line yet, as new innovations could help reverse the damage

WORDS: **HELEN SCALES**

Scan this QR Code for the audio reader


TRIPLEX

A reef shark slides past, an arm's length away, then another. And moments later a third. These sleek hunters pay me no attention and seem accustomed to having people nearby. Scuba divers like me flock to visit the sharks and other marine life flourishing around the remote islands of Palau in the western Pacific Ocean. This special place offers a glimpse of how things used to be before human activities began emptying the oceans.

Palau remains a rare underwater wonderland, in part because the government takes marine protection seriously. In 2015, the country's president, Tommy Remengesau Jr, declared 80 per cent of the nation's waters off limits to fishing. This is one of a new generation of marine reserves. More recently, in August 2016, Barack Obama announced a huge expansion of Hawaii's Papahānaumokuākea marine reserve. It's the biggest yet, a massive 1.5 million square kilometres – around the size of Spain, France and Germany combined.

The drive to set up these reserves, plus various other measures to protect the seas, stems from growing awareness that the oceans are in trouble. It's becoming clear there are no longer plenty more fish in the sea.

In 2006, a prominent group of marine scientists published a paper in the journal *Science* scrutinising the state of the oceans around the world. From their survey of the abundance and diversity of marine life emerged a headline-grabbing forecast: by 2048, all existing fish stocks could have collapsed.

Not all experts agreed on that data, which assumes the present rate of collapse will continue at its current rate – already a third of all fish stocks have collapsed since 1950. Others have re-analysed the same data and pushed the date forwards to the 2070s or even 2100s. Still, it's a dire prognosis for fisheries that feed billions of people worldwide.

"From the survey emerged a headline-grabbing forecast: by 2048, all existing fish stocks could have collapsed"

BELOW: Fishing lines and nets lost at sea do not readily break down, so they can continue trapping animals for years

And now, 11 years later, there are very few signs of improvement. "The picture painted in that paper is largely true," explains Prof Callum Roberts, a marine conservationist from the University of York. "Wild seafood stocks are still declining rapidly."

Last year a major study, published by marine biologist Dr Daniel Pauly and colleagues from The Sea Around Us project, warned that the world has probably already passed 'peak fish'. A team of 400 researchers gathered data from small-scale, recreational and illegal fisheries that normally remain under the radar. They showed that the total seafood catch, comprising all the fish, shellfish and other invertebrates caught from the seas worldwide, is far higher than official figures suggest. This may appear to be good news: if more seafood is being caught, maybe the oceans aren't as empty after all. Far more worrying, though, are the trends over time. It had been thought that since the 1990s, the global catch had levelled off and stayed roughly the same year-on-year. These latest, more complete figures indicate that global fisheries peaked at 130 million tonnes in 1996. Since then, catches began to drop by 2 per cent every year. Despite expanding fleets and advancing technologies, fisheries are unable to catch as much as they used to.

WHERE HAVE ALL THE FISH GONE?

Behind the global fishing crisis lies a catalogue of problems. First and foremost, there are simply too many fishing boats chasing fewer and fewer fish. This is partly because of financial subsidies and other perks keeping fisheries afloat. Governments provide cheap fuel for boats, tax rebates, low-interest loans and other measures to maintain fisheries that would otherwise become unprofitable and fold as fish become scarce.

Fishing also physically damages the marine environment. Trawlers and dredgers scrape heavy nets across the seabed, smashing delicate, centuries-old habitats. Huge quantities of unwanted sea life are caught that have no market or quota. This so-called bycatch is usually thrown straight back into the sea, already dead or dying.

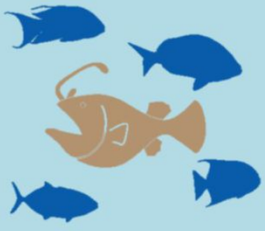
Added to all this are convoluted impacts of pollution and climate change. Warming seas are driving certain species towards the poles, rearranging ecosystems and causing coral reefs to bleach and die, while carbon emissions are making oceans more acidic, which weakens shellfish and alters fishes' hearing and behaviour. To make matters worse, fish that end up on our plates are also becoming filled with fragmented plastic. ▶

THE STATE OF OUR SEAS

OVER

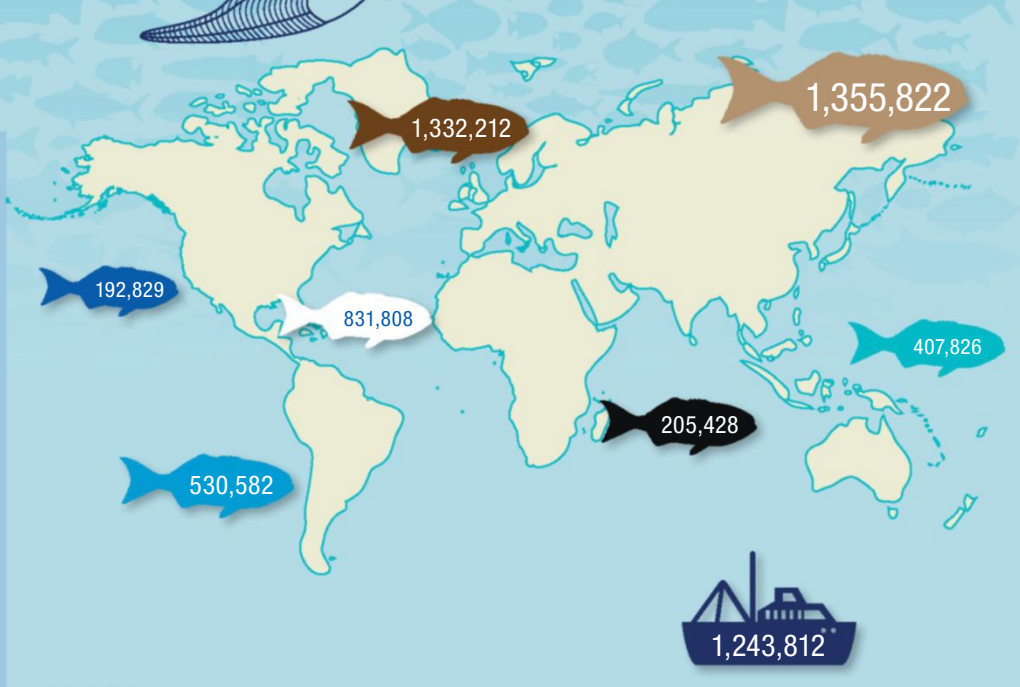
2.5

billion people rely on fish for a major source of protein



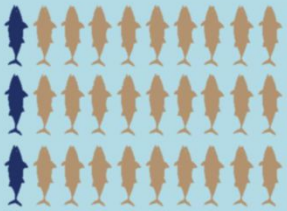
ONE IN FIVE FISH IS CAUGHT ILLEGALLY

Every day, the amount of longlines set out in the oceans would wrap around the globe 500 times



ANNUAL DISCARD RATE (IN TONNES) BY OCEAN REGION

- NORTHEAST PACIFIC
- NORTHWEST PACIFIC
- SOUTHEAST PACIFIC
- WEST INDIAN OCEAN
- NORTHEAST ATLANTIC
- WEST CENTRAL PACIFIC
- WEST CENTRAL ATLANTIC
- REST OF THE WORLD



10%

of the global fish catch is certified as sustainable by the Marine Stewardship Council

Plastic waste in the oceans could outweigh the fish by 2050

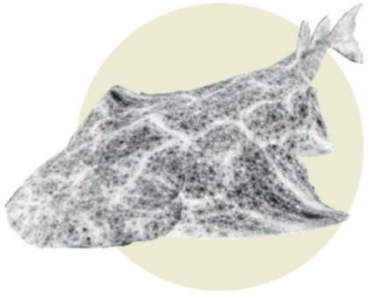
FISH STOCKS

could be declining three times faster than official figures suggest

PHOTO: JORDI CHIAS/NATUREPL.COM

THE BIGGEST LOSERS

Some species are more sensitive to pollution and fishing than others…

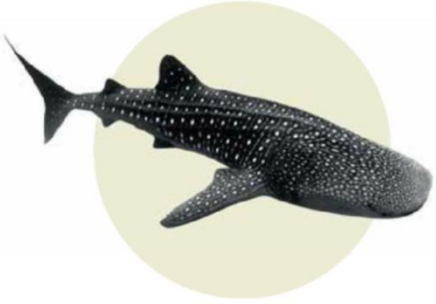


ANGEL SHARK

The angel shark was once common from the North Sea to the Mediterranean. As it lives on the seabed, it is taken as bycatch by trawlers and has been almost completely wiped out. Now it only lives around the Canary Islands.

TOTOABA

Illegal fishing is driving the totoaba to extinction in its native range in the Gulf of California. Its swim bladder, an organ that regulates buoyancy, is worth up to $8,150 a piece in China to make into soup.

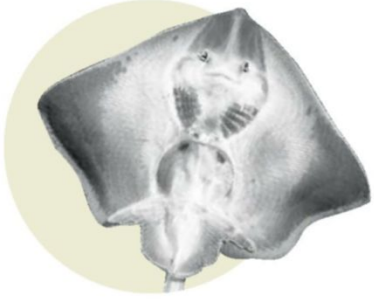


WHALE SHARKS

In 2016, the whale shark was listed as endangered by the World Conservation Union because its numbers have halved in the last 75 years. It only becomes sexually mature at between 20 and 30 years old, so populations take a long time to recover.

COMMON SKATE

With a name that's become sadly ironic, the common skate is critically endangered in the Atlantic and Mediterranean, and extinct in the Baltic. Along with some other skate species, its large size makes it vulnerable to being caught in nets.



EUROPEAN EELS

Numbers of young European eels have crashed by up to 95 per cent in the last 30 years. Declines are blamed on habitat loss, pollution and barriers to migration. Eels are born in the Sargasso Sea, before migrating across the Atlantic and up into rivers and streams, where they mature.

Certain fishing methods indiscriminately plunder the seas, sometimes catching vulnerable species, such as sharks, dolphins and turtles

Fixing all these problems is undeniably an immense task; they don't act in isolation but together, often worsening each other. Nevertheless, effective solutions are already available.

SAVING THE SEAS

Marine reserves are a proven way of restoring fish populations. By excluding fishing from particular areas, reserves allow marine species to recover from previous exploitation.

A 2009 study brought together hundreds of papers on the subject and showed that reserves tend to work well in both tropical and temperate waters. Reserves dramatically boost the density of marine species, by 166 per cent on average; species diversity also goes up by around 20 per cent. Reserves also keep habitats healthy and help make ecosystems more resilient to climate change. A well-known example comes from the Philippines. In the 1980s, 10 per cent of the coral reefs around Apo Island were closed to fishing. Twenty years later, the total quantity of the two main targeted fish groups, surgeonfish and jacks, had tripled inside the reserve. Benefits also spill out as adult fish and larvae move into unprotected areas, replenishing the wider seascape. The fishermen of Apo saw a 50 per cent increase in their catches outside the reserve. Similar stories are coming in from reserves around the world.

The portion of the oceans that falls within some form of marine reserve is gradually rising. A major

PHOTOS: GETTY X3, RICHARD HERRMANN/FLPA, SOLVIN ZANKL/NATUREPL.COM

“Consumer campaigns have made a big difference to the way supermarkets think about sourcing their fish”

obstacle, though, is enforcement. Many countries lack resources for patrols, especially in very large, remote reserves. “Here you have an activity that becomes invisible when it gets beyond the horizon,” says Jackie Savitz, from the non-profit group Oceana. She’s heading up a new initiative to make fishing more visible.

Global Fishing Watch (globalfishingwatch.org), which launched in September last year, is a free online tool showing where fishing is happening anywhere in the world. The project uses data from Automated Information Systems (AIS) required on many watercraft over a certain size to avoid them crashing into each other. AIS broadcasts public information via satellite on the vessel’s location, heading and speed. These data are being mined to detect which vessels are fishing, where and when.

Oceana brought Google to the party, to help analyse the big data generated by AIS devices and detect the characteristic movements of fishing. The Global Fishing Watch website currently tracks over 35,000 fishing vessels in near real-time; typically data go online around 72 hours from the present. It’s hoped governments will use the website to enforce sustainable fisheries regulations, such as closed seasons and marine reserves. Kiribati, a small nation located in the Pacific Ocean, has already used the data to fine a commercial vessel $1m for illegally fishing inside the Phoenix Islands Protected Area.

Technology is also being applied to deal with bycatch. The conservation group WWF runs Smart Gear, a competition to develop new ways to stop unwanted species being caught. Winners in 2014 included Super Polyshark. These pellets of slow-release non-toxic, biodegradable shark repellent are inserted in the bait that’s used on longline hooks. Tests show they reduce the number of sharks that go for the bait and get snagged. Other devices include scarers to reduce seabird deaths, and trapdoors in trawl nets that let turtles and cetaceans escape.

Back in Palau, studies are underway to limit bycatch in the 20 per cent of their national waters where fishing continues. The Nature Conservancy is testing different types of hooks in the tuna longline fishery to reduce the bycatch of sharks and turtles, species highly valued by divers. Every living shark in Palau is worth up to $2m a year to the dive industry.

RECONNECTING WITH YOUR FISH

Seeing supermarket shelves still stocked with seafood, it can be difficult to make sense of reports of emptying seas. It’s true that management successes have allowed some collapsed stocks to recover. In the 1970s, North Sea stocks of herring dramatically collapsed. “After a moratorium on fishing, together with some excellent management approaches, they’ve rebuilt the stocks,” says Roberts. However, seafood supplies today are largely maintained by fishing in distant waters. Imports account for 90 per cent of seafood eaten in the US and around 60 per cent in Europe. This puts mounting pressure on other regions like West Africa, where there is little supervision to prevent overfishing and habitat loss.

This widening gap between plate and ocean makes it more important than ever for us all to care about where our seafood comes from. “Consumer campaigns have made a big difference to the way supermarkets think about sourcing their fish,” says Roberts. More seafood is being certified as sustainable through eco-labelling schemes and awareness is growing over issues of bycatch and damaging fishing techniques. Plus, shoppers can easily check their seafood while in the supermarket by using apps such as the *Good Fish Guide*. “The more people who come into shops and say that this matters to me, the more likely it is that supermarkets will take note,” Roberts adds.

Helen Scales is a marine biologist, writer and keen scuba diver. Her latest book is *Spirals In Time*

THE CURSE OF THE NINE-DAY QUEEN

Lady Jane Grey was put on the English throne by her scheming father-in-law, deposed by her power-hungry cousin and condemned to death by her own father's treason. Nicola Tallis tells the story of a tragic victim of her royal blood

On 13 November 1553, the 17-year-old Lady Jane Grey became the youngest royal woman to be condemned for treason in British history. Her trial – staged at Guildhall in the heart of the city of London – was a very public humiliation. For Jane, its outcome was a personal catastrophe.

How had it come to this? A mere four months earlier, some of the most powerful men in England had conveyed Jane, the great-niece of Henry VIII, to the Tower of London, where they proclaimed her queen. But now here she was, facing her accusers, her nine-day reign well and truly over, her very life hanging by a thread.

The seeds of Jane's spectacular fall from grace were sown, earlier in 1553, by one of Edward VI's last acts as king of England. Edward was a committed Protestant and when he succeeded his father, Henry VIII, as king in 1547, he immediately took it upon himself to impose religious reforms upon his people.

But championing Protestantism in his lifetime wasn't enough for Edward. ▶

This portrait, painted in c1590–1600, is thought to depict Lady Jane Grey. England's shortest-reigning monarch was a reluctant pawn in her father-in-law's bid for power, and when that bid went wrong she was to pay the ultimate price

GETTY IMAGES

Scan this QR Code for the audio reader

He wanted the work to continue after his death, and that meant preventing his fiercely Catholic elder half-sister, Mary, from succeeding to the throne. His solution was to author a famous document, 'My Devise for the Succession', in which he excluded both Mary, and his other half-sister, Elizabeth, on the grounds of their illegitimacy (as his father had done before him). Lady Jane Grey, a fellow Protestant who had sat third in the line of succession, suddenly found herself anointed Edward's heir.

What made Edward's 'Devise' all the more significant – and explosive – was the fact that it had in part been orchestrated by the young king's chief advisor, John Dudley, Duke of Northumberland. Northumberland was an ambitious man, desperate to retain his grip on power, something that would inevitably be diminished should Mary succeed to the throne – for the simple fact that she loathed him, for both religious and political reasons.

BONDS OF ALLEGIANCE

Edward's 'Devise' gave Northumberland a priceless opportunity to shore up his position – and in May 1553 he did just that, persuading Jane's naïve father, the Duke of Suffolk, to allow Jane to be married to Northumberland's fourth son, Guildford. The alliance was an attempt to cement the bonds of allegiance for what lay ahead – chiefly Jane's succession to the throne, for which Northumberland's support was essential.

When, on 6 July 1553, Edward VI died – possibly from tuberculosis – Northumberland's scheme appeared to be falling into place perfectly. But, even as Jane processed to the Tower of London to be formally proclaimed queen four days after the king's death, Northumberland's plan was beginning to unravel. The people of London, who were overwhelmingly sympathetic to Mary's claim to the throne, greeted Jane's accession with shock and hostility – so much so that the imperial ambassador reported that "no one present showed any sign of rejoicing".

Worse still, Northumberland had fatally misjudged Mary's popularity throughout the country. As each day passed, the clamour for Henry VIII's eldest daughter to be given the crown grew louder. Soon it had gathered an unstoppable momentum. On 19 July, just nine days after she had been proclaimed queen, Jane was overthrown in Mary's favour.

Edward VI (top left) rejects the pope (sat below him) in an allegorical painting from c1570. The boy-king was a committed Protestant

ALAMY

Edward was determined to prevent Mary succeeding to the throne. So Jane suddenly found herself anointed his heir

With her short reign at an end, Jane and her husband remained in the Tower – prisoners in the same building that had so briefly been their palace. As the country erupted into joy at the succession of Mary I, few spared a thought for Jane's predicament. In fact, many would have considered her fate a foregone conclusion: after all, she had, albeit unwillingly, accepted the crown in defiance of Mary, an act of high treason. Surely she would be executed.

But Mary was eager to begin her reign by demonstrating clemency, and by the middle of August she had intimated to those at court that she "could not be induced to consent that she [Jane] should die". Not only was Jane her cousin, Mary was also acutely conscious of Jane's youth and the fact that she had been manipulated. It seemed that Jane's life was safe. There was to be no such mercy for the Duke of Northumberland, and on 22 August his head was cut off.

QUEEN'S PREROGATIVE

The next few months passed by uneventfully for Jane in the Tower, but she had not been forgotten. As the autumn drew in, under immense pressure from her supporters to punish those who had been involved in the coup, Mary agreed that Jane and her husband should stand trial. Some form of justice had to be seen to be done, and in Mary's eyes the trial was a formality, one that would help to pacify those who urged her to act against her cousin. As queen, it was Mary's prerogative to administer mercy where she deemed fit.

On the morning of 13 November, Jane and Guildford were conducted on foot from the Tower to Guildhall. As they passed through the streets, "with the axe before them" according to standard procedure, people gathered to watch, but Jane was absorbed in the prayer book that was open in her hands.

Upon arrival at Guildhall, the prisoners were escorted to the Great Hall, where their trial was staged in a room full of spectators.

LADY JANE GREY: A LIFE CUT SHORT

1536

Lady Jane Grey was probably born in the later half of 1536, perhaps at Dorset House in London. She was the eldest daughter of Henry Grey, later Duke of Suffolk, and Lady Frances Brandon.

28 January 1547

Henry VIII dies, leaving his nine-year-old son, Edward, as his heir. Jane is now officially third in line to the throne.

HENRY VIII DEPICTED IN A CONTEMPORARY LEAD MEDAL

Edward VI (left) draws up and makes several amendments to 'My Devise for the Succession', whereby he disinherits his half-sisters, Mary and Elizabeth, naming Jane his heir.

Spring and Summer 1553

25 May 1553

Lady Jane Grey is married to Guildford Dudley, the fourth son of the Duke of Northumberland, in a magnificent ceremony at Durham House.

Jane enters the Tower of London, from where she is publicly proclaimed queen. The same evening, a letter from Mary arrives at the Tower, declaring herself to be queen.

6 July 1553

Edward VI dies at Greenwich Palace, and Jane becomes queen of England.

MARY I ENJOYED THE SUPPORT OF THE PEOPLE OF LONDON

10 July 1553

Jane is officially deposed in Mary's favour. As London erupts in celebration, Jane is escorted from the royal apartments to prison quarters, there to await news of her fate.

19 July 1553

JANE WITH HER HUSBAND, GUILDFORD DUDLEY

Jane and Guildford stand trial at Guildhall. They both plead guilty, and are condemned to death. The couple return to the Tower.

13 November 1553

Jane's father, the Duke of Suffolk, joins the Wyatt Rebellion against Queen Mary.

January 1554

JANE REBUTS JOHN FECKENHAM'S ATTEMPTS TO CONVERT HER TO CATHOLICISM

The Wyatt Rebellion ends in disaster. Sir Thomas Wyatt and his supporters are captured in London and sent to the Tower.

7 February 1554

THE DOOMED REBEL THOMAS WYATT

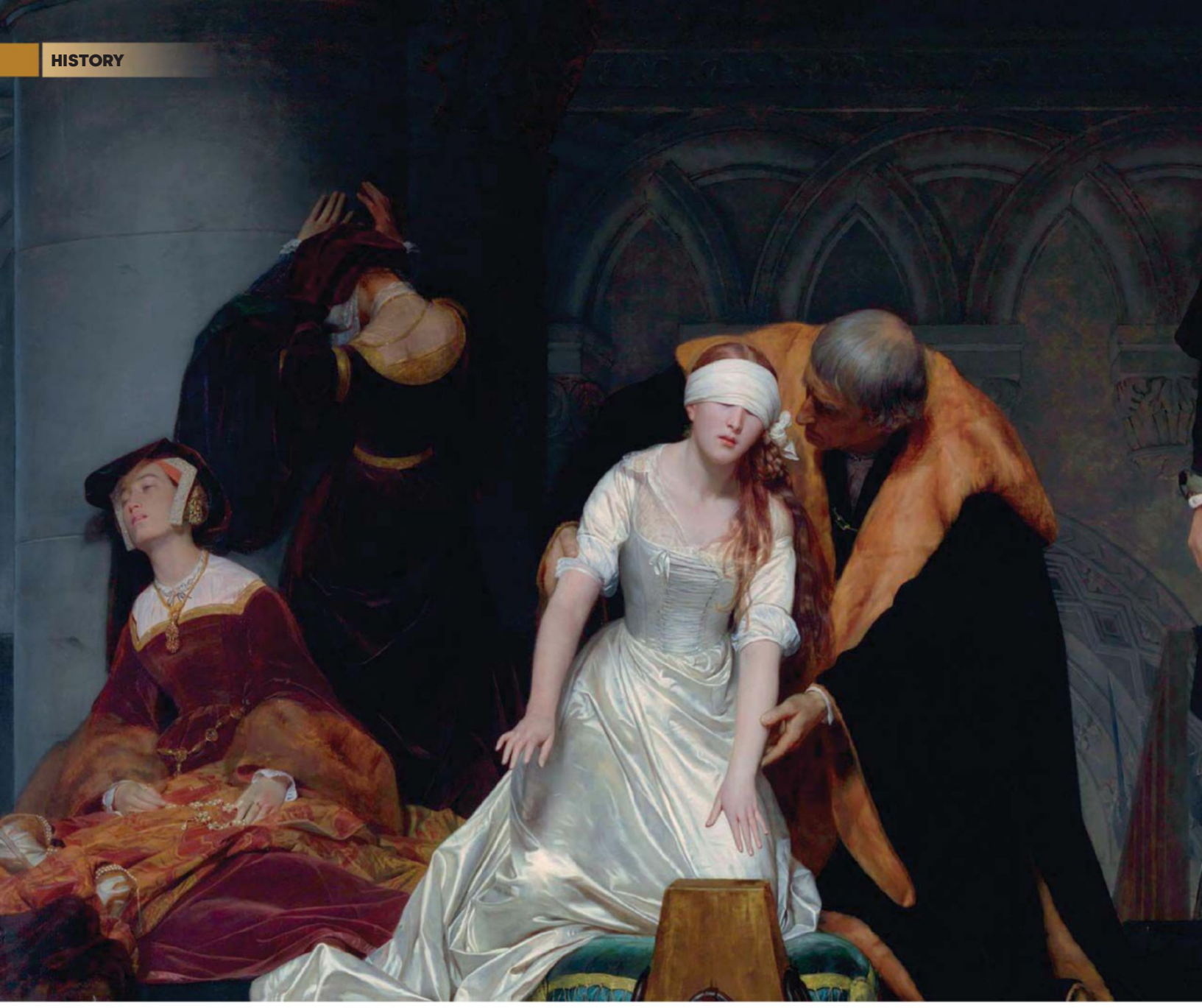
8 February 1554

Dr John Feckenham arrives at the Tower. He and Jane begin a series of religious debates instigated by Feckenham in an unsuccessful attempt to convert Jane to Catholicism. Jane prepares to meet her end.

Jane and Guildford are executed. Guildford is subjected to a public beheading on Tower Hill, while Jane is granted a private execution within the confines of the Tower.

12 February 1554

ALAMY/TOPFOTO/BRIDGEMAN/GETTY IMAGES



A whole host of Mary's supporters had been appointed to oversee the proceedings, headed by the Duke of Norfolk. The queen had commanded those who sat in judgment to "apply yourself diligently" to the task, and to ensure that justice prevailed.

The charges against Jane were read out, and the evidence was laid before the court: Jane had "falsely and treacherously" accepted the crown of England and acknowledged herself as "Jane the Queen", thereby depriving Mary of "her royal status, title, order and power of her kingdom of England". In so doing, she had committed high treason.

All eyes were upon Jane as those in the court waited to hear how she would plead to the charges. Her answer came soon enough: "Guilty." This one word placed Jane "at the mercy of the queen" and, as such, the court's verdict was a foregone conclusion: Jane and her husband were found guilty of treason and condemned to die. For Jane, the sentence was that "on the order of the queen herself", she should be "burned, or the head cut off, as it will then please the queen".

Following their condemnation, Jane and Guildford were returned to the Tower, there to await Queen Mary's decision as to their fate. Despite the enormity of the sentence that had been passed, however, Mary remained true to her initial desire to show mercy, and it was commonly believed that "Jane will not die". Life as a Tower prisoner began to resume its normal course for Jane, as it became evident that the sentence passed against her would not be carried out.

As Christmas approached, Mary relaxed the conditions of Jane's confinement and permitted her to exercise in the Tower grounds. There seemed every reason to hope that not only would the queen spare Jane, but that she may eventually set her at her liberty. However, the machinations of ambitious men were to put Jane in terrible danger once more.

MARITAL WOES

By early 1554, Mary had signalled her desire to marry Philip, future king of Spain. Many of her subjects vehemently opposed the union – primarily because they feared that Philip would try to embroil England in Spanish wars, and because the Spanish

TOPFOTO

Paul Delaroche's heavily idealised depiction of Lady Jane Grey's final moments, painted in 1833, shows Jane being guided to the block by Sir John Brydges, lieutenant of the Tower. The painting is given greater poignancy by the fact that two of Jane's ladies are shown weeping and that even Jane's executioner is moved to avert his eyes

king was a Catholic. Mary, however, was unmoved, and plans for the wedding continued unabated.

But Mary, it seems, had underestimated the level of opposition to the union. Unbeknown to the queen – and, tragically, also to Jane – there were those among her subjects who were preparing to take a stand against the marriage. In the heart of the Kent countryside, a gentleman named Sir Thomas Wyatt and several of his friends were planning a rebellion that aimed not only to protest against the Spanish marriage, but also to overthrow Mary and replace her with her half-sister, Elizabeth. Worse still, the rebels had recruited a supporter closely connected to Jane: her own father.

We can't be sure why Jane's father chose

The sentence was that Jane should be "burned, or the head cut off, as it will then please the queen"

to throw his weight behind the Wyatt Rebellion, but one thing is certain: in doing so, the Duke of Suffolk had placed Jane's life at mortal risk.

The rebellion was fatally compromised almost before it began. The rebels had been careless planners, and in January 1554 their plot was discovered. Soon the Duke of Suffolk was fleeing towards the Midlands in order to evade capture and rally support for the uprising. He failed dismally and, on 2 February, was captured in Warwickshire, and dispatched to the Tower as a prisoner. Thomas Wyatt would soon join him. Londoners' steadfast support for Queen Mary had shattered his attempts to take control of the capital and, on 7 February, he too was captured.

Jane had known nothing of the rebellion but now, as she languished in the Tower, she may have been painfully conscious that her life depended on its outcome. Its failure sealed her fate. Though Mary was, even after all that had happened, "considering to have her reprieved", through the insistence of her advisors she was left with no choice but to order Jane's execution. The decision may have been made as late as 7 February, and it was probably that evening that Jane was told to prepare herself for death. She had already been condemned, and thus the formalities had already been settled. Jane prepared for her end with courage, and began writing her final farewells to her family.

Mary may have decided that Jane could not live, but she was still concerned for her cousin's spiritual welfare. So, on 8 February, the queen tasked her chaplain, Dr John Feckenham, with converting Jane to Catholicism. Feckenham certainly gave it his all, even managing to delay Jane's execution by three days to complete his assignment.

Several contemporaries later referred to the chaplain's encounter with Jane, most famously John Foxe, the martyrologist. Foxe tells that, having failed to break Jane's resolve, and realising that he was getting nowhere, Feckenham took his leave, saying that he was sorry for her: "'For I am sure,' quoth he, 'that we two shall never meet.'"

Foxe continues: "'True it is,' said she, 'that we shall never meet, except God turn your heart; for I am assured, unless you repent and turn to God, you are in an evil case.'"

As Feckenham discovered, Jane's resolve had hardened. By now she had resigned herself to the fact that death was inevitable, and she was determined to be remembered as a Protestant heroine. Even Feckenham was impressed with her steadfast spirit.

LIFELESS CORPSE

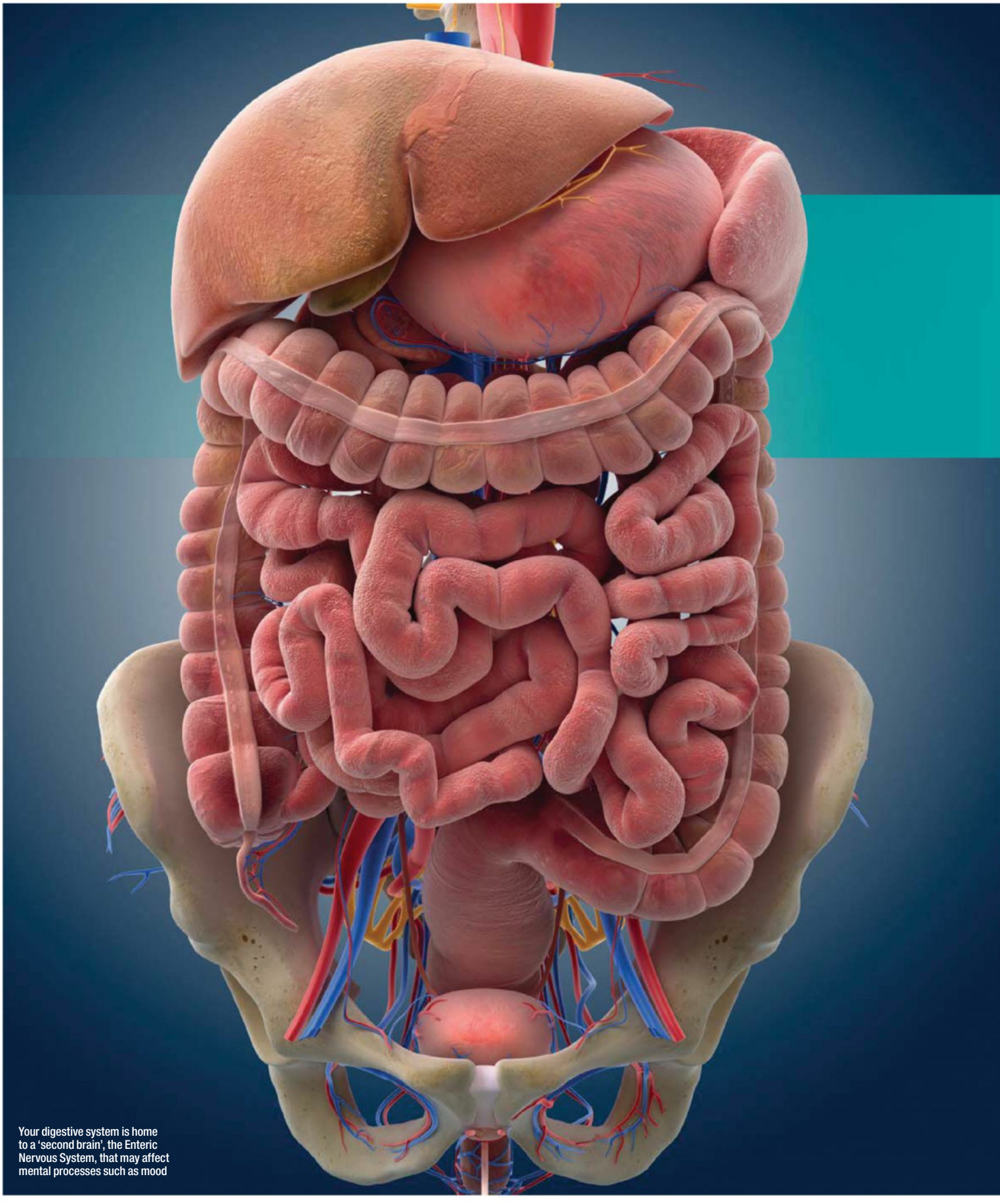
On the morning of 12 February, Jane mounted a scaffold that had been specially prepared within the precincts of the Tower. Shortly before, she had watched as her husband's lifeless corpse was returned to the Tower on a cart, following his execution on nearby Tower Hill. Unperturbed by this gruesome spectacle, she faced death with courage. She made a short speech urging those who were present to pray for her and, having been blindfolded, she knelt on the straw.

Then her calm momentarily deserted her, as she found that the block was just out of her reach. "What shall I do? Where is it?" she cried out in panic. She regained her composure as her hands were guided to the block. Moments later the axe fell and severed her head with a single stroke.

Jane's death made her a martyr, not just to Protestants in England but across the continent too. Elsewhere in the realm, though, her end went almost unnoticed. It was not until later centuries that Jane began to be remembered as one of history's most tragic victims. And in this image there is some truth: Jane was both a victim of circumstance, and of her royal blood.

Mary I certainly did not wish for Jane's execution and did everything in her power to prevent it. But, from the moment 'the nine-day queen' was deposed in July 1553, death cast a long shadow over her. Her father's actions made it a cruel reality. For Jane, the royal blood that the two cousins shared had been a deadly inheritance, and one for which she was forced to pay the highest price.

Nicola Tallis is an author and historian specialising in Tudor England



Your digestive system is home to a 'second brain', the Enteric Nervous System, that may affect mental processes such as mood

MEET YOUR SECOND BRAIN

Decision-making, mood, disease… scientists are discovering that the network of neurons in our gut is involved in a lot more than just digestion

WORDS: **ROBERT MATTHEWS**

You're facing a big decision – whether that's to go into a business partnership with a friend, say, or put money into a promising new idea. It's a tough call, as there are very few hard facts to go on. So it's time to use your second brain. Don't worry, you've probably used your second brain countless times before; it's just that when you did, you more likely referred to it as 'gut instinct'.

New research is showing that this age-old phrase is surprisingly accurate. We really *do* have a second brain that influences our judgment, and much else besides. Known as the Enteric Nervous System (ENS) – enteric meaning 'to do with intestines' – it's an extensive network of brain-like neurons and neurotransmitters wrapped in and around our gut.

Most of the time, we're unaware of its existence, as its prime function is what one would expect: managing digestion. Yet the presence of all that brain-like complexity is no coincidence. The ENS is in constant communication with the brain in our skull via the body's own information superhighway – the vagus nerve. And it's now becoming clear that all those signals flowing ▸

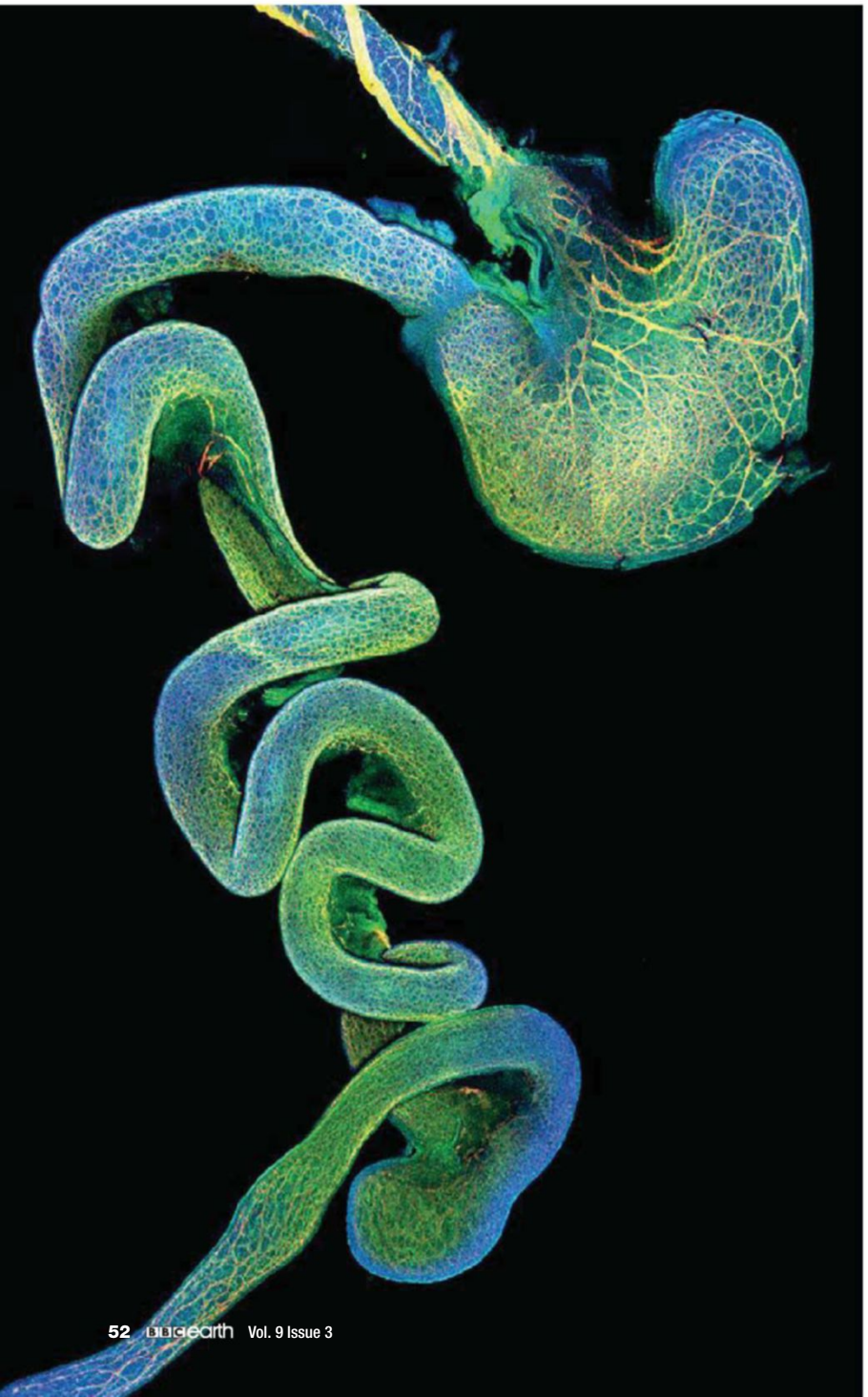
PHOTO: GETTY

BELOW: The Enteric Nervous System (ENS) centres on the vagus nerve and the digestive tract

BELOW RIGHT: Stimulating the vagus nerve externally via an ear clip can help with depression

back and forth can influence our decisions, mood and general well-being.

"Your gut has capabilities that surpass all your other organs, and even rival your brain," says ENS specialist Dr Emeran Mayer of the University of California, Los Angeles, who is author of a new account of the science of the ENS, *The Mind-Gut Connection*. "This second brain is made up of 50-100 million nerve cells, as many as are contained in your spinal cord."



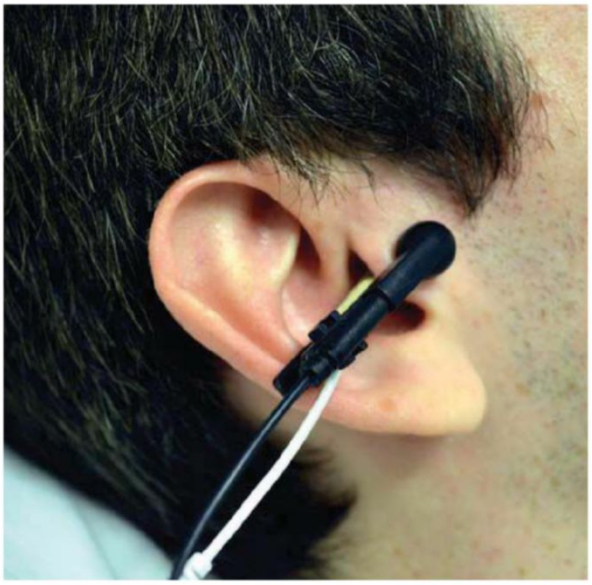
Researchers worldwide are now racing to explore the implications. The results are revealing the key role of the ENS in everyday health – and also what happens when it malfunctions. Links are emerging between the ENS and a host of disorders ranging from obesity and clinical depression to rheumatoid arthritis and even Parkinson's disease.

That, in turn, is opening up new approaches to treating these conditions, with some quite promising results already appearing.

GLORIOUS GUTS

The ENS and the brain-gut connection look set to become a major focus for 21st-Century medicine. Yet the first hints of its importance actually emerged over a century ago, when researchers began making some strange discoveries about our digestive system.

Experiments by British doctors on animal organs revealed that the stomach and intestines have the bizarre ability to work autonomously, processing food even after they've been removed from the rest of the body. The ENS, it seemed, was clearly far more sophisticated than just a bag of nerves surrounding various organs, though the reason for its complexity was far from clear. Then in the 1980s, researchers made another startling discovery: the ENS is awash with neurotransmitters, the biochemicals that are vital to brain activity. By the late 1990s, researchers began talking of the ENS as the body's second brain. That led



PHOTOS: NAOMI TJADEN, UNIVERSITY OF LEEDS ILLUSTRATION: ACUTE GRAPHICS

to some misconceptions, says Mayer: “There was a lot of hype around the idea that the ENS may be the seat of our unconscious mind”.

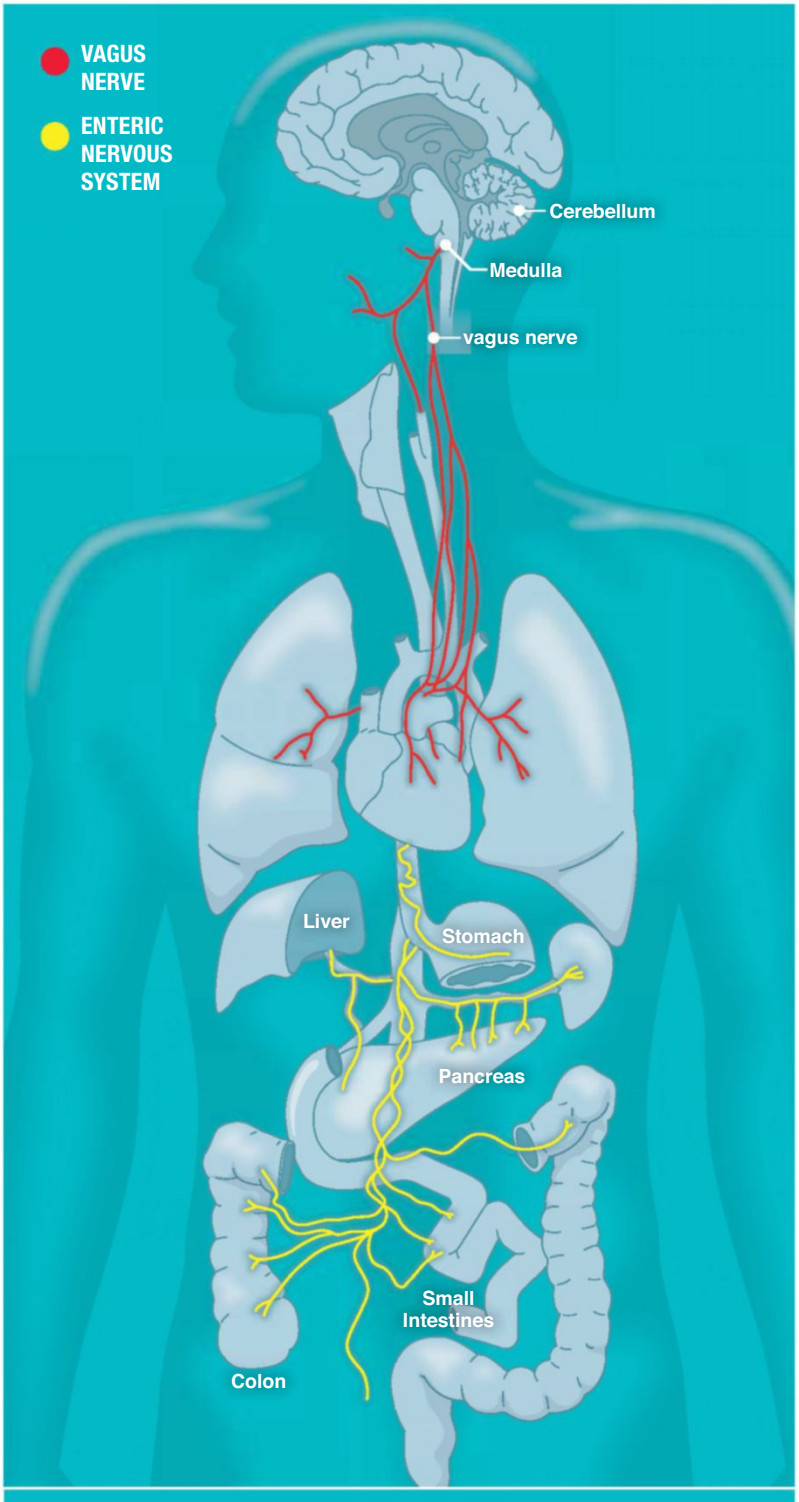
The reality is more nuanced and involves another of the key targets of current medical research: the microbiome. This vast array of bacteria, viruses and other organisms is found throughout the body, but the biggest and most diverse collection is in the gut.

Like the ENS, these microbes are principally focused on the complex business of dealing with digestion. But their behaviour in the gut is constantly monitored by the ENS, and the information is relayed via the vagus nerve straight to the brain.

A clue to the key role the state of our gut plays in our well-being comes from the fact that around 80 per cent of the vagus nerve is dedicated to reporting information to the brain. Suddenly, the idea of having a ‘gut instinct’ no longer seems so ridiculous. We’ve all experienced sensations like queasiness and butterflies when faced with challenges, or felt ‘sick to the stomach’ when things don’t go well. According to Mayer, the brain labels memories of such situations with the effect they had on our gut. The result is a rapid-access library that helps assess new challenges based – literally – on gut feeling rather than conscious, rational thought.

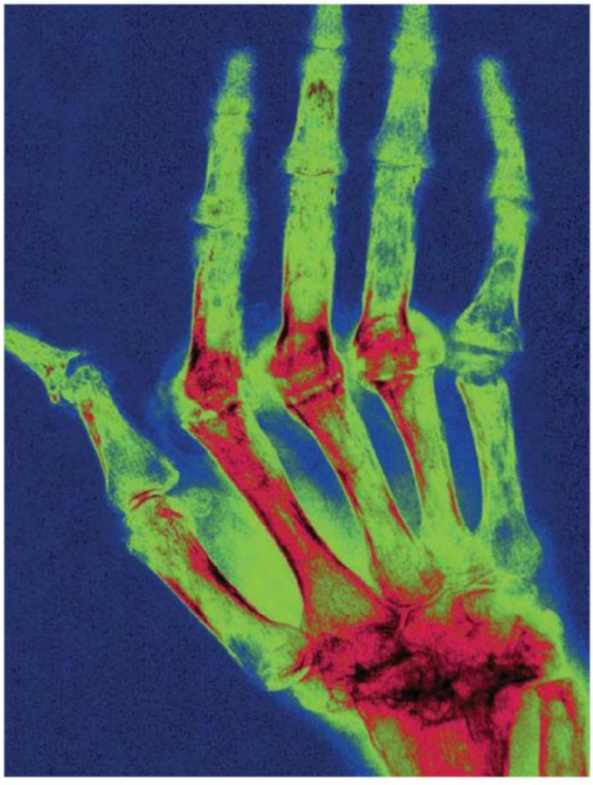
That’s not to say you should always go with your gut. “The quality, accuracy and underlying biases of this gut-brain dialogue vary between different individuals,” says Mayer. While fast, its response can also be warped by other life events or even what you ate. And sometimes it’s just plain wrong. Faced with a huge financial decision, cool-headed analysis is a better bet than a snap gut decision. ▶

Around 80 per cent of the vagus nerve is dedicated to reporting information to the brain. Suddenly, the idea of having a ‘gut instinct’ no longer seems so ridiculous



THE BRAIN YOU NEVER KNEW YOU HAD

If you thought the only brain in your body is in your head, think again. Your grey matter is in constant communication with a vast network of neurons and neurotransmitters in your gut making up the so-called Enteric Nervous System (ENS). And the two are linked by an information superhighway known as the vagus nerve, which runs down each side of your neck and into your chest, branching out across your entire gut.



LEFT: Better knowledge of the ENS could help us treat conditions such as arthritis (pictured)

BELOW LEFT: The intestinal muscles are full of nerve cell bodies (black) and their axons and dendrites (yellow and orange)

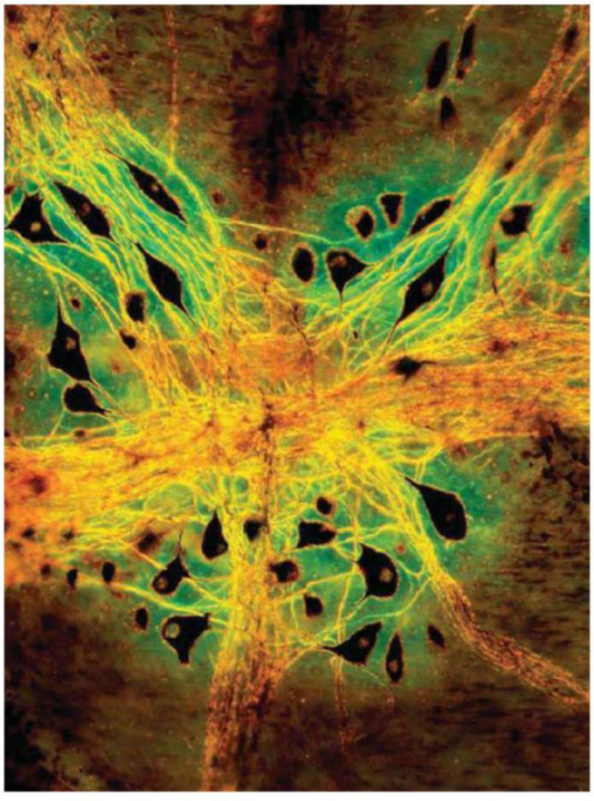
ELECTRIC FEEL

It's becoming increasingly clear that the ENS influences our brain at deeper, more subtle levels as well. Evidence is emerging that the ENS influences our mood, and even plays a role in depression. Exactly *how* it does this is still unclear, but researchers are currently focusing their efforts on one of the many neurotransmitters that are found in the ENS: serotonin.

Imbalances in serotonin have been implicated in depression for a long time, which is why it is the target of many drugs that have been developed to treat the condition, such as Prozac. Yet around 95 per cent of the body's serotonin is produced not by the brain, but by the ENS, and is affected by what we eat, the state of our microbiome and the signals sent along the vagus nerve to the brain.

This mind-brain connection is now leading to new approaches to treating depression. Studies have found that sending electrical pulses along the vagus nerve can influence the brain's use of serotonin, helping to alleviate severe depression.

Until recently, fitting patients with the necessary pulse-generating implant required invasive surgery. But researchers at Harvard University and the China Academy of Chinese Medical Sciences have now developed a device that stimulates the vagus nerve



By stimulating the gut to produce serotonin, it's possible to affect eating behaviour, alleviate anxiety and even enhance brain functioning

externally, at the point where it's most easily accessible: the ear.

Tests of the clip-on device with 34 patients with clinical depression has already produced promising results, says research team member Dr Peijing Rong: "This non-invasive, safe and low-cost method of treatment can significantly reduce the severity of depression in patients."

Recognition of the key role of the vagus nerve in gut-brain communication is leading to other conditions being treated in similar ways – including obesity. In July, the journal *Proceedings Of The National Academy Of Sciences* published the results of an international study of vagus nerve stimulation among patients with the crippling disease rheumatoid arthritis, which affects half a million people in the UK alone. The technique, which currently requires an implant, appeared to benefit some

PHOTOS: GETTY, ISTOCK, SCIENCE PHOTO LIBRARY

HOW TO HACK FAT

Wave goodbye to treating obesity with gastric bands and bypasses

The obesity epidemic sweeping the world has led to a surge in the use of bariatric surgery to help the most seriously obese. The idea seems simple enough: by removing up to 75 per cent of a patient's stomach, even small meals will be filling.

But studies of patients undergoing such operations have revealed a more subtle effect: the surgery also affects the vagus nerve connecting the enteric nervous system with the brain. This has opened the way to less radical methods of tackling obesity, by blocking the vagus nerve signals controlling appetite.

A study published last year reported that by using an implanted device developed by US company EnteroMedics, obese patients lost around a third of their excess weight over a year, with a quarter losing at least 50 per cent. Researchers in France have now set up a trial to see if similar success can be achieved using a device that does not require surgery.

patients by reducing inflammation in the body, a phenomenon also linked to many other conditions including ulcerative colitis and cancer.

Meanwhile, evidence is emerging for surprising links between the gut and other disorders usually thought to start elsewhere, such as Parkinson's disease. A team led by Dr Elisabeth Svensson at Aarhus University, Denmark, recently reported that patients whose vagus nerves had been severed to treat other medical conditions benefited from a substantially reduced risk of developing Parkinson's.

Work is now underway to understand this link, and use it to treat or even prevent the degenerative nerve disease. "To be able to do this will naturally be a major breakthrough," says Svensson.

REAL-TIME DATA

The explosion of research interest in the ENS is impressive, but it's still early days in the quest to understand precisely how it works. Most of the trials of vagus nerve stimulation are pilot studies whose positive results may fade in bigger trials.

The sheer complexity of the gut-brain connection is daunting, says Dr Xiling Shen of Duke University: "Disorders like irritable bowel syndrome are only diagnosed by symptoms, but their causes and mechanisms are completely unknown." Together with colleagues at universities across the US, Shen is working on a key tool for unlocking the mysteries of the body's second brain: a device capable of monitoring the action of the ENS in real time.

The prototype, which is currently being used in animal studies, features an electronic implant that can show how the ENS responds to different neurotransmitters, drugs and diseases. This is already casting new light on how the second brain interacts with the one in our skull. According to Shen, by stimulating the gut to produce serotonin, it's possible to affect eating behaviour, alleviate anxiety and even enhance brain functioning.

And this is just the start, explains Shen: "We are currently developing non-invasive ENS recording technology that will allow personalised and precision treatments."

At this rate of progress, we may all have to prepare ourselves for the day when our family doctor clips a device on our ear with the words: "I just want to check on the state of your second brain."

Robert Matthews is a visiting professor in science at Aston University, Birmingham

BOUNCING BACK

Until late 2014, African wild dogs were on the brink of extinction. But in a few places these exciting predators are flourishing, bucking the trend. Rosie Woodroffe reveals how conservation can win the war

It's a dog's life, they say. But the life of the African wild dog is one that the average pet pooch can only dream of. Through the heat of the day these canids rest in the shade – great piles of them, with heads on rumps and legs intertwined, challenging researchers' attempts to count bodies as they doze in a doggy embrace. Then, as the air begins to cool and shadows lengthen, they start to get restless.

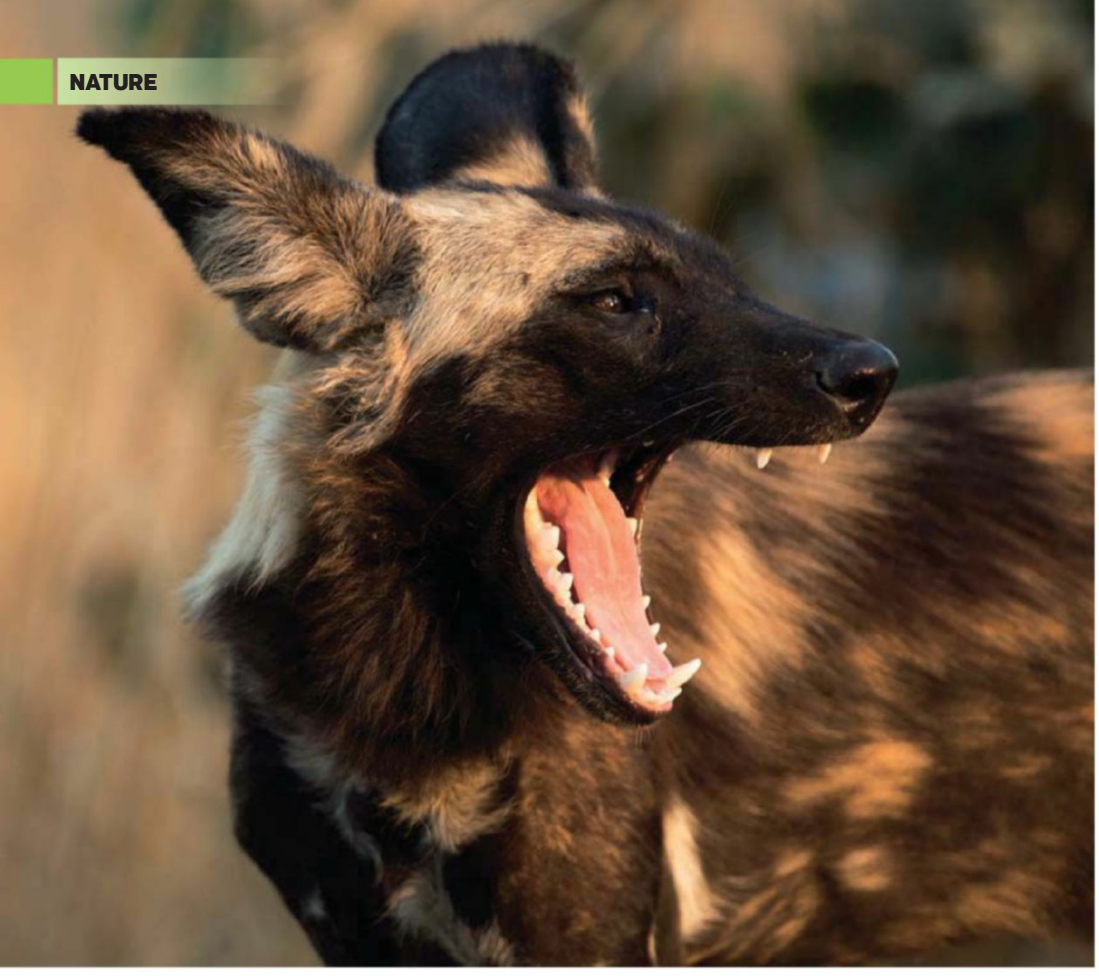
The youngsters stir first. They rise, stretch and lope to greet one another with lowered heads and bird-like, high-pitched cries. At first the older dogs resist, but one by one they join in one of the world's greatest wildlife spectacles: the evening rally of the African wild dog. Within seconds the rally reaches a climax, with dogs dashing about, ducking under bellies, leaping over backs, twittering and wriggling in a carnival of unbridled exuberance.

Wound up by the excitement of the rally, the dogs race off to hunt. Though each dog is only the size of a Labrador, packs can easily bring down antelope such as impala and kudu. But seeing them chase a half-ton Grévy's zebra, or jumping to snap at a giraffe's knees, it's hard not to think that sometimes they do it for fun.

African wild dogs may not be the biggest, fiercest or fastest mammals, but they win the world record for enthusiasm. Sadly, though, their future looks uncertain. The species remains in just 7 per cent of its former range, with a total wild population below 700 packs. John 'Tico' McNutt, founder of the Botswana Predator Conservation Trust, has spent longer than anyone studying wild dogs and fighting for their conservation. "It's a sad but unavoidable fact that wild dogs compete directly with people for habitat and resources," he says.

To put their plight in context, in spite of the terrible onslaught of poaching there are still 50 elephants left in Africa for every wild dog. Each year more broods of rare cirl buntings are raised in Devon than wild dog litters in the whole of Africa. Two decades ago wild dog conservation looked almost hopeless. The species remained only in the very largest of Africa's national parks. Irrepressible wanderlust drove the dogs to range over vast distances, within park boundaries and beyond. Nominally protected, they were being killed by farmers' bullets, poachers' snares and rabies caught from domestic dogs.

And if parks could not protect wild dogs, what hope was there outside protected areas? In 1997 canid expert Prof. David Macdonald felt moved to write: "The African wild dog is not of the twentieth ▸

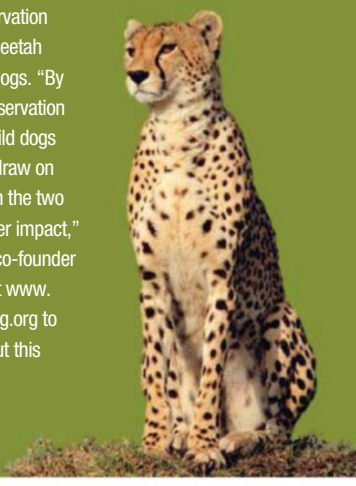


ABOVE: Wild dogs are highly vocal and produce sounds not made by any other canids, such as twittering

BELOW: Each dog is only around the size of a Labrador, but a pack can bring down prey as large as this wildebeest

SAVING CATS AS WELL AS DOGS

While Africa's parks and reserves have been reasonably successful at conserving lions, leopards and hyenas, wild dogs need much larger areas to survive. The same is true of cheetahs, which, like wild dogs, require conservation at scales of tens or hundreds of thousands of square kilometres. So experts on the two species teamed up to establish the Rangewide Conservation Programme for Cheetah and African Wild Dogs. "By implementing conservation for cheetah and wild dogs together, we can draw on synergies between the two and so have greater impact," says programme co-founder Sarah Durant. Visit www.cheetahandwilddog.org to find out more about this programme.



century, and we may fear that it will not be for the twenty first."

Barely two years after Macdonald's mournful prophecy, I was running an errand for my lion conservation project in the Laikipia Plateau in northern Kenya. Wild dogs had vanished from the area 20 years before. I was driving along when three animals exploded out of a bush. For two or three seconds the world was a riot of gaudy coats, flashing tails and satellite-dish ears, then they were gone.

Had I really just seen what I thought I saw? I stopped the car and promptly burst into tears. Against all hope, the wild dogs were bouncing back.

THE CO-EXISTENCE CONUNDRUM

For wild dogs to recover in Laikipia, we needed to learn how they might co-exist with people. Raising awareness among the human population could promote understanding – and even pride at their return. But we had to know what impact wild dogs would have on the livelihoods of local people, and what impact they would have on the returning wild dogs.

At the edge of the Laikipia Plateau, parched hills tumble down to the plains a kilometre below. It's a landscape of rocks and thorns, where cattle rely on scattered water holes dug into the rivers of sand. For most of the year local pastoralists choose to graze elsewhere, bringing in their cattle only when more hospitable pastures are exhausted. These dry, steep slopes form the boundary between the Maasai and Samburu tribes, and in the past were a hide-out for bandits and cattle rustlers. Yet the returning wild dogs chose these hills to raise their first litter. I loaded my rucksack with radio-tracking kit, and followed.

Like a wild dog, I'm an optimist – but the years that followed surpassed my wildest hopes. One pack became two, then four, then eight. Nine years on, the area supported 30 packs – the sixth-largest population left in the wild. Some packs entertained tourists on private land, but most inhabited community lands, living cheek by jowl with local people and their livestock.

Excitingly, as the years passed and our catalogue of the dogs' births and deaths grew, we could discern no

Curiosity can lead to danger, but these dogs have their eye on Will Burrard-Lucas's remote-controlled BeetleCam

difference between the private and community lands: both saw numbers grow at 20 per cent a year. If wild dogs could thrive here, perhaps there was hope for wild dog recovery elsewhere?

As the dogs spread to new areas we followed them, fitting tracking collars to more than 100 animals over a decade. Our research showed that wild dogs had recovered here because there was space for them. Laikipia is the focal point of a vast rangeland, where cattle share the landscape with half of Kenya's black rhinos, 7,000 elephants and 80 per cent of the remaining Grévy's zebras. The livelihoods of thousands of people depend on these lands, but for much of the year their livestock graze close to clustered settlements.

More remote areas are set aside for the dry season, unintentionally creating refuges for wildlife. Data from our tracking collars showed how wild dogs focus on these areas, and, in so doing, avoid coming into contact with people.

Over time local people have become more aware of their land's importance for wildlife, and of the potential for it to earn them money through ecotourism. The hills where wild dogs first denned have been declared the Naibunga Conservancy. "Here, at least, wild dogs are still able to move freely across the landscape," says Naibunga's manager Beatrice Lempaira.

WORKING WITH HERDERS

Lempaira highlights another reason for the wild dogs' successful recovery. "There may be an ever-present risk of the dogs killing goats and sheep, but despite this, communities in most cases still choose not to kill them," she says. Indeed, in more than a decade of tracking wild dogs in the area that Lempaira manages, none of our radio-collared individuals has been deliberately killed by people.

For two or three seconds the world was a riot of gaudy coats, flashing tails and satellite-dish ears

Play fights are an important part of life for wild dogs, as for other pack animals

The truth is that in places such as the Naibunga Conservancy wild dogs seldom take livestock. This is because there is still plenty of wild prey, and because cattle and goats are constantly accompanied by herders who drive away both predators and livestock thieves.

Herders are the key: abandonment of this kind of traditional shepherding has been linked to predator declines worldwide. Nevertheless, when wild dogs do attack cattle or goats, individual farmers can be devastated. As Lempaira tactfully notes, in a society where people's wealth depends entirely on livestock "it is not encouraging when 10 goats are killed in one homestead".

Mohammed Boru is working hard to avoid such terrible impacts. As community liaison officer for the Zeitz Foundation in the Laikipia Plateau, he provides local people with the practical information they need to co-exist with wild dogs. "Most people admire the dogs' swiftness and ▸

TRUE ALTRUISTS
EXTENDED FAMILY

Wild dogs are the ultimate team players. Usually only one dominant female will give birth in each pack, but all of the group helps to care for her pups. Pack members who are not the pups' parents frequently pass up the opportunity to hunt and instead remain as 'babysitters' at the den. In the same way, pack members that have hunted will regurgitate a proportion of their kill to feed the pups and babysitters. This extra care helps mothers in large packs to raise more pups than those in smaller groups. Wild dogs have also been found to adopt unrelated pups, and will help to feed injured pack members for weeks or even months. This caring urge can be amazingly strong: in 2011 a female living alone in Botswana's Okavango Delta was filmed repeatedly regurgitating food to black-backed jackal pups.

Pack members work as a team to feed mothers, babysitters and their pups

Researchers in Zimbabwe take blood samples and measurements

teamwork," says Boru. "But sometimes when I try to talk to herders about ways to prevent depredation, they are very angry and can get aggressive."

Boru conveys his message with the help of a team of actors, who visit local markets and football games to perform a play about living with wild dogs. He explains that after people have seen the play, which conveys our research findings in a sitcom setting, most are pleased to have learned how to prevent the dogs from preying on their livestock. "They can see how they are able to prevent depredations," he says. "And, of course, they're also happy when they realise that the dogs are a draw for tourists."

Indeed, tourism may be the animals' lifeline, bringing $20 million to Laikipia's economy each year. Annabelle Carey runs Laikipia Wilderness Camp. "We have been following one pack of wild dogs for seven years and have frequent encounters with them," she says. "About 40 per cent of our international visitors come to photograph and follow the wild dogs." Staff at Carey's camp are among 6,500 people directly supported by tourism in the area.

If wild dogs can co-exist so successfully with the people of Laikipia, why did they disappear in the first place? Some died of disease, but many were shot by ranchers – the fathers and grandfathers of those who now show wild dogs to tourists. Unfortunately the animals' inquisitive nature and close social bonds made them shockingly easy to kill. When an individual was shot, others would come to investigate, and be shot in turn. In this way a whole pack could be

Wild dogs range over far wider areas than would be expected from body size alone

THINKING BIG
AFRICA'S LARGEST PROTECTED AREA

More than anything else, wild dogs need space. The average pack ranges over 700km^2 – roughly the area of Anglesey. The Kavango–Zambezi (KAZA) Transfrontier Conservation Area provides 440,000km^2, almost twice the area of Britain, and links parks and reserves in Botswana, Namibia, Zambia, Zimbabwe and Angola. Much of this land has a low human population density – another factor that helps wild dogs thrive – and as a result the region supports an estimated 24 per cent of all surviving wild dogs, including the Okavango Delta packs seen in the BBC's Planet Earth series. Recognising the area's importance for wild dogs, KAZA range states are working to conserve the vast wilderness and landscape connections needed to ensure a future for the species.

Actors perform a play about living with wild dogs that conveys our research as a sitcom

finished off in a matter of minutes.

"This apparent tolerance of tourists on safari is what makes a few hours spent with a pack of African wild dogs one of the most spectacular and engaging of all African wildlife experiences," says 'Tico' McNutt. "The irony is that this is the very trait that has also resulted in their extirpation from the majority of their historical range."

And so, co-existence is precarious. Laikipia's wild dogs became extinct once – and can do so again. But the story of Laikipia gives hope. If wild dogs can thrive here, then maybe they survive in other community lands where conservationists never thought to look for them – for example, in Somalia, Chad or Angola.

If the Maasai's traditional care of their land and livestock has helped wild dogs to bounce back in Laikipia, could the same tools help the species recover elsewhere on the continent? Perhaps in a few years a village elder in Cameroon or Congo might hear an owl-like call, smile and tell his children: "The wild dogs have come home." There is still hope.

Rosie Woodroffe has studied wild dogs since 1996, and is a senior research fellow at the Institute of Zoology in London

WINSTON CHURCHILL: ATOMIC WARRIOR, NUCLEAR PEACEMAKER

At the dawn of the Cold War, Churchill was one of the west's leading champions of the atomic bomb. But, as Britain found itself in the crosshairs of a Soviet attack, his attitude changed – and that, writes **Kevin Ruane**, set him at odds with the United States

ILLUSTRATION BY **HUGH COWLING**

In 2013, a short royal family home-movie came to light. Dating from early October 1952, it shows Queen Elizabeth II, eight months into her reign, enjoying a family fishing expedition at Balmoral. Also prominent is the unmistakable figure of Winston Churchill, returned as prime minister a year earlier and now, a month shy of his 78th birthday, the Queen's honoured guest.

Churchill sits at the water's edge, chatting amiably to a young Prince Charles. He is relaxed but he is not off-duty. His thoughts, we now know, regularly drifted from autumnal Scotland to a barren, windswept outpost of the Commonwealth called the Montebello Islands. There, 80 miles off the coast of north-west Australia, Britain's first atomic bomb was about to be tested.

For Churchill, a great deal rested on the success of Operation Hurricane, as the test was codenamed, not least Britain's admission to the exclusive A-bomb 'club' alongside the US and the Soviet Union. "Pop or flop?" Churchill asked his scientific advisors in the build-up to the test. "Pop!" came the reassuring reply.

On 3 October 1952, the Hurricane device exploded with a violence greater than either of the A-bombs used against Japan in 1945.

We have no record of what Churchill said to the Queen later that day. How did a former cavalry officer of the late Victorian era explain that now, at the dawn of the second Elizabethan Age, he had in his hands not a sword but a weapon containing the pulsing energy that fuels the stars? Did he dwell on the fate of Hiroshima and Nagasaki? Two bombs, two flashes, and 100,000 dead in an instant.

If he also thought to himself "At last!", that would be understandable. Churchill had waited a long time for this moment.

NUCLEAR AMBITIONS

In August 1941, with Britain in the throes of a global war, Churchill gave the go-ahead for a top-secret effort to build a super-weapon – an atomic bomb. A passion for new military technology, a love of science fiction (HG Wells was a favourite) and, above all, the dread thought of an A-bomb in Hitler's hands should Nazi scientists win the battle of the laboratories, ensured his backing for Tube Alloys, as the project was christened.

Following the US's entry into the war,

In the decade after 1945, the A-bomb and "its monstrous child, the hydrogen bomb" played a critical part in shaping Churchill's Cold War outlook

Scan this QR Code for
the audio reader

Tube Alloys became subsumed into the much larger Manhattan Project, the American bomb programme. However, in a series of agreements with President Franklin D Roosevelt, Churchill defended Britain's rights as an atomic partner of the US and established the principle of mutual consent by those two partners before the use of any weapon.

By mid-1945 an A-bomb was combat-ready, and Harry Truman, who had became president following Roosevelt's death in the spring, duly sought Churchill's consent to employ the bomb against Japan.

The war in Europe was over but the war in Asia was expected to grind on for another 18 months. Mindful of the great loss of Allied life that was bound to result from an invasion of Japan, Churchill gave his consent willingly. In August 1945, in the wake of the obliteration of Hiroshima and Nagasaki, Japan surrendered unconditionally. To Churchill, it was clearly cause and effect.

If Churchill's role in the Second World War's atomic end-game is seldom acknowledged, the 'nuclear Churchill' of the Cold War is arguably even less well known. Yet, in the decade after 1945, the A-bomb – "the perfected means of human destruction", as Churchill described it – and "its monstrous child, the hydrogen bomb", played a critical part in shaping his Cold War outlook.

Soon after losing office in July 1945, Churchill began sounding the alarm over the next great threat to freedom in Europe. With the Red Army occupying eastern Europe, and with Soviet dictator Josef Stalin refusing to honour previous pledges to permit democratic elections in the area, Churchill called on the US – most famously in his March 1946 'Iron Curtain' speech – to take the lead in organising the free world's resistance to Soviet communism.

When, in 1947, Truman answered the call, the Cold War really began to bite. But Churchill also entertained 'hot war' thoughts. He was keen for the US to exploit its atomic monopoly by issuing an ultimatum to Stalin to accept peace in Europe on western terms – or face the nuclear consequences. As Churchill put it to the US ambassador in 1948, the time had come to tell the Soviets that if they did not 'retire' from East Germany and eastern Europe, "we will raze their cities".

Churchill knew that his views would be poorly received by a British public still hopeful that differences with the USSR could be resolved peaceably, and he mostly pressed the merits of atomic diplomacy in private. This has led some historians to conclude that Churchill was blustering or bluffing. But the vehemence with which he spoke of a nuclear showdown suggests a seriousness born of his loathing of Stalinist totalitarianism.

The US opted for the patient, long-term containment of the USSR in preference to atomic menaces. In February 1950, Churchill's own outlook appeared to change when he called publicly for a Cold War 'summit' – the first time the term had been used to describe a meeting of the great powers.

What prompted this shift? Six months earlier, the USSR successfully tested an atomic device. In a flash, the American nuclear monopoly disappeared. A disturbed Truman administration responded by advancing plans to develop a hydrogen bomb – a thermonuclear weapon with a destructive potential many hundreds of times greater than the A-bombs used against Japan. This was the troubled backdrop against which Churchill issued his call for a summit.

At the time, Labour accused him of insincerity and of preying on popular nuclear nervousness merely to win votes – and unsuccessfully so, since Churchill lost the February 1950 general election. The Labour charge does seem to have merit. Over the following 18 months, Churchill repeatedly argued that the Americans should use their atomic superiority (if no longer monopoly) to try to shape a European peace on western terms. The summit Churchill envisioned would not

Thermonuclear dawn A 10.4-megaton device, codenamed Ivy Mike, is detonated by the US on 1 November 1952 at Enewetak Atoll in the South Pacific. It was the world's first thermonuclear test and made Britain's own recently acquired nuclear bomb seem puny by comparison

Transatlantic rift Churchill, flanked by Anthony Eden, on his return from a conference with US president Dwight D Eisenhower in 1954. By this point in the Cold War, with Britain in range of Soviet bombs, Churchill was growing increasingly alarmed by American sabre-rattling

involve negotiations in the true sense of the word: there would be no give and take, only atomic-infused dictation.

BRITAIN IN THE BULL'S-EYE

In October 1951, when Churchill finally returned as prime minister, nuclear issues were becoming pressing. Under Labour, the US had been granted bases for its atomic-capable B-29 bombers in East Anglia. This, Churchill recognised, put the UK in the bull's-eye of Soviet nuclear retaliation if the Cold War ever escalated into World War Three.

At the same time, Churchill applauded the efforts of his predecessor, Clement Attlee, in pursuing a British A-bomb. The prospect of a postwar Anglo-American nuclear partnership had been thwarted when the US congress passed the 1946 McMahon Act prohibiting collaboration with other countries. This meant that the Attlee government was forced to build a bomb from its own limited resources. In October 1952, the success of the Labour-inspired Operation Hurricane left the Tory Churchill as the first prime minister in British history to have at his disposal a nuclear weapon.

This triumph was soon overshadowed by the news that the US had tested an enormous (10.4-megaton) device in the Pacific. In comparison, the British bomb was puny – a mere 25 kilotons. However, because the US authorities refused to confirm that their test involved a hydrogen bomb, it was the USSR that was able to claim in August 1953 that it had become the world's first thermonuclear power. The Soviet H-bomb jolted Churchill. "We were now as far from the age of the atomic bomb as the atomic bomb itself from the bow and arrow," he reflected.

By 1954, the spectre of the H-bomb had wrought a profound – and this time genuine – change in Churchill's Cold War outlook. That February, President Dwight D Eisenhower confirmed that the US possessed deliverable hydrogen bombs. Then, the following month, when the US tested a monstrous 15-megaton H-bomb in the Pacific, Churchill learned a new word: fallout.

Codenamed Bravo, the US test generated clouds of radioactive debris that drifted many miles from ground zero, showering a Japanese tuna trawler with toxic ash. Around the world, panic spread that the H-bomb was out of control. An ill-judged statement by the chairman of the US Atomic Energy Commission, claiming

"Even if some of us temporarily survive in some deep cellar," Churchill reflected, "there will be nothing left to do but to take a pill to end it all"

that a single H-bomb could destroy New York City, pushed anxiety levels higher still.

Churchill was more disturbed than most. According to a top-secret report from his nuclear experts, 10 hydrogen bombs dropped on 10 major UK cities would kill one-third of the country's population instantly, and expose a further third to the fatal effects of fallout. No wonder he confessed to being "more worried by the hydrogen bomb than by all the rest of my worries put together".

The apocalyptic implications of the "horror bomb", as the British press dubbed it, went on to reinvigorate Churchill's quest for a summit. It also invested that quest with real sincerity. Never again did he speak of dictating to Moscow. Instead, with Stalin dead and his successors in the Kremlin talking of peaceful co-existence, Churchill dedicated the final year of his premiership to bringing about east–west reconciliation.

But while he was working for peace, Churchill took no risks with national security. He viewed the H-bomb as the ultimate deterrent and, in July 1954, he persuaded his cabinet that Britain must have its own weapon. Three years later, the UK would graduate as the world's third thermonuclear power.

THE THREAT OF AMERICA

For most historians, Churchill's H-bomb decision reflected his preoccupation with national prestige – the bomb was a status symbol – and, more especially, his determination to keep his country safe from danger.

But what kind of danger? Ironically, by 1954 Churchill was almost as worried by the nuclear policies of the US, Britain's ally, as he was by the threat from the Soviet enemy.

In February, Eisenhower wrote Churchill an emotionally charged letter about the need to "throw back the Russian threat" and "sharpen up [one's] sword for the struggle that cannot possibly be escaped". To Churchill, the US seemed to be contemplating what he called a "forestalling" war on the USSR before the latter could develop intercontinental bombers or rockets – and this made him deeply uneasy.

In 1954, the US was beyond the range of Soviet bombers. Not so the UK – it would be devastated by any H-bomb assault. "Even if some of us temporarily survive in some deep cellar under mounds of flaming and contaminated rubble," Churchill reflected, "there will be nothing left to do but to take a pill to end it all."

The Soviets, he suspected, being far behind the US in nuclear mega-tonnage, would behave cautiously. And if the UK were to stand a chance of restraining the US, he felt, it needed to be respected as an ally. "Influence," Churchill maintained, "depended on possession of force," especially thermonuclear force.

GENOCIDAL H-BOMB

To Churchill's regret, a summit never materialised before he retired as prime minister in April 1955. By then, however, he had concluded that nuclear arms, especially the genocidal H-bomb, were a potentially stabilising element in world affairs, and this took some of the edge off his disappointment.

The "annihilating character of these agencies may bring an utterly unforeseeable security to mankind", he predicted. If the nuclear arsenals of the superpowers could be balanced, then by a "sublime irony… safety will be the sturdy child of terror, and survival the twin brother of annihilation".

A good decade before the phrase Mutually Assured Destruction entered the Cold War vocabulary, Churchill was displaying distinct signs of MAD-ness.

Churchill's approach to nuclear weapons evolved over 15 years of war and then Cold War. In the process, he proved to be a shape-shifter. Does it diminish Churchill the thermonuclear peacemaker of the 1950s that he had once been a would-be atomic warrior? Hardly. It confirms instead his remarkable capacity to adapt and learn, and shows that even in old age he was capable of visionary thinking on the great life-and-death issue of the postwar age.

Kevin Ruane is professor of modern history at Canterbury Christ Church University

MEET THE HAPPIEST PEOPLE ON THE PLANET

January is one of the coldest months for people living in the Northern Hemisphere. Summer seems like a long way off but why do the world's happiest people keep smiling through these miserable weather conditions?

WORDS: **JHENI OSMAN**

Once again, it's been raining all day. It got dark hours ago. And a bitterly cold January night beckons in the city of Copenhagen. Many people would find all this pretty depressing. But not most Danes.

In 2016, Denmark was ranked as the happiest nation on the planet in the World Happiness Report. This might sound surprising given that in mid-winter the country is plunged into darkness for 16 hours a day, deprived of that supposed vital ingredient of happiness: sunshine. So what are their secrets?

The annual World Happiness Report typically assesses criteria such as: per capita income; life expectancy; people's freedom to make life decisions; generosity; social support; and corruption in government and business. For the 2017 report, researchers are looking in depth at Africa and China, happiness in the workplace, happiness over the course of life in general, and the sources and consequences of trust – the vital glue for ensuring stable social foundations.

"The most surprising thing we've found is that building the positives is more important than identifying and curing the negatives," says John Helliwell, professor emeritus of economics at the University of British Columbia. He co-edits the World Happiness Report and is remaining tight-lipped about ▶

who he thinks will take the number one spot this year – results are due this month. "The aim of the report is to increase public and policy awareness of the importance and meaning of internationally comparable measures of the quality of life," he adds.

Helliwell and his colleagues believe that happiness provides a better indicator of human welfare than separate measures of income, poverty, education, health and good government. And they have found that people are happier living in societies where there is less happiness inequality. However, results show that happiness inequality has increased significantly in most countries, in almost all global regions, and for the population of the world as a whole.

DOES MONEY BUY HAPPINESS?

It's not surprising to learn that wealth does play a small part in happiness. After all, incomes are more than 25 times higher in the happiest countries than in the least happy ones. "Income is one of the bigger elements in explaining international differences," says Helliwell. "Having at least sufficient material resources is one of the prime supports for a good life. But, of course, they are not the major part of the story."

Meik Wiking, CEO of the Happiness Research Institute, a Copenhagen-based think tank, agrees that money is not the sole root of happiness: "The Danes decouple wealth and well-being. We focus on the small things that really matter, including spending more quality time with friends and family, and enjoying the good things in life."

Wiking is the author of *The Little Book Of Hygge: The Danish Way To Live Well*. Hygge (pronounced 'hooga') is the latest buzzword on the lips of every advertising agent, lifestyle magazine editor and blogger. It is usually translated as 'cosiness', but Danes would say it's much more than that.

"Hygge has been called everything from the 'art of creating intimacy' to 'cocoa by candlelight'," says Wiking. "Some of the key ingredients are togetherness, relaxation, indulgence, presence and comfort. The true essence of hygge is the pursuit of everyday happiness and it's basically like a hug, just without the physical touch."

Now, before you start thinking that all you need to be truly happy is to win the lottery so that you can settle down in a blissful state of hygge and never lift another finger, think again. Even if you're wealthy, work is a great tonic for gloominess.

"It is not work itself, but how it is done, with whom, and in what circumstances, that creates or destroys happiness," says Helliwell. "People are happier doing things with other people, especially if they feel they're doing important things in a friendly and trustworthy environment. This is true for life both in and out of the workplace. People who work in a high-trust workplace and think of their superior more as a partner than a boss are as happy on weekdays as on weekends."

And there we were feeling miserable about the decades of hard toil that stretch ahead of us…

SUBJECTIVE SMILES

So, the next big question: can one really rate happiness subjectively? Surely, surveys are subject to individual bias? We all know how we Brits like to put a brave face on, picnic on a rainswept beach (just because the Met Office told us it was going to be a scorcher), and always say 'Fine, thanks!' when someone asks us how we are (even if we're going through a crushing bout of existential angst, having spilt our cup of tea).

"There are three different types of subjective well-being measures," explains Helliwell. "These include positive affect [how we experience positive emotions], negative affect [how we experience negative emotions], and life evaluations, where respondents say how happy they are with their lives as a whole." According to Helliwell, life evaluations tend to be determined by individual circumstances and are more variable among countries. All three measures are subjective reports based on the individual's responses – just like when doctors ask patients to report on their pain levels.

Yet not all scientists are satisfied with these subjective assumptions. Associate professor Wataru Sato and his team at Japan's Kyoto University have used scans of the brain to try to determine which area is involved in feeling happy. Their results showed that volunteers who rated highly on happiness surveys had more grey matter mass in the precuneus, which is involved in self-reflection and consciousness.

But scientists aren't just looking at the brain. They are also turning to genetics to determine why some of us are happier than others.

IN THE GENES

Researchers at Vrije Universiteit in Amsterdam have isolated the parts of the human genome that may explain the differences in how we each experience happiness. After analysing the DNA of over 298,000 people from around the world, the team found three genetic variants for happiness. Crucially, they discovered that two of the variants are linked with differences in the symptoms of depression, a mental

BELOW: Denmark's capital city of Copenhagen, where residents commute by bicycle and there's always time for a cinnamon bun. What's not to love?

PHOTO: GETTY ILLUSTRATION: DAN BRIGHT/LOST STUDIO

HYGGE YOUR HOME

Meik Wiking, CEO of the Happiness Research Institute, offers his five top tips for creating a cosy sanctuary

1 MAKE A HYGGEKROG

Every home needs a hyggekrog, which roughly translates as 'a nook'. It is the place where you love to snuggle up with a book and a hot drink.

2 BRING IN NATURE

Danes feel the need to bring the entire forest inside. Any piece of nature you find is likely to get the green light. Leaves, flowers, pine cones… basically, think how a Viking squirrel would furnish a room.

3 THINK TACTILE

A hyggelig interior is not just about how things look, it is just as much about how things feel. Letting your fingers run across a warm, wooden table is a different feeling from being in contact with something made from cold steel or plastic.

4 LIGHT CANDLES

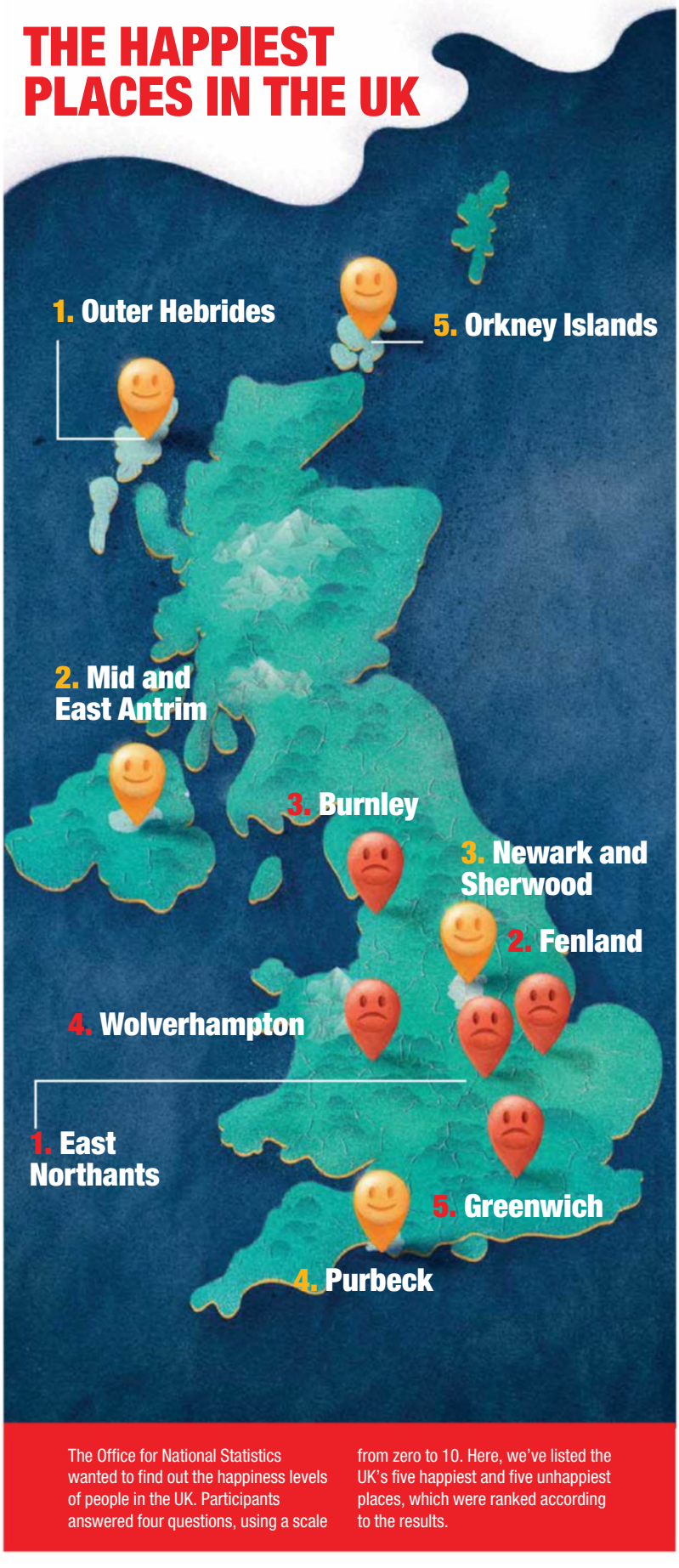
As soon as it gets dark, Danes tend to light candles, especially in the winter. Candles instantly create a cosy mood and offer a softer light than overhead bulbs.

5 LINGER LONGER

Danes love to linger, particularly after a delicious meal. While many people around the world start to clear up as soon as a dinner party is finished, Danes just relax – giving time for mindfulness.

"The Danes focus on the small things that really matter, including spending quality time with friends and family"

THE HAPPIEST PLACES IN THE UK



The Office for National Statistics wanted to find out the happiness levels of people in the UK. Participants answered four questions, using a scale from zero to 10. Here, we've listed the UK's five happiest and five unhappiest places, which were ranked according to the results.

disorder that is one of the greatest medical challenges of our time.

"The genetic variants that influence subjective well-being largely overlap with those that explain differences in depressive symptoms," says Prof Meike Bartels, who carried out the research. According to Bartels, this overlap indicates that it could be useful to promote well-being in conjunction with preventing and treating mental illness. So it seems that taking steps to keep your population happy is just as important as safeguarding them from mental illness.

Meanwhile, a paper published in the *Journal Of Happiness Studies* suggests that the DNA of people who regard themselves as happy is more likely to contain a specific gene variant involved in sensory pleasure and pain reduction.

Elsewhere, research at the University of Warwick has shown that national levels of happiness depend on how close we are genetically to our smiley friends, the Danes.

"Our research showed that the 'genetic distance' of a country from Denmark correlates with the average life satisfaction in that country," says Proto.

Intriguingly, the research also showed a link between mental state and the version of the gene that influences the uptake of serotonin. The serotonin transporter gene comes in two forms: long or short. According to the research, the short variation, which some scientists

LEFT: Spending quality time with friends and family is vital for happiness, according to the Danes

BELOW: Economist John Helliwell thinks that happiness is a better measure of well-being than wealth or education

"The 'genetic distance' of a country from Denmark correlates with the average life satisfaction in that country"

consider to be linked to depression, is more common in countries that report lower average levels of life satisfaction. While the link is controversial, the short variation has also been associated with higher scores on neuroticism and lower life satisfaction. Denmark and the Netherlands appear to have the lowest percentage of people with this short variation.

HAPPINESS IS LAW

The great news is that we British are not too far removed genetically from our Nordic cousins across the sea. "The British have no excuse – they are sufficiently close to the Danish in terms of genetic distance," says Proto, adding jokingly: "Although weather is also an important determinant of subjective well-being!"

Back in 2010, David Cameron commissioned a study into the happiness of the British and, according to the government, happiness rates are on the rise in the UK. Politicians have latched on to the importance of happy citizens. Ministers of happiness have been appointed in Ecuador, the United Arab Emirates, Venezuela and Bhutan. In the latter, happiness is now embedded in the national constitution. And the National Academy of Sciences in the US has formed a panel to establish how happiness measurements can help develop policy.

So, is the world becoming a happier place?

"There's not much of a global trend yet," says Helliwell. "Data is only starting to become available for a long enough period to find significant trends among nations. Over the very long term, even if lives in less happy countries are becoming better, we might expect to see that for the world as a whole there may be some adjustment in expectations as people raise their sights and see even better potential lives."

Maybe it would do us all good to bear in mind the wise words of one of the Founding Fathers of the US, Benjamin Franklin, who said: "Happiness consists more in small conveniences of pleasures that occur every day than in great pieces of good fortune that happen but seldom".

Jheni Osman is the author of *100 Ideas That Changed The World*, and presenter of SciTech Voyager

LOST FOREVER?

Many animals have gone extinct throughout history, but the latest scientific techniques may allow us to resurrect some of these creatures to increase the biodiversity of modern Earth

Scan this QR Code for the audio reader

UNDERSTAND DE-EXTINCTION

Mammoths, Tasmanian tigers and even Elvis could soon be brought back from the dead, thanks to intriguing advances in cloning and gene editing. But would they be the real McCoy?

WORDS BY **HELEN PILCHER**

Imagine travelling to the wilds of Siberia to see a woolly mammoth lumbering through its natural habitat. Or getting up close to a living, breathing Tasmanian tiger. Thanks to developments in cloning and gene-editing technology, the prospect of bringing back extinct animals is looking more likely than ever.

De-extinction is about creating populations of healthy, genetically vibrant animals that can be released into the wild where they'll be able to breed naturally and contribute positively to the environment. But it's not just about bringing back the dead. The same techniques being developed to help resurrect extinct species can also be used to help save living species on the brink of extinction.

So how does de-extinction work, what are its limits, and do we really need to bring back long-dead animals?

HOW FEASIBLE IS DE-EXTINCTION?

De-extinction is very much a science in development, but it's moving at a rapid pace. The first milestone was in 2003 when European scientists resurrected the Pyrenean ibex (or bucardo), a type of mountain goat that had gone extinct a few years earlier. Sadly, the kid died a few minutes after she was born, so the bucardo was not just the first animal to be brought back from extinction, but also the first to go extinct twice.

Since then, scientists have been refining their methods and developing new de-extinction techniques. In Australia, Prof Michael Archer and colleagues are working on bringing back the gastric-brooding frog, a remarkable animal that nurtured its young in its stomach before burping up fully-formed froglets. So far, the team has produced embryos that 'almost' turn into tadpoles but not quite. The next step is to persuade these embryos to turn into frogs, something that Archer is convinced they will achieve.

WHAT OTHER ANIMALS COULD WE MAKE DE-EXTINCT?

In America, scientists are working on bringing back the passenger pigeon, a rosy-breasted bullet of a bird that once flocked in the billions; and the heath hen, a stumpy avian wallflower that lived in the scrubby plains of New England. In the UK, researchers are considering whether or not to bring back the so-called 'Penguin of the North', the great auk. Meanwhile, in South Africa, they're trying to revive the quagga, a bizarre zebra-like creature with a stripeless behind! In South Korea, Japan and the US, three separate teams are racing to bring back that most iconic of Ice Age beasts, the woolly mammoth.

HOW DO YOU 'DE-EXTINCT' SOMETHING?

It depends on the species. Some projects use 'back-breeding'. Quaggas, for example, ▸

Scientists are trying to bring back the gastric-brooding frog, which went extinct in the 1980s

Harvard's Prof George Church is working on resurrecting the mammoth

are related to living zebras. So scientists are choosing the zebras that look most like quaggas and letting them breed. The aim, over successive generations, is to create animals that look like quaggas. Other projects, however, involve assisted reproduction and some rather elegant genetics. Some are using cloning; others, stem cell science. For example, Prof George Church at Harvard Medical School aims to create a mammoth by 'editing' mammoth genes into elephant cells.

WILL THESE ANIMALS BE THE SAME AS THE ORIGINALS?

No, they can never be exactly the same. When he is done, Church will have created not a true mammoth, but an elephant with a sprinkling of judiciously placed mammoth DNA. It will have long, shaggy fur, thick rolls of insulating body fat, and haemoglobin that can ferry oxygen around the body at sub-zero temperatures. This will be an animal that looks like a mammoth, but is really an elephant whose DNA has been altered so it can live in the cold. You could call it a 'mammophant' if you like, or an 'elemoth'.

Added to that, we now realise that all animals are a product of their DNA and of the environment in which they live, along with the interaction between the two. Created in a lab, nurtured in the womb of a modern elephant, and raised in a world that has changed radically since mammoths went extinct thousands of years ago, the experiences of this new-age pachyderm will be different to those of its Ice Age doppelgänger… all of which will conspire to make it less similar to the original woolly mammoth. But does this matter? Many will argue that, if the de-extinct animal looks and acts like its predecessor, then that's good enough.

COULD WE RESURRECT DINOSAURS?

Sadly, a real-life Jurassic Park is out of the question. There are limitations on which species can undergo de-extinction. First up, scientists need to have a source of the animal's DNA. Sometimes this comes from preserved museum specimens or from cells that have been collected from live animals and frozen away. Sometimes it can come from fossils. But DNA disintegrates over time, meaning that after a couple of million years there is simply no DNA left. Dinosaurs famously went extinct 65 million years ago, so their DNA is lost forever. No DNA, no dinosaurs.

And if you're hoping to meet a dodo, that icon of extinction, then don't hold your breath either. Although it died out

Although the dodo only died out in the 16th Century, we don't have any DNA samples to clone it

JARGON BUSTER

CLONING
This is one of the principle methods used to bring back certain animals. DNA from an adult cell is coaxed into a more youthful state, which is then used to create an animal that's almost genetically identical to the donor.

ECOSYSTEM
This is a biological community of interacting life forms and the space they live in. Healthy ecosystems are essential to the survival of life on Earth: they provide services including purifying the air, pollinating our crops and sequestering carbon.

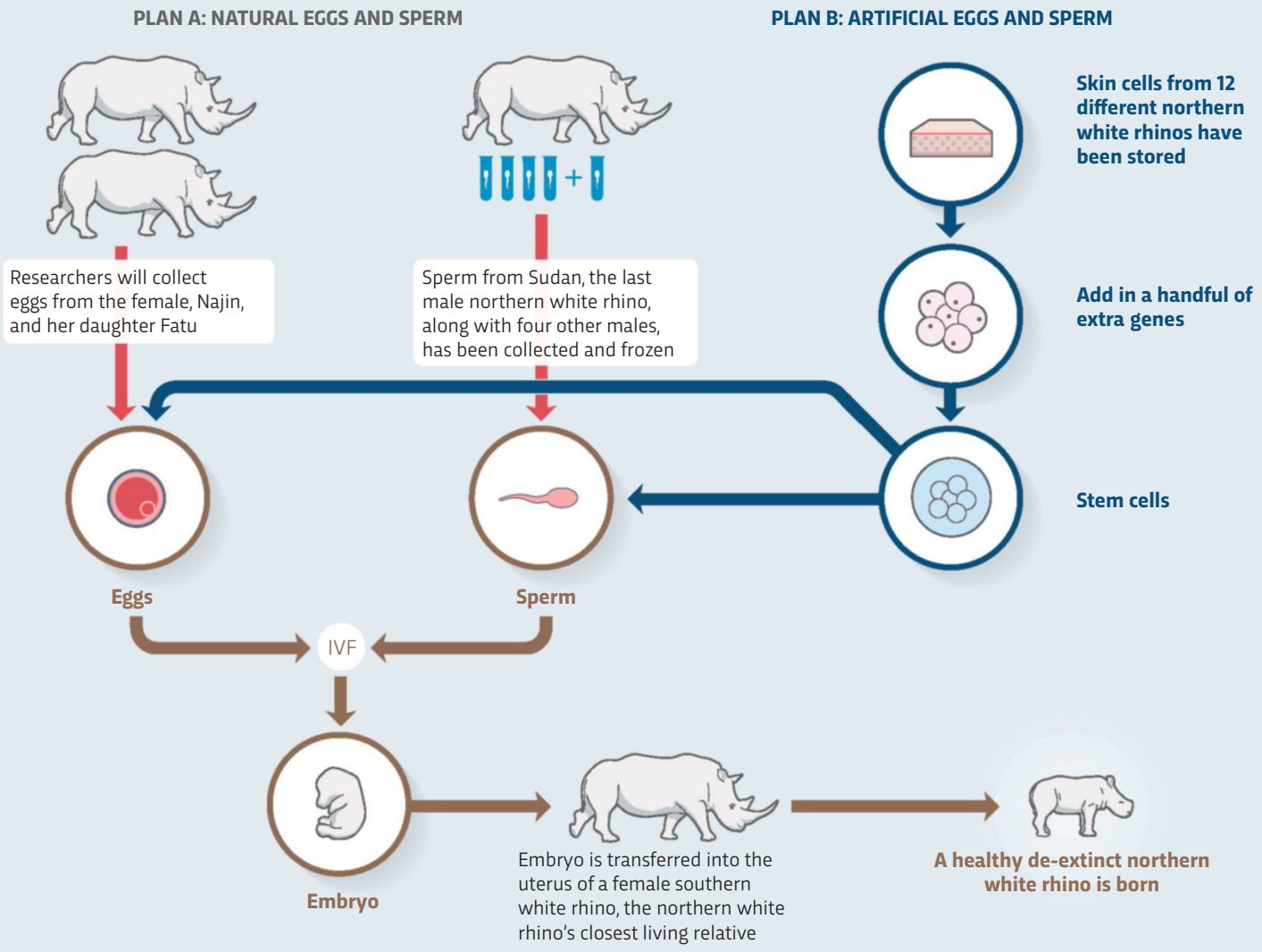
GENE EDITING
The ability of scientists to alter the DNA of living things with pinpoint accuracy. The core components of DNA can now be removed, replaced or added to at will using a process called CRISPR-Cas9.

RESURRECTION BIOLOGY
Another term for de-extinction. This blend of high-tech methods is enabling scientists to bring back species from the brink of extinction and beyond.

STEM CELL
These versatile 'shape-shifting' cells can turn into other cell types. Scientists have made northern white rhino stem cells, and next plan to use them to produce eggs and sperm for rhino IVF.

HOW TO SAVE THE NORTHERN WHITE RHINO

The last three northern white rhinos are unable to breed naturally. A Berlin-based team hopes to de-extinct this animal using IVF and advanced stem cell biology



WHAT WE STILL DON'T KNOW

1 HOW CLONING WORKS

Although we've been cloning animals for years, we still don't understand how it actually works. During the process, DNA inside an adult cell is somehow reprogrammed to a more youthful state, so that it can drive embryonic development. It's like restoring the factory setting on your phone, but no one knows exactly how it happens or how to fully control it. Crack that, and scientists stand a better chance of creating healthy, viable animals.

2 HOW RESURRECTED ANIMALS WILL BE PROTECTED

To qualify for legal protection, an organism must be listed as endangered, but for that, the animal must be living in the wild. The first few generations of any newly resurrected species will be kept in captivity while researchers checked their health, so during this time their legal status will be uncertain. Without protection, the animals could be threatened by poaching or habitat loss.

3 HOW DE-EXTINCT ANIMALS WILL FARE IN THE WILD

When it comes to releasing the animals, all we can do is study their previous ecology, and send them into the most suitable environment available. We'll then need to monitor them carefully: it's vital to know why a species went extinct first time round, to make sure it doesn't happen again. With each successive re-wilding attempt, we'll learn more about maximising the animals' chances of survival.

In one tweet…

De-extinction, fast becoming reality, has the power to save species, shape evolution and sculpt the future of life on our planet.

comparatively recently – a few hundred years ago – its final resting place, Mauritius, was simply too hot to preserve its DNA.

WHAT'S THE POINT OF DE-EXTINCTION?

There are lots of good reasons to bring back extinct animals. All animals perform important roles in the ecosystems they live in, so when lost species are returned, so too are the 'jobs' they once performed. Woolly mammoths, for example, were gardeners. They knocked down saplings, ate grass and fertilised the ground via their nutrient-rich dung. But when they disappeared, the gardening stopped, biodiversity plummeted and the lush mammoth steppe was replaced by species-poor tundra. Studies suggest that if large grazers were returned to the far north, biodiversity would increase again.

It could be the same for other de-extinct animals, too. De-extinction provides a means to enhance biodiversity and help restore the health of ailing ecosystems. It could be a conservation tool, and by choosing to bring back animals that are genetically unique – like the gastric-brooding frog or the Tasmanian tiger (a stripy, pouched, dog-like marsupial also known as the thylacine) – we could replace not just twigs, but entire branches on the tree of life.

Then there are the benefits that humans could glean. The gastric-brooding frog somehow converted its stomach into a makeshift womb. It stopped producing stomach acid so it didn't digest its young. If scientists could figure out the changes involved in this, it could lead to treatments for stomach ulcers or could help people recovering from stomach surgery.

Every day, between 30 and 150 species disappear from the face of our planet, and studies reveal that extinction rates today are 1,000 times higher than they were during pre-human times. We live in a time of mass extinction, and de-extinction has been proposed as a key way to undo some of that harm. To reverse extinction would undoubtedly be a huge moment for the fields of biology and conservation, and a feat that could motivate future generations of scientists and wildlife defenders.

We could use DNA from preserved mammoths to create elephants with mammoth-like qualities

WHERE WOULD THE ANIMALS LIVE?

De-extinction is a process that begins with creating a single animal in the lab and then ends, many years later, with the release and survival of sustainable populations in the wild.

Ecosystems are fluid, dynamic entities – they change quickly. But if a species has gone extinct recently, there is a chance it could be returned to its original ecosystem. The Tasmanian tiger is thought to have gone extinct 80 years ago, but in that time, its native woodland has stayed more or less the same – this de-extinct species could potentially 'go home'. A de-extinct Christmas Island rat, however, would not be so lucky. Since its extinction over 100 years ago, Christmas Island has become riddled with invasive species that would likely pose a problem. In this case, a suitable alternative habitat would have to be found.

WHAT IS THE IDEAL CANDIDATE FOR DE-EXTINCTION?

It may seem an odd thing to say, but one of the ideal de-extinction candidates could be an animal that is actually still alive… just. There are only three northern white rhinos left alive on the planet: a grandfather, a mother and a daughter, who spend their days at the Ol Pejeta Conservancy in Kenya. But they are too old, too ill and too related to breed naturally.

So the northern white rhino is 'functionally extinct': the ghost of a magnificent species

IN A NUTSHELL

1 WE'RE TURNING BACK TIME

Scientists are on the verge of being able to reverse extinction. They are taking DNA from fossils and museum specimens, and using some fancy, high-tech science to make copies of various extinct animals.

2 IT'S ALL FOR A REASON

The idea isn't to create some lonely zoo exhibit or biological freak, but to generate entire populations of healthy animals that can breed naturally and live sustainably in the wild. Through their actions, and the positive effects they have on other species in their ecosystem, de-extinct species could help boost the overall levels of biodiversity.

3 A NEW ERA FOR CONSERVATION?

Despite the best efforts of conservationists, species are going extinct at an alarming rate. De-extinction is new, unfamiliar and untested, but it could become a vital instrument in the conservationist's toolbox. Over the coming decades, we'll be able to assess its worth and decide how, or indeed 'if', the technology should be used.

Elvis's quiff would be seething with DNA that we could use to bring him back to life

that once manicured the diverse African grasslands on which so many other species depend. Saving it counts as an act of de-extinction. For many reasons, it's easier to de-extinct an animal from the recent past than it is from dim and distant history. But it's easier still to focus on those that are still with us. The northern white rhino is currently the focus of an de-extinction project.

BUT IS IT RIGHT TO BRING BACK EXTINCT ANIMALS?

Some people are against de-extinction because they say it feels unnatural. They are wary of genetic modification and accuse scientists of playing God. But proponents argue that the techniques being developed to make de-extinction happen all have natural counterparts in the wild. For example, there are species of lizard that reproduce via cloning, while the gene editing process being used to bring back the mammoth hails from a primitive bacterial immune system.

Just as IVF has become an accepted medical technique, so de-extinction researchers hope that concerns about their experiments will fade once the science has proved its worth.

Critics also claim that de-extinction is stealing funds and attention from traditional conservation efforts. But none of the big wildlife charities are putting any money into de-extinction, and a big resurrection success story could even help to draw attention to the plight of the world's wildlife, rather than detract from it. It's true that it's still too early to know exactly how de-extinction will pan out, but its supporters argue that if we don't at least develop the technology needed to make it happen, we'll never make a genuine assessment of its worth.

COULD WE BRING BACK OUR PETS?

The labs at Sooam Biotech Research Foundation in Seoul, South Korea, regularly produce cloned dogs for the Korean National Police Agency and will even clone your pet pooch for around $82,325. But although the doppelgänger will look like your faithful friend, it will never be the same. Just as identical twins develop different personalities, physical characteristics and diseases, 'Fido II' will grow into a different dog.

AND HOW ABOUT... ELVIS?

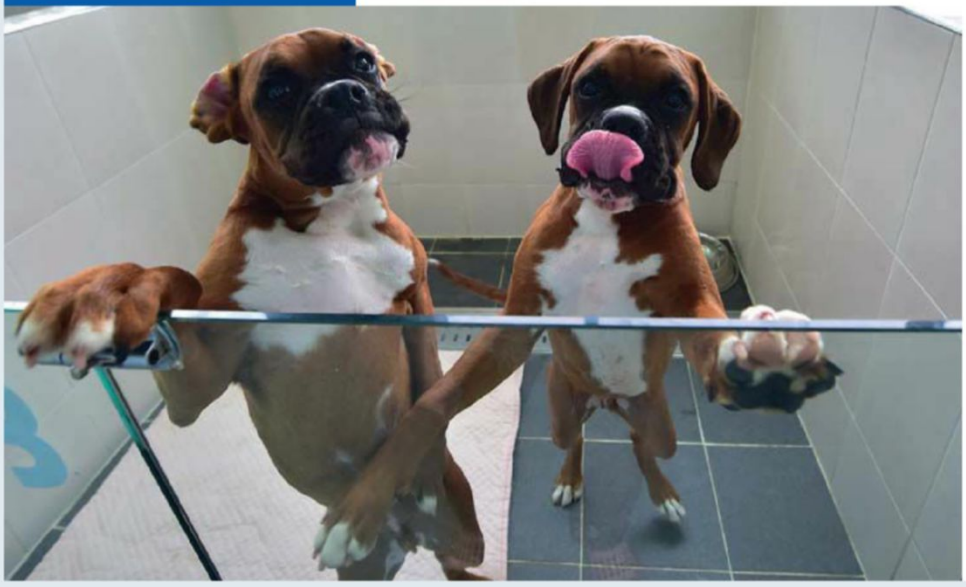
If we can resurrect animals, could we bring back long-dead humans? In theory, it's possible. Take Elvis Presley as an example. Scientists could retrieve DNA from some of his iconic quiff, sequence his full genetic code, edit the 'genetic essence' of Elvis into a regular human cell and then use that to create a cloned baby.

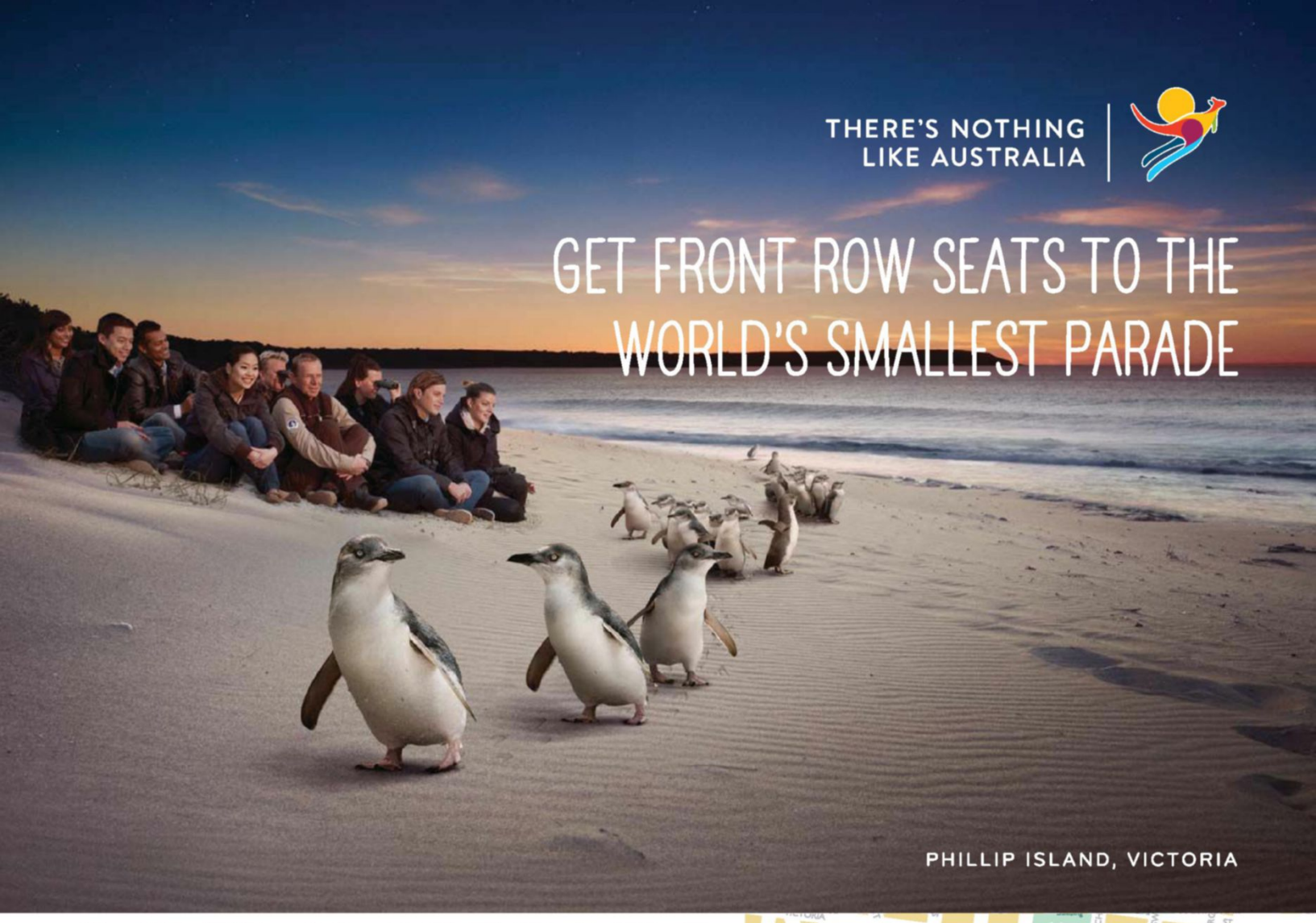
In reality, though, it's a terrible idea. Reproductive human cloning is illegal and unethical, and the process carries many risks. What's more, a clone of Elvis might well end up more into drum 'n' bass and Dr Martens than rock 'n' roll and blue suede shoes.

But this cheeky thought experiment does show how far the science underpinning de-extinction can take us. Elvis? Maybe not. But woolly mammoths and Tasmanian tigers? Don't bet against it.

Helen Pilcher is a science writer, performer and author of *Bring Back The King: The New Science Of De-extinction*

BELOW: Cloned boxer dogs jostle for attention at the Sooam facility in South Korea





MELBOURNE

Educational trip

You are invited to visit..

- City tour : Fitzroy Garden, Captain Cook's Cottage, Shrine of Remembrance. Drive pass- Royal Exhibition Building, Federation Square
- Brighton Beach Box Huts
- Puffing Billy Steam Train
- Rayner's Orchard
- Penguin Parade with penguin PLUS
- And MANY MORE!!!

*Terms and Conditions apply

AUSTRALIA AUSSIE SPECIALIST PREMIER

PNL TRAVEL
Sharing Experiences

PNL TRAVEL SDN BHD (143718-V) KKKP/PL : 0908

+603-9284 4859 | PNL Travel

tours@pnltravel.com.my | www.pnltravel.com.my

24, Mezzanine Floor, Jalan Serkut, Taman Pertama, Cheras, 56100 Kuala Lumpur

Q&A


DR ALASTAIR GUNN
Astronomer, astrophysicist


ALEXANDRA CHEUNG
Environment/ climate expert


DR PETER J BENTLEY
Computer scientist, author


PROF ALICE GREGORY
Psychologist, sleep expert


PROF MARK LORCH
Chemist, science writer


CHARLOTTE CORNEY
Zoo director, conservationist


DR HELEN SCALES
Marine biologist, writer


DR CHRISTIAN JARRETT
Neuroscientist, writer


EMMA DAVIES
Heath expert, science writer


LUIS VILLAZON
Science/tech writer

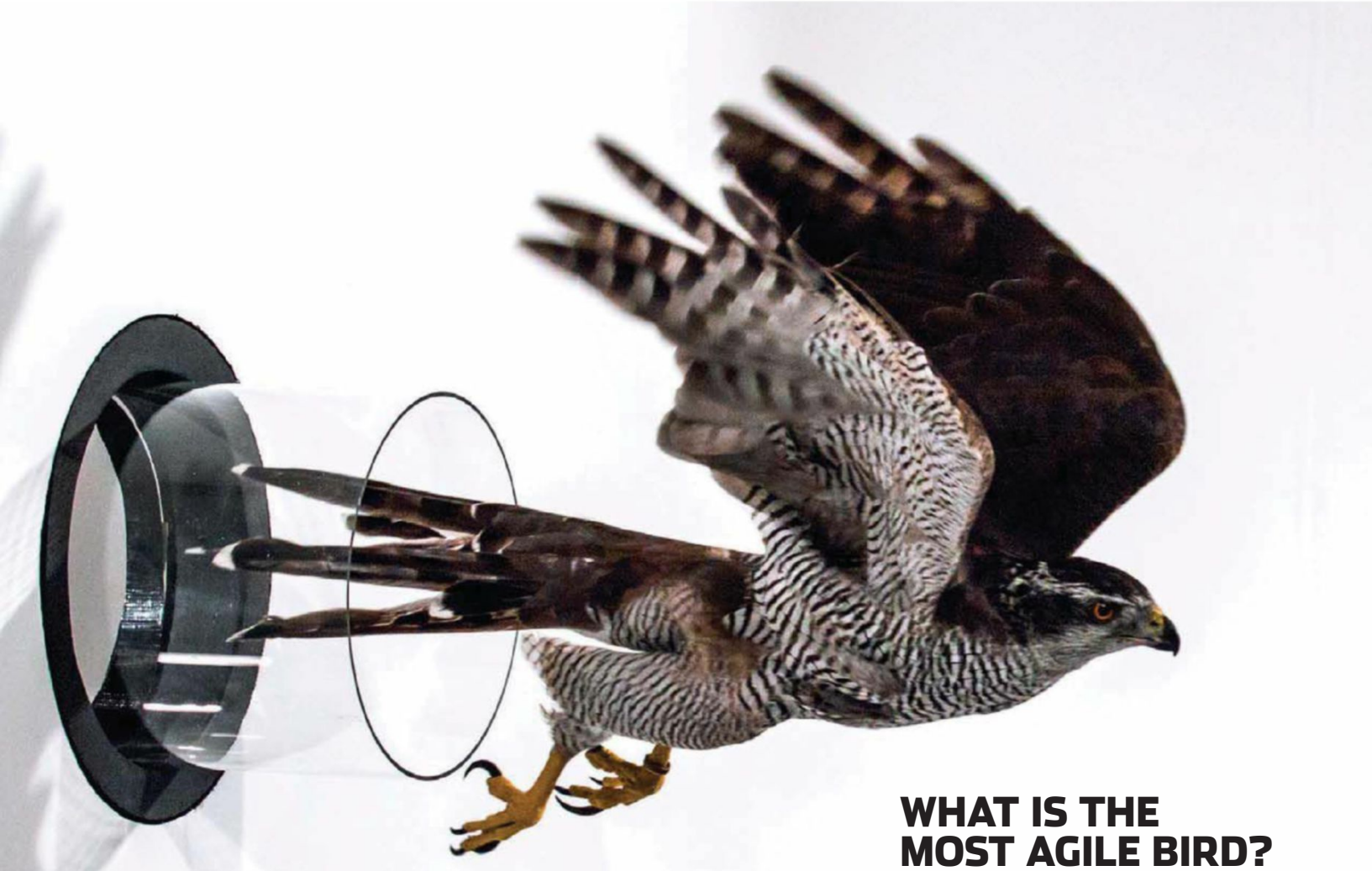

DR AARATHI PRASAD
Biologist, geneticist


PROF ROBERT MATTHEWS
Physicist, science writer

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL

editorial-bbcearth@regentmedia.sg



Eat your heart out, Tom Cruise, the northern goshawk outstrips your aeronautical tomfoolery

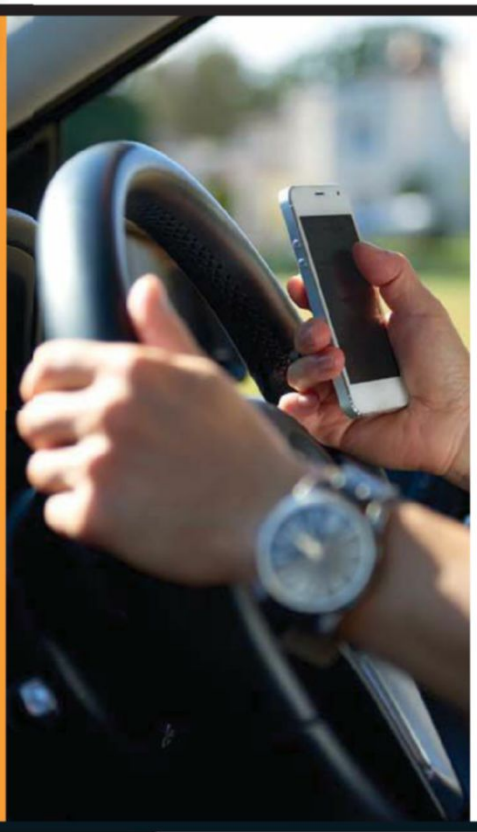
PHOTO: SCIENCE PHOTO LIBRARY

WHAT IS THE MOST AGILE BIRD?

The masters of low-speed aerobatics are the hummingbirds, which can hover with millimetre precision, and fly sideways or backwards. But in the avian Olympics, the slalom medals are all won by woodland raptors such as the northern goshawk. Despite having a wingspan of over a metre, these birds can chase prey at up to 60km/h while weaving through dense forest. **LV**

WHY ARE RASPBERRY DRINKS BLUE?

In the 1950s, raspberry-flavoured foods were coloured dark red using a dye called amaranth. This later turned out to be carcinogenic and was banned in the US. Food manufacturers started using the bright blue dye instead, partly because it helps to distinguish it from cherry or strawberry flavours, but also because children seem to like brightly coloured foods. **LV**



WHY ARE SOME PEOPLE MORE EASILY DISTRACTED THAN OTHERS?

Differences in attention span are a result of genes and environmental experiences. These influences can impact upon brain development and functioning, making it more difficult for one person to pay attention than another.

A distinction can also be made between 'bottom up' and 'top down' attention. The former involves us becoming distracted by a salient feature in our environment, such as a bright light. The latter is when we focus on something based on our internal goals – we may give a boring document our full attention because we want to pass an exam. These types of attention share some underlying mechanisms, with the frontoparietal network of the brain important for both, for example. **AGr**

Nope, this isn't Tim Burton's latest creation, it's a uniform that was worn by 17th-Century plague doctors

COULD THE BLACK DEATH HAPPEN AGAIN?

No. Bubonic plague killed at least one-third of the population of Europe between 1346 and 1353. But that was before we knew it was caused by the bacterium Yersina pestis. Bubonic plague does still occasionally occur in small flare-ups of a few dozen cases, but we have antibiotics to treat it now. Plus, better hygiene makes it very hard for a disease spread by flea bites to become a global pandemic again. **LV**

IN NUMBERS

53

The percentage of a chromosome that's made up of DNA. The other 47 per cent is a sheath enclosing the genetic material.

3,300

The grip strength, in newtons, that a 4kg coconut crab can exert with its claw.

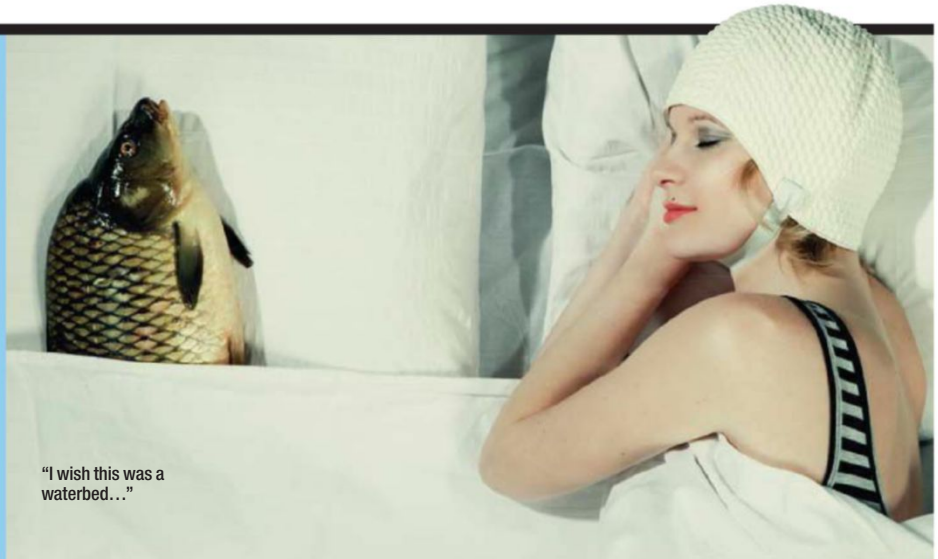
204

The number of cubic metres of soil dug up each year by a single echidna as it forages for insects.

PHOTOS: GETTY X2, ALAMY

WHAT IS TIDAL LOCKING?

Tidal locking is the phenomenon by which a body has the same rotational period as its orbital period around a partner. So, the Moon is tidally locked to the Earth because it rotates in exactly the same time as it takes to orbit the Earth. That is why we only see one side of the Moon. If both bodies are of comparable size and are close together, both bodies can be tidally locked to each other – this is the case in the Pluto-Charon system. Tidal locking is a natural consequence of the gravitational distortions induced by a body on another. **AGu**



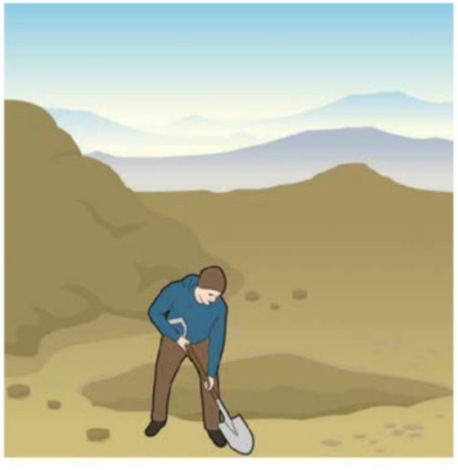
"I wish this was a waterbed…"

HOW DO FISH SLEEP?

It's hard to say if fish sleep like we do. Most can't close their eyes and have no neocortex, which is the part of the mammalian brain that displays distinct patterns of activity during sleep. Even so, many fish settle down for the night on the seabed. Parrotfish sleep inside a mucous bubble, perhaps so predators can't smell them. At night, zebrafish float in the water column and are difficult to rouse. Some fish never seem to sleep, including blind cave fish and fish swimming in shoals through featureless water. It could be they receive limited sensory input and their brains don't need to rest. **HS**

THE THOUGHT EXPERIMENT

HOW MUCH WOULD YOU HAVE TO DIG TO ALTER EARTH'S ORBIT?

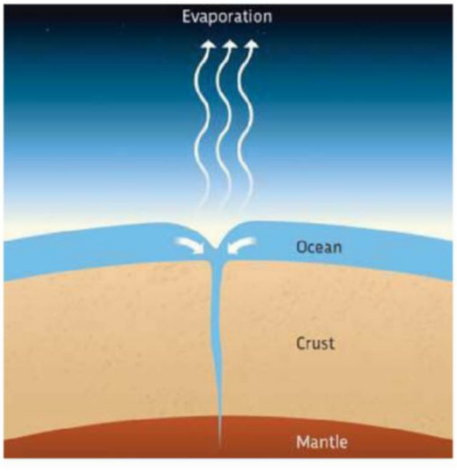


1. EARTH MOVING

Digging a hole into the ground doesn't apply any net force on the Earth. But as you remove soil from the hole and pile it up into a heap, you are very slightly shifting the centre of mass of the planet. This will cause it to wobble a little as it rotates. The effect is very small, however.

2. SOIL LAUNCHING

If you fling each spadeful of soil into space, then you could apply a net force to the planet. You'd need to throw it hard enough to achieve escape velocity, but every billion tonnes you throw over your shoulder would change Earth's orbital velocity by two nanometres per second.



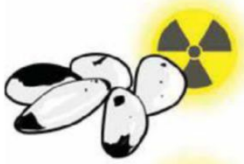
3. SEA BOILING

Alternatively, you could dig a hole at the bottom of the Pacific Ocean deep enough to drain all the water down into the mantle. If this boiled all the ocean into steam and jetted it into space, it might add an extra 1.5km/h to the Earth's normal orbital speed of 108,000km/h.

PHOTOS: GETTY X2 ILLUSTRATIONS: ACUTE GRAPHICS

TOP 10

COMMON RADIOACTIVE FOODS PER KG



1. BRAZIL NUTS
pCi* per kg: 12,000
pCi per serving: 240

2. BUTTER BEANS
pCi per kg: 4,600
pCi per serving: 460

3. BANANAS
pCi per kg: 3,500
pCi per serving: 420

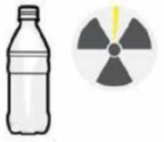
4. POTATOES
pCi per kg: 3,400
pCi per serving: 850

5. CARROTS
pCi per kg: 3,400
pCi per serving: 255

6. RED MEAT
pCi per kg: 3,000
pCi per serving: 240

7. AVOCADOS
pCi per kg: 2,500
pCi per serving: 420

8. BEER
pCi per kg: 390
pCi per pint: 222



9. WATER
pCi per kg: 170
pCi per pint: 100

10. PEANUT BUTTER
pCi per kg: 120
pCi per serving: 3.6

* pCi = picocurie

WHY DOES RUBBER HAVE HIGH FRICTION?

Despite decades of research into the frictional properties of rubber by tyre manufacturers, the precise causes of the 'stickiness' of rubber are still the subject of argument. Current theories suggest that when rubber moves over smooth surfaces, it's the molecular forces between the two that are the main cause of friction. But when the surface is rough, it's the deformation of entire molecular layers of rubber that's the chief cause of friction. **RM**

HOW LONG CAN A GERM SURVIVE ON A DOORKNOB?

On a hard, non-porous surface like a door handle, most viruses are destroyed within 24 hours. The survival time for bacteria is more variable. *Salmonella* only lasts four hours, but MRSA can last several weeks and *C. difficile* has been found to survive for up to five months. On clothing or skin, the survival time is roughly halved. This may be because these surfaces dry out more quickly, or because they interfere with the bacteria's ability to produce protective biofilms. **LV**

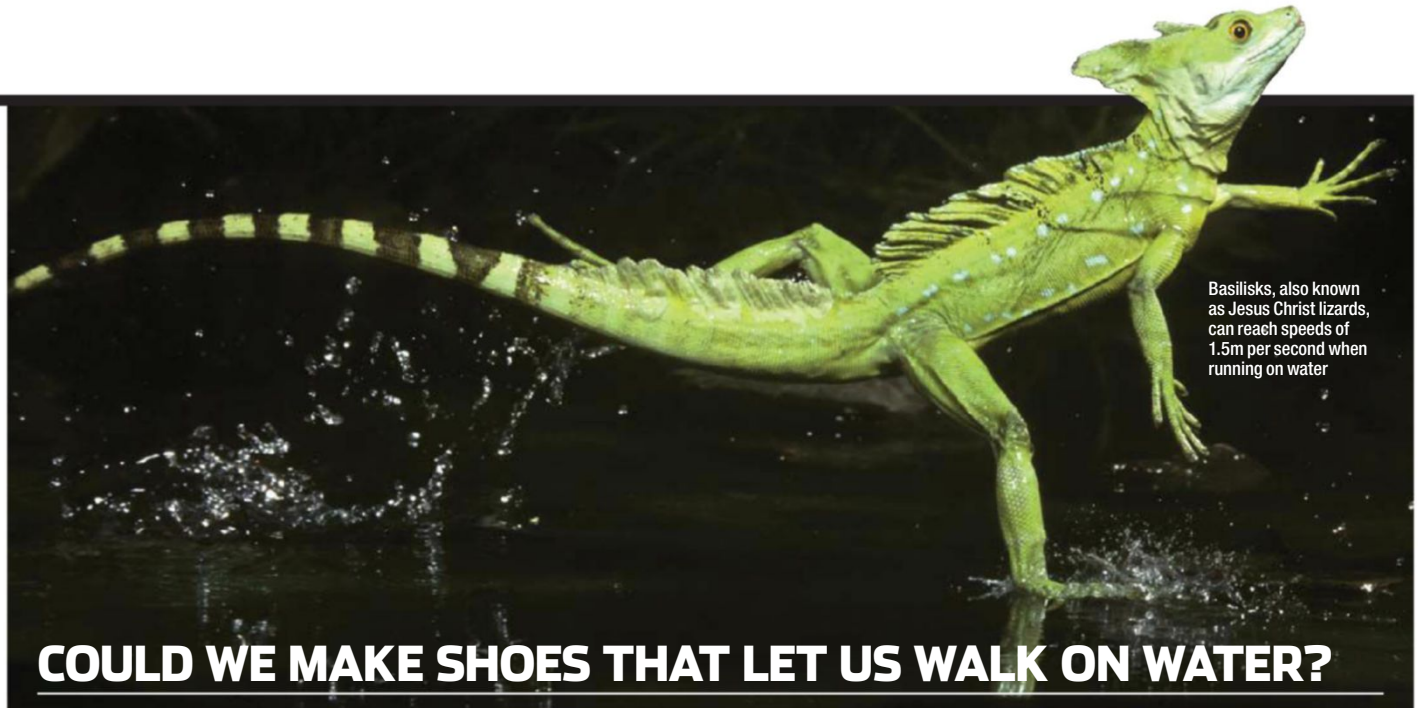
IN NUMBERS

85
The percentage of European urbanites exposed to harmful particulate matter.

1,445
The number of new viruses discovered in invertebrates as part of a recent study.

60
The amount by which Pluto may have tilted, due to its heavy, ice-filled, heart-shaped basin.

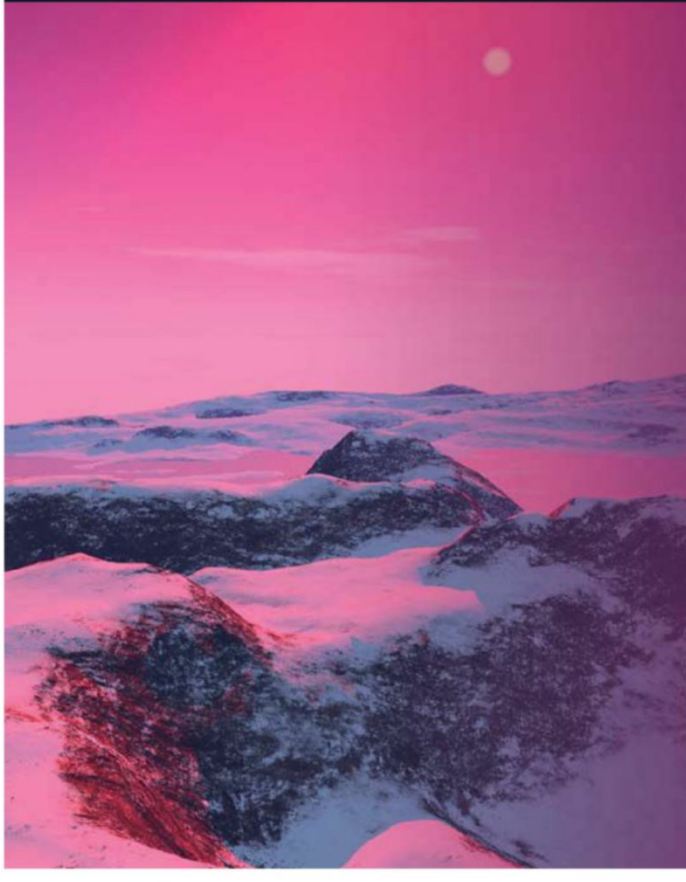
PHOTOS: GETTY X2



Basilisks, also known as Jesus Christ lizards, can reach speeds of 1.5m per second when running on water

COULD WE MAKE SHOES THAT LET US WALK ON WATER?

Shoes that provide enough buoyancy to keep you afloat are simple but bulky. You're really just cutting a raft in half and standing with one foot on each half. Leonardo da Vinci sketched an idea for this in the 15th Century and it is a common school project for physics students. The hard part is designing shoes that provide enough traction to let you push against the water, without being so cumbersome that you exhaust yourself after a few steps. But skipping over the surface, like the basilisk lizard does, is much tougher. A 1996 study at Harvard discovered that the lizard strikes the water hard enough with each step that it creates a bubble of air surrounding each foot, and then pulls its feet up again fast enough to clear the surface before the bubble collapses, which minimises drag. When you scale the forces up to human size, you would need to run at over 100km/h (62mph) to pull this off. At least in Earth's gravity. A 2012 study at Rome's Laboratory of Neuromotor Physiology found that if you wore flippers, and could find a suitable pool, you could run on water on the Moon. **LV**



WHAT COLOUR IS THE SKY ON AN EXOPLANET?

The colour of the sky on an exoplanet depends on many things: the pressure, density and chemical composition of its atmosphere, the presence or absence of dust particles, vapour and clouds, the spectrum of the planet's parent star, as well as the size, composition, colour and even biology of the planet itself. On Earth, the sky is predominantly blue but becomes orange or red near the setting or rising Sun. On Mars, the opposite is true. These differences are mainly due to which compounds or gases are scattering and absorbing the sunlight. Scattering is the predominant factor in most atmospheres and since molecules scatter short wavelengths best and longer wavelengths the least well, this often results in blue skies. But large amounts of dust will lighten and sometimes redden sky colours. Mars' atmosphere appears red because of the presence of iron oxide-rich dust particles. High-pressure atmospheres would be much lighter than lower pressure ones and could appear completely white or yellow. Given the number of factors involved it isn't unreasonable to suppose that exoplanet skies could be any colour at all – from blue or cyan, through green and yellow to red, orange and purple – even brown and white are possible. **AGu**

PHOTOS: GETTY X2

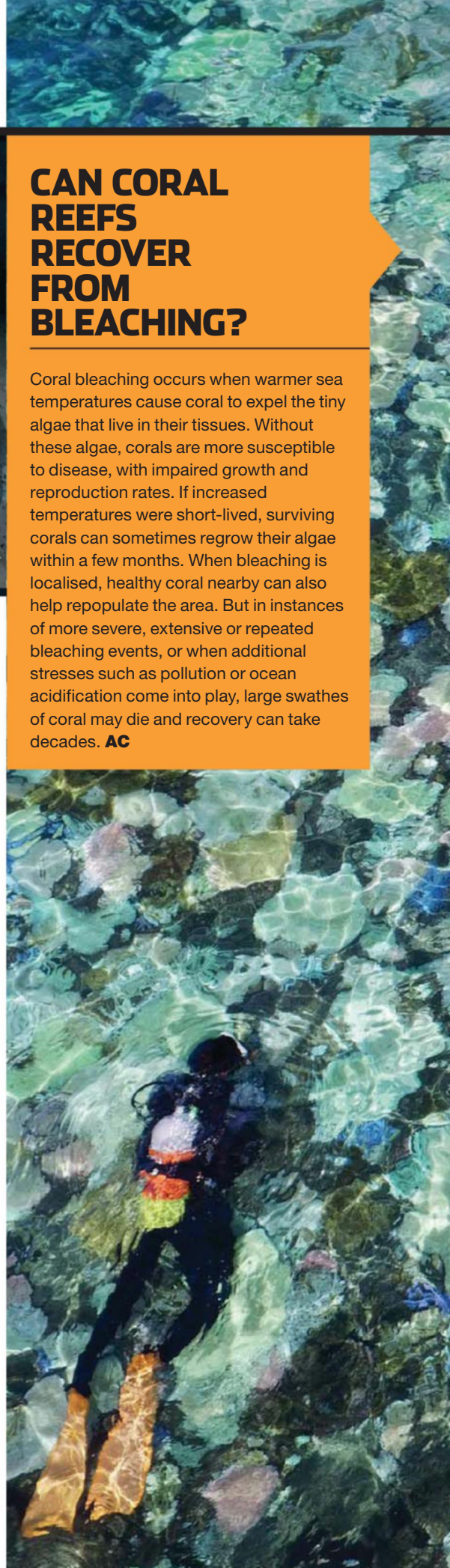
HOW OLD IS WATER?

Kuiper Belt Objects are the prime suspects for delivering water to Earth

As Earth was intensely hot following its formation 4.6 billion years ago, little of today's water is likely to date back that far. Instead, it's thought to have arrived later, in collisions with objects from elsewhere in the Solar System. Comets were long thought to be the most likely source, but data sent back from the recent Rosetta mission has confirmed suspicions that these 'dirty snowballs' contain water with a mix of isotopes different to water found on Earth. So attention has now switched to so-called Kuiper Belt Objects (KBOs) orbiting far beyond Neptune. Studies of these asteroid-like objects have revealed the presence of water, and they are now suspected of having delivered it to Earth when swarms of them smashed into our planet around 3.8 billion years ago. **RM**

CAN CORAL REEFS RECOVER FROM BLEACHING?

Coral bleaching occurs when warmer sea temperatures cause coral to expel the tiny algae that live in their tissues. Without these algae, corals are more susceptible to disease, with impaired growth and reproduction rates. If increased temperatures were short-lived, surviving corals can sometimes regrow their algae within a few months. When bleaching is localised, healthy coral nearby can also help repopulate the area. But in instances of more severe, extensive or repeated bleaching events, or when additional stresses such as pollution or ocean acidification come into play, large swathes of coral may die and recovery can take decades. **AC**



HEAD TO HEAD

VS

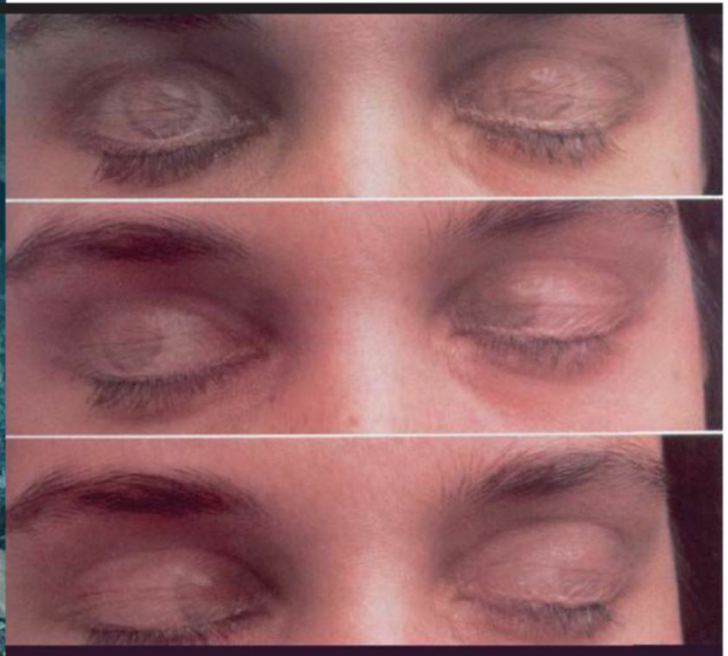
COW'S MILK* (PER 100ML)		ALMOND MILK (per 100ml)
35	CALORIES	13
<0.1g	SATURATED FAT	0.1g
3.4g	PROTEIN	0.4g
0.1g	SALT	0.13g
trace	VITAMIN D	0.75mcg (7.5% RDA)
120mg (12% RDA)	CALCIUM	124mg (12% RDA)

Almond milk and skimmed cow's milk are nutritionally very similar. That's because almond milk is a synthetic product designed to resemble milk. The fat and salt content are virtually identical, and while cow's milk has more protein, it's still too little to make much difference to your diet. As well as being suitable for lactose-intolerant people, almond milk is slightly healthier though because it contains vitamin D, which cow's milk does not.

** Skimmed*

Japan's largest coral reef, Sekiseishoko, is starting to bleach and die because of higher sea temperatures

PHOTOS: GETTY X2; PRESS ASSOCIATION; SCIENCE PHOTO LIBRARY



WHY DO OUR EYES MOVE WHEN WE SLEEP?

Our sleep can be split into two main stages – rapid eye movement (REM) and non-rapid eye movement (NREM) sleep. It is during REM sleep that our eyes dart about. This is also the stage of sleep during which we are most likely to dream. The movement of our eyes is due to specific brain activity that is characteristic of this stage of sleep. Research suggests that eye movements may allow us to change scenes while we are dreaming. Scientists found that the neuronal activity following eye movements during REM sleep resembled that seen when people are shown or asked to remember an image when they are awake. **AGr**

WHY CAN'T WE REGROW TEETH?

Your baby teeth and adult teeth all began developing before you were even born. Our DNA still contains all the genes that sharks use to grow their endless conveyor belt of replacement teeth, but in humans these genes are deactivated by the 20th week of foetal development. The advantages of keeping the same teeth through adulthood is that they can be securely anchored in the jawbone, which allows us to chew tough plants and grains. **LV**

WHAT CREATURE MAKES THE BIGGEST SEASHELL?

Seashells are the exoskeletons of animals called molluscs, including snails, nautiluses, mussels, scallops and oysters. The biggest are giant clams, *Tridacna gigas*. Their twinned shells can grow to well over a metre across and tip the scales at 200kg, the same as two newborn elephants. Giant clams, like all shell-making molluscs, sculpt their protective homes from calcium carbonate and gradually expand them throughout their lives. They inhabit coral reefs and can live for at least a century. Demand for their meat as a delicacy in many countries is making them vulnerable to extinction. **HS**

IS ANTARCTICA MELTING?

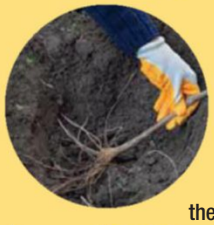
Antarctic sea ice undergoes an annual cycle of freezing and melting, reaching its maximum extent in October and then melting. In the past few decades, the maximum amount of Antarctic sea ice has increased slightly, but on land it's a different story. While a few areas of the frozen continent's gigantic ice sheet have been growing, overall Antarctica is losing ice, with glaciers in West Antarctica undergoing the most rapid melting. Ice shelves fringing the Antarctic land mass, where land ice meets the ocean, are also shrinking. As global temperatures increase, scientists expect to see further melting, contributing to global sea level rise. **AC**

WHAT CONNECTS...

...NUCLEAR WEAPONS AND FINE WINE?

1. In 1945, the US Army conducted the first nuclear weapons test, as part of the Manhattan Project. Since then, there have been over 2,000 nuclear explosions around the world.

2. Each nuclear explosion releases several hundred grams of the radioactive isotope caesium-137. This has a half-life of about 30 years, so it is not normally found in nature.



3. Caesium-137 dust gets dispersed in the atmosphere and reacts with rainwater to form soluble salts. From there it is absorbed, in tiny quantities, by plants through their roots.

4. Although it is quite safe to drink, any wine bottled after 1945 has detectable amounts of caesium-137 and this can be used to spot fake bottles claiming to be much older.

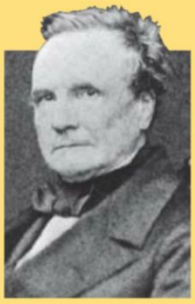
PHOTOS: FLPA/NORBERT WU, BARCROFT MEDIA, GETTY X4, IRIS CHRISTIANI/BIONERD23/FLICKR

SKY HIGH

Brighton's British Airways i360, designed by the creators of the London Eye, is the world's tallest moving observation tower. Visitors climb aboard the glass pod, seen here, then ascend 138m where they can enjoy panoramic views across Brighton and the South Downs. A total of 1,336 bolts, weighing a whopping 30 tonnes, hold the i360 together. The structure has a diameter of a svelte 3.9m, earning it a Guinness World Record as the world's most slender tower.

WHO REALLY INVENTED?

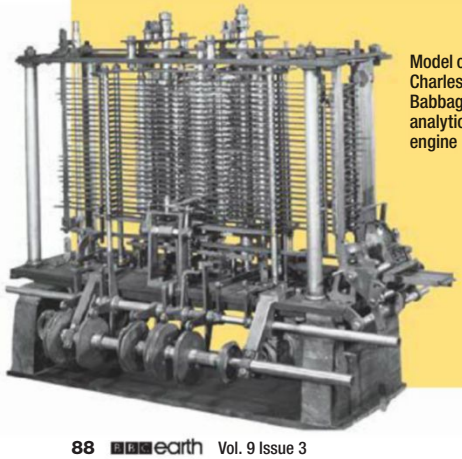
THE COMPUTER



CHARLES BABBAGE

ALAN TURING

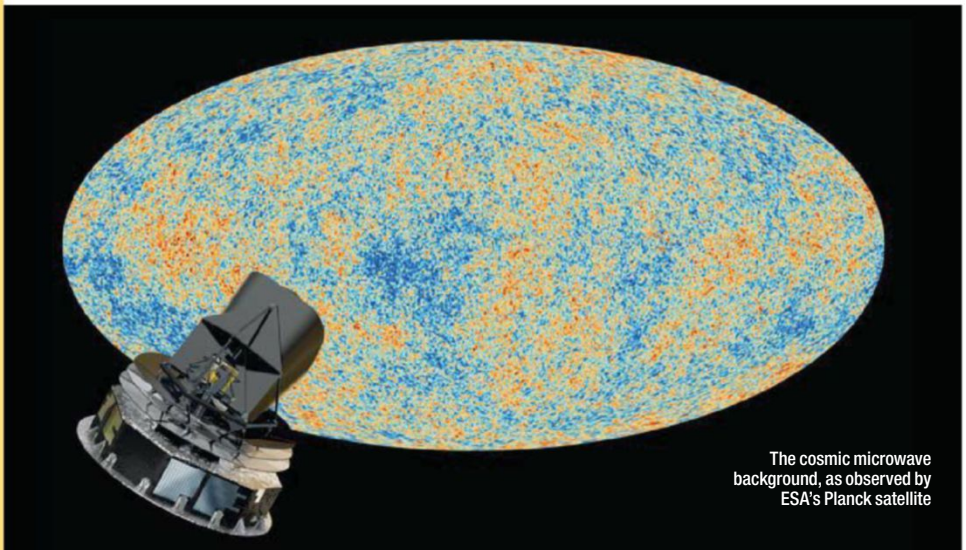
Computers are far more than ultra-fast number-crunchers. Crucially, if given a new set of instructions, a computer's processor and memory can – in principle, at least – do anything from word-processing to flying a plane. Credit for being the first to consider building so versatile a device goes to the British mathematician Charles Babbage, who in 1834 began drawing up plans for what he called the 'analytical engine'. His dream was to create a device whose gears, rods and wheels could be arranged – programmed – to perform a myriad of tasks from solving equations to composing music. Sadly, only a fragment of this Victorian engineering miracle was ever completed. It took another 100 years before another British mathematician, Alan Turing, revived the idea of a 'universal machine' and investigated its theoretical powers. During WWII, his code-breaking colleagues at Bletchley Park exploited some of these powers. Their electronic device was called Colossus, and it broke Hitler's most secret ciphers. Historians still argue about who built the first genuine computer, but it's generally agreed that engineers in the US and Britain both succeeded in creating electronic machines embodying Babbage's dream by the late 1940s. **RM**



Model of Charles Babbage's analytical engine

WHY IS EVERYTHING IN MOTION?

Everything in the Universe is in motion because forces exist in the Universe. The gravitational force and the electromagnetic force ensure large objects are in motion while the weak and strong nuclear forces ensure the quantum world is constantly in motion. If there were no forces, there would be no motion. The question of why there are forces in the Universe is currently unanswerable by science. They appear to be fundamental and demonstrable facts but there may not be an ultimate reason for their existence, just as there may not be a root cause for the existence of the Universe itself. **AGu**



The cosmic microwave background, as observed by ESA's Planck satellite

WILL THE COSMIC MICROWAVE BACKGROUND DISAPPEAR?

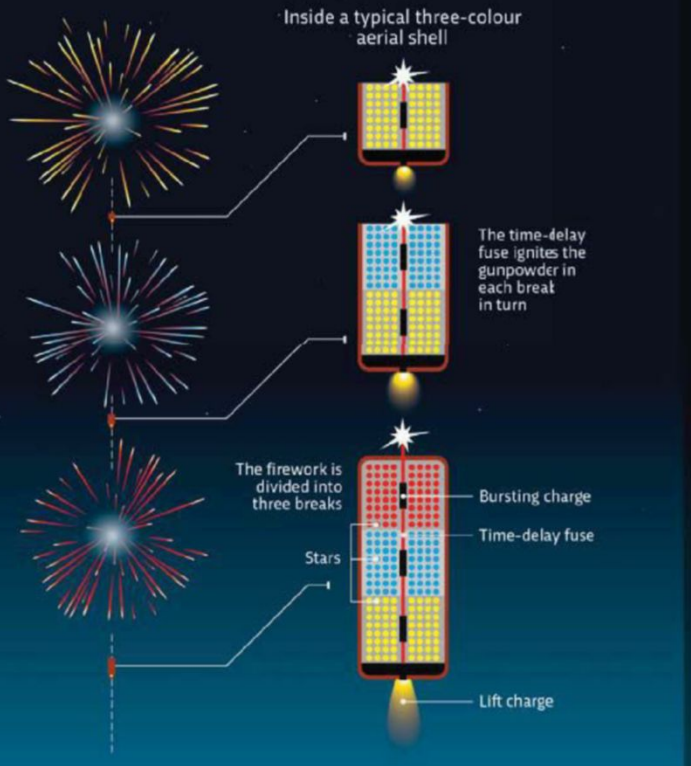
Yes. This relic radiation left over from the Big Bang is being increasingly redshifted as the Universe expands. So its energy is being constantly diluted. After another few trillion years, the current cosmic microwave background will have redshifted into insignificance and will no longer be detectable. In this far-flung future, the Universe will have expanded so much that even the closest galaxies will be well beyond our sight. At this time, there will be no visible evidence that the Universe is expanding or that there was ever a Big Bang! **AGu**

PHOTOS: GETTY X4, NASA/ESA

HOW IT WORKS

FIREWORKS

When the firework is lit, a fuse ignites a pouch of black powder in the base that launches the firework into the air. A second 'time delay' fuse ignites, leading to the centre of the firework. The chemicals in the 'stars' are the magic of the firework, creating all the dazzling colours.



WHY DO SOME PLANES LEAVE TRAILS AND OTHERS DON'T?

Technically known as contrails, these white trails are created from water vapour produced by the combustion of fuel in aircraft engines. At their cruising altitude of 10,000m, temperatures are around -55°C. As it's so cold, the water turns to ice particles, but how long they remain visible depends on humidity. If the air is relatively humid, the contrails will grow and remain visible long after the aircraft has disappeared. **RM**

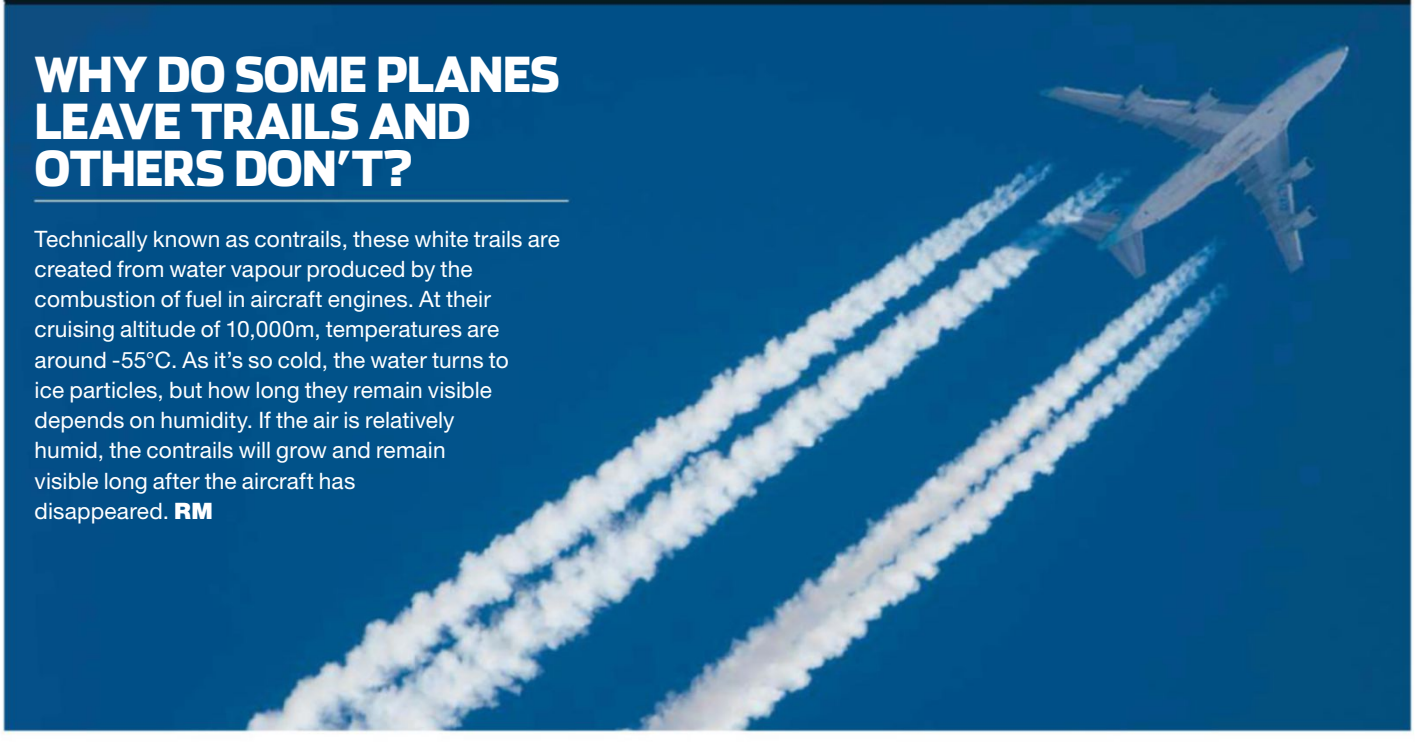


PHOTO: GETTY ILLUSTRATION: ACUTE GRAPHICS

01 SPY IN THE WILD

BBC One, January.

MEET THE SPYCREATURES

Well, wouldn't you be surprised too? A grey langur does a double take as it meets its animatronic equivalent in Rajasthan, India.

This candid shot was taken during filming of the BBC's new five-part series Spy In The Wild, a follow-up to previous 'spy' series including Spy In The Huddle and Spy In The Pod. This time around, Spy In The Wild sees over 30 robotic animals being released into habitats around the world.

There are animatronic fish, birds, mammals and reptiles, from tiny SpyCrocHatchlings to a full-size SpyOrangutan. Made to look and smell as realistic as possible, and even to move just like the real creatures they represent, the SpyCreatures allow us to get remarkably close to wild animals, infiltrating their most intimate moments and witnessing some surprisingly human-like behaviour.

Turn over for an interview with one of the show's creators.

PHOTO: MATHEW GORDON/BBC

Q&A: ROB PILLEY

How were the creatures made?
Each spy animal has a bare metal skeleton, a chassis, and a complicated system of servos and motors that allow it to move. Most of the skins are made of latex, and the fur is generally acrylic. For the birds, we typically used dyed goose and chicken feathers, each one having to be individually punched into the skin in the correct position. We also had to make some of the animals smell like the real thing by rubbing poo all over them!

Which was the most challenging SpyCreature to build?
The SpyCrocodile: it has 26 individual motors and an onboard computer to allow it to walk realistically, with the limbs, spine, pelvis and tail all moving simultaneously. It took two people to operate it in the field, constantly adjusting its gait as it moved over different terrains.

Who were they made by?
There's no one person out there who is able to build spy animals this detailed, so each robot was a collaboration between a team of precision engineers, animatronics specialists, programmers, model makers and make-up artists from all over the world.

Was the entire series filmed from the SpyCreatures' perspective?
No, in order to make these films emotionally rich, we needed a range of viewpoints. For each shoot, we'd have potentially 10 individual cameras: the SpyCreatures themselves, peripheral spy cameras such as 'log cams' and 'boulder cams' and then one or two natural history camerapeople too. You need all of these elements to tell the story – it would be exhausting to see everything from the SpyCreatures' point of view only.

Can you pick out a couple of personal highlights from the series?
To be up close and personal with these animals is something else. To be gently picked up in the mouth of a crocodile because she thinks you're one of her babies is a unique moment in time! SpyTortoise in particular had an eventful journey. He met some chimps, who pulled him up a tree and used him as a pillow. He eventually got squashed by an elephant, but not before he'd met a real tortoise and got involved in some romantic antics…

What was your favourite part of making Spy In The Wild?
We had over 8,000 hours of material in total, and when you go through it, you see the same animals again and again. So you start to get to know them, and you realise how their emotions, their relationships, and their mischievous sides are so incredibly human-like. That was one of the pinnacles of the series for me, to step into the world of these animals like never before.

SPIES IN THE WILD

Meet some of the stars of the show…

SpyOrangutan…
learns how to use tools from wild orangutans in Borneo.

SpyPufferfish…
spies on young dolphins who are 'getting high' by chewing on real pufferfish.

SpyOstrichChick…
witnesses the plight of a daring female ostrich as she lures lions away from her chicks.

SpyWarthog…
makes some unlikely mongoose friends, who offer him their grooming services.

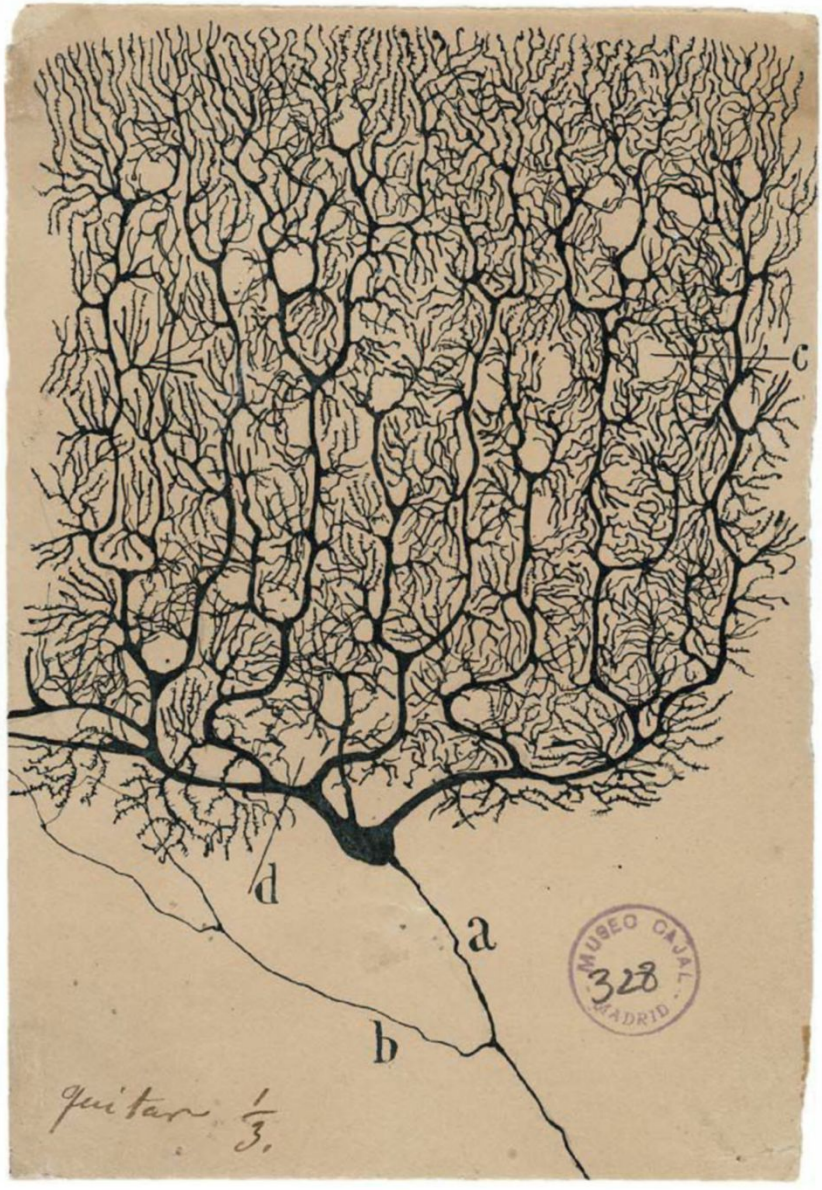
SpyTortoise…
is adopted by a curious chimpanzee, and finds himself in the middle of a love tryst with another tortoise.

02 EXPLORE THE BEAUTIFUL BRAIN

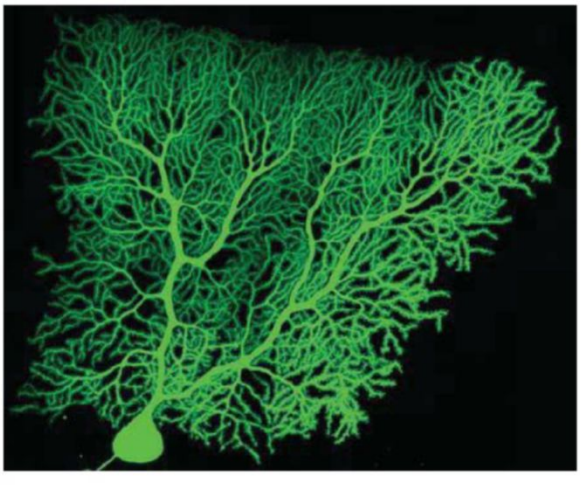
THE BEAUTIFUL BRAIN: THE DRAWINGS OF SANTIAGO RAMÓN Y CAJAL
is out now

Long before MRI and CT scanners arrived on the scene, a Spanish pathologist called Santiago Ramón y Cajal (1852-1934) was studying the brain by examining thin, chemically stained slices under a microscope. Viewed by many as the creator of modern neuroscience, Cajal produced nearly 3,000 drawings, making the fundamental observation that the brain is made up of individual nerve cells, or neurons.

This new book gathers together over 80 of Cajal's most important illustrations, including the intricate Purkinje neuron seen here. With their elaborate, tree-like structure, these are some of the largest, most distinctive cells in the human brain. They're located in the cerebellum, a structure that plays a central role in motor control. The clarity and elegance of Cajal's drawings means they're still relevant today.



BELOW: Santiago Ramón y Cajal
LEFT: His drawing of the Purjinke neuron
BOTTOM: A modern image of the Purjinke neuron, taken with a microscope



PHOTOS: INSTITUTO CAJAL DEL CONSJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS MADRID/2017 CSIC X2, BORIS BARBOUR/CNRS

SPECIAL SUBSCRIPTION OFFER!

4 EASY WAYS TO SUBSCRIBE

WANT TO BE IN THE KNOW? JOIN THE CLUB

SAVE 15% OFF YOUR SUBSCRIPTION!

GO ONLINE*
e-shopping.sg
READ.EXPLORE

OR EMAIL
subscription@regentmedia.sg

FAX TO
SINGAPORE
65-6449 9945

MALAYSIA
603-42926251

CALL HOTLINE
SINGAPORE
65-6446 6888

MALAYSIA
603-79548989

MAIL TO
Regent Media Pte Ltd,
20 Bedok South Road,
Singapore 469277
or
Unit 6.02 Level 6, Menara Maxisegar
Jalan Pandan Indah 4/2
Pandan Indah
55100 Kuala Lumpur.

GREAT REASONS TO SUBSCRIBE

- Every issue delivered direct to your door
- Exclusive subscriber-only offers and discounts

BBC EARTH MAGAZINE SUBSCRIPTION OFFER

YES! I WANT TO SUBSCRIBE!

PLEASE TICK ACCORDINGLY

❍ Singapore, 1 year subscription, 12 issues for S$77

❍ Malaysia, 1 year subscription, 12 issues for RM184

***Rates are inclusive of postage in SGP and MY**

PERSONAL PARTICULARS

Title Surname

Name

DOB NRIC

Tel Mobile

Email

Address

Country Postal Code

MY PROFILE

Gender	Age Group	Occupation	Annual Income
❍ Male	❍ Below 30	❍ Executive	❍ Below $50,000
❍ Female	❍ 31 - 40	❍ Management	❍ $50,001 - $100,000
	❍ 41 - 50	❍ Professional	❍ $100,001 - $150,000
	❍ Above 50	❍ Businessman	❍ Above $150,000

YOUR PAYMENT OPTIONS

❍ CHEQUE

Please enclose a cheque made payable to:
Singapore: Regent Media Pte Ltd
Malaysia: Regent Media Sdn Bhd

Cheque No.:

Amount:

❍ CREDIT CARD* (VISA & MASTERCARD ONLY) **Singapore only*

Debited amount under"Golf Events and Marketing" will be reflected in your credit card statement for subscribers in Singapore.

Name on Credit Card:

Credit Card No.:

Expiry Date:

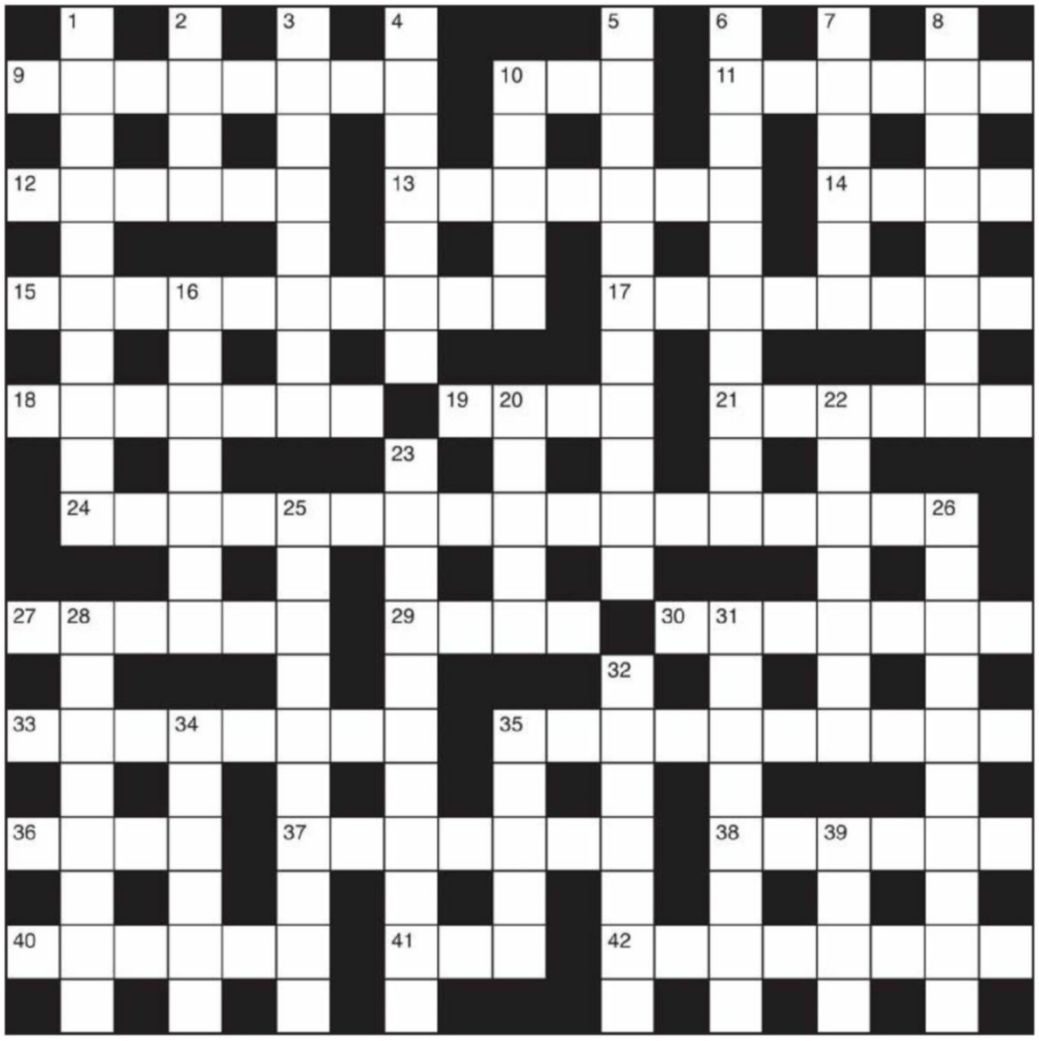
Amount:

Signature: Date:

TERMS & CONDITIONS:
- This subscription offer is non-refundable
- Promotion is valid till the end of March 2017
- Subscription gifts where applicable are available on a while stocks last basis
- The above subscription rates are only applicable to readers residing in Singapore & Malaysia
- Gifts must be taken as provided and are neither transferable nor exchangeable for cash
- Company reserves the right to replace gift when stock is unavailable
- All prices are inclusive of GST and taxes
- Please allow 4-6 weeks for processing
- Subscribers/Winners will be notified by post
- Subscription gifts/lucky draw prizes are to be collected at address stated on notification letter
- Other terms and conditions apply

CROSSWORD PUZZLE

BACK BY POPULAR DEMAND



ACROSS

9 A bond to money takes shape (8)
10 Appearing to have something to eat (3)
11 Projection brings comfort (6)
12 Its art involved clouds (6)
13 Interpretation of victory in sore need of revision (7)
14 Snide answer about notion (4)
15 Eastern character gets first book on transformation theory (10)
17 Terrible anger about old book of spells (8)
18 Care about lad wandering in crater (7)
19 Offence involving hard part of leg (4)
21 Register for a large drink (6)
24 Editors – softies – worried about chap having Paget's disease (8,9)
27 Hydrocarbon in chalk – a necessity (6)
29 Leaf-chewing insect (4)
30 Paul's worried about internal bone (7)
33 Cite Arab translation of tiny organisms (8)
35 Get laconic about producing milk (10)
36 Cap on pike distribution (4)
37 Worker gets a group of detectives a remedy (7)
38 King takes gold ore back to Maori meeting (6)
40 Old official finds bit of glass on French article (6)
41 Low-flying bird (3)
42 Sauce manufactured with special rain (8)

DOWN

1 Old instrument of variable volume (10)
2 Attorney volunteers facts (4)
3 Producer of French singer went mad (8)
4 Vast aim – to improve reversion to former state (7)
5 Kitchen utensil somehow generated parking fine (6,5)
6 Semiconductor sorts train out (10)
7 Real binoculars lacking pigment inside (6)
8 Intelligent bishop gets registered during breakfast (8)
10 City for cavorting pairs (5)
16 Aide got to work at the plant (7)
20 Dodge questions about a barrier (5)
22 Former spouse has enough for a specimen (7)
23 Start to drift if getting tiny bit of deviation (11)
25 Large ship that makes for easy conversation (10)
26 Preparing salad, tiger is adapted to jump (10)
28 Metal has even changed using yeast (8)
31 Plates around the garden (8)
32 A scoundrel to point to my place of learning (7)
34 Editor wrote about valve (6)
35 Left coal production in the vicinity (5)
39 Call for sign of tree's age (4)

ANSWERS

Solution to crossword in the previous issue

ROBIN INCE ON... HABITS

"IT TAKES AN AVERAGE OF 66 DAYS TO FORM A NEW HABIT. THERE ARE NO QUICK FIXES"

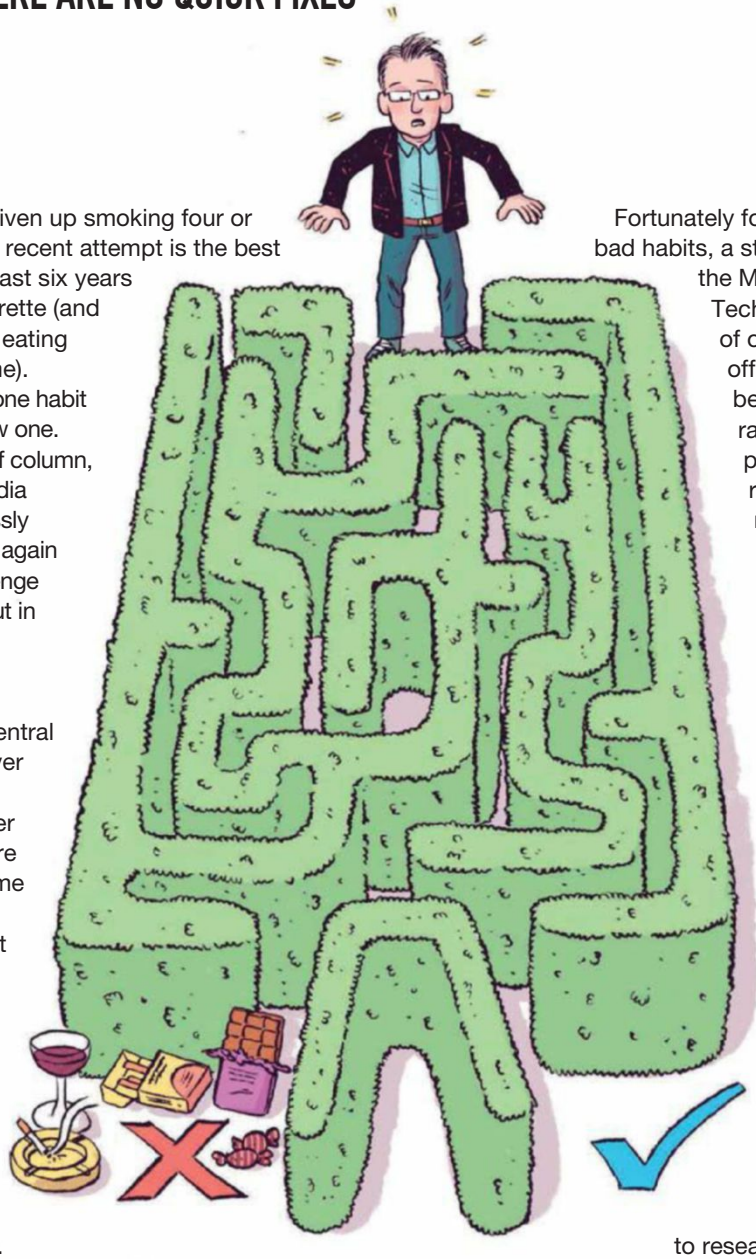
I have successfully given up smoking four or five times. My most recent attempt is the best so far: it's now at least six years since I last puffed on a cigarette (and tried to disguise the fact by eating toothpaste on the walk home).

Unfortunately, removal of one habit usually creates time for a new one. During the writing of this brief column, I have checked on social media four times. I am a rat mindlessly hitting a pedal over and over again in the belief that a snack lozenge of gossip or fact will shoot out in 140-character form.

Habits aren't always bad. In fact, they can be useful, stopping us crashing into central reservations or being run over as we cross the road. It's estimated that around 40 per cent of our daily activities are performed in almost the same situations every day.

According to psychologist Prof Wendy Wood at the University of Southern California, as we learn a new habit, the information shifts from a decision-making part of the brain (the basal ganglia) to an automatic process that we're largely unaware of (the sensory-motor system). So how can we go about shifting those bad behaviours?

Wood investigated this using stale popcorn. After checking that people preferred fresh popcorn to stale, she found that cinemagoers who have a habit of eating popcorn at the movies ate just as much stale popcorn as fresh. As long as the environmental cue is there, the habit is maintained. It's the same problem with giving up smoking – a battle must be fought every time you find yourself in one of your old smoking haunts. Wood suggests that habitual loops can be broken by altering our environments and disrupting the familiar cues, perhaps by changing where we take our work breaks.



Fortunately for those trying to kick bad habits, a study by neuroscientists at the Massachusetts Institute of Technology has shown that not all of our rational brain is switched off when we perform habitual behaviours. The team trained rats to run a T-shaped maze, prompting them to turn left or right at a junction. The rats' reward for turning left was some chocolate milk, and even when this treat was laced with nausea-inducing lithium chloride, they still continued to turn left. The rats had developed a habit.

What's interesting is that the researchers could break this habit by inhibiting the rats' infralimbic cortex, which is an area of the prefrontal cortex (part of the brain's planning centres). This suggests that this region of the brain is responsible for turning habits on and off – and habits might not be as inflexible as often thought.

As for those who are trying to make a new habit: yes, I know you've joined a gym, but you have to be prepared to put the time in. According to researchers at University College London, it takes an average of 66 days to form a new habit. There are no quick fixes: tenacity, backed by the knowledge that the brain can change, is the key.

Let's see how long it takes me to break my social media addiction and create my new habit of searching for chocolate milk in mazes. I'd better remember not to tweet while I'm at Hampton Court #nochocolatemilkinthistudorhedge.

Robin Ince is a comedian and writer who presents, with Prof Brian Cox, the BBC Radio 4 series The Infinite Monkey Cage

ILLUSTRATION: JAMIE COE

PROF DANIELLE GEORGE

"WHEN THE ROYAL INSTITUTION EMAILED ME, I PRESUMED IT WAS A JOKE – SO I DELETED IT"

Danielle George, professor of radio frequency engineering at Manchester University, talks to Helen Pilcher about the importance of tinkering

Where does your interest in science come from?
As a kid, I went through various science 'phases'. My parents bought me a microscope, then a chemistry set. But it was the next gift – a telescope – that I really loved. I used to get my sisters up at night to watch the lunar eclipses.

What is your area of research?
I engineer tools of scientific discovery. In particular, I design and make devices to pick up signals from space.

So, have you eavesdropped on any little green men?
No, but I helped design the amplifiers and receivers that enabled the Planck spacecraft to detect the leftover radiation from the Big Bang. It's called the cosmic microwave background radiation and it's given us the most accurate map of the Universe to date.

What else can you use these sorts of devices for?
All sorts. We're designing electronic devices that could be ploughed into the soil and then send signals to farmers. They would be able to tell the farmer everything, from which parts of their land need irrigating most, to where the weeds are most likely to grow and when is the best time to harvest their potatoes.

Of what are you most proud?
2014 was a big year for me. My husband calls it 'the three Ps'. I became a professor, got pregnant and presented the Royal Institution's Christmas Lectures. I gave birth just two weeks after I finished filming.

How was that? The lectures, not giving birth...
Amazing! The funny thing was that when they emailed me to ask if I was interested, I presumed the message was a joke, so I deleted it. Luckily, they contacted me again a few days later and asked for my ideas.

What did you pitch them?
I wanted to show people how creative engineering can be. I wanted to set some big, wacky challenges that would make people go, 'Wow, was that engineering?' We ended up talking to an astronaut in space and turning the Shell Centre in London into a giant game of Tetris. The whole experience was life-changing.

How so?
I do a lot more public engagement and media work now. We recently devised a citizen-engineering project where we got people to build musical robots from recycled objects. The Robot Orchestra was born. It's going to be at Cheltenham Science Festival and on Radio 1's Live Lounge.

But how are you at changing light bulbs?
Good. I'm very handy in the house. I'm thinking about designing an invisible infrared fence for my L-shaped garden so if my daughter goes round the corner where I can't see her, an alarm will sound.

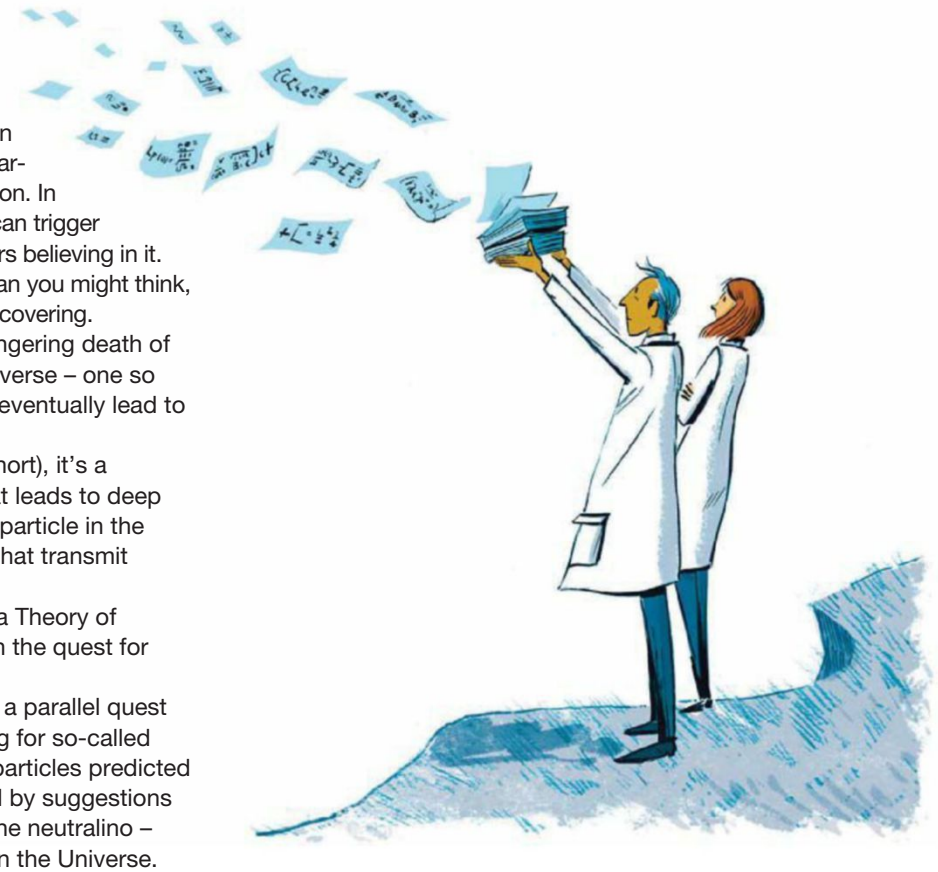
What do you worry about?
I worry we're so busy protecting our children that we don't allow them to fail. But there is so much to be learned from failure. Children should be allowed to tinker and get things wrong. It helps to build confidence, resilience and the natural skills that underpin innovation.

Prof Danielle George is professor of radio frequency engineering at the University of Manchester

ILLUSTRATION: NATALIE FOSS

ROBERT MATTHEWS ON... LETTING THEORIES GO

"THE DEATH OF A CHERISHED THEORY COULD GIVE SCIENTISTS THE CLOSURE THEY NEED TO MOVE ON"



People trying to deal with a tragedy often talk of the need for 'closure', some clear-cut event that will allow them to move on. In science, the death of a long-cherished theory can trigger something similar among those who spent years believing in it. But getting scientific closure is much harder than you might think, as an entire generation of theorists are now discovering.

For years they have witnessed the slow, lingering death of a beautiful theory about the nature of the Universe – one so beautiful, in fact, that many thought it would eventually lead to the Theory of Everything.

Known as 'supersymmetry' (or SUSY for short), it's a mathematical property of space and time that leads to deep connections between the two basic types of particle in the Universe: those that form matter, and those that transmit forces between them.

SUSY is just what you'd expect to go into a Theory of Everything, and for over 30 years theorists on the quest for this Holy Grail have put their trust in it.

Meanwhile, experimentalists have been on a parallel quest to put SUSY to the test. They've been looking for so-called 'sparticles' – the counterparts of the known particles predicted by the theory. They've also been encouraged by suggestions that one of these undiscovered sparticles – the neutralino – may be the mysterious 'dark matter' lurking in the Universe.

Yet for all the excitement, SUSY appears to be a beautiful idea that the Grand Designer just ignored. There were high hopes that sparticles would be found in experiments at the Large Hadron Collider (LHC), but so far experimentalists there have found zilch. Those trying to detect dark matter have also found nothing.

Or at least, nothing so far. Some theorists insist it's too early to throw in the towel, and are working on tweaks to the basic idea of SUSY to patch it up and keep it going.

But others see this as pretty desperate, and are insisting it's time to move on. Clearly, what both sides need is closure.

Ideally, of course, closure would take the form of a press conference at the LHC, where the experimentalists announce the exciting discovery of the first supersymmetric particle – preferably the neutralino.

What's never going to happen, though, is what many regard is the hallmark of science: an announcement that SUSY has been proved false. The idea that scientific theories can always be falsified is only ever taken seriously by those who know little about how science really works.

This idea of falsification was popularised by the philosopher Karl Popper in the 1960s. But it had already been debunked by, unsurprisingly, a real scientist named Pierre Duhem years earlier. Duhem pointed out that ailing scientific theories can always be propped up by blaming, say, dodgy data or inventing some tweak or other.

So if lack of hard evidence can't bring closure for SUSY, what can? Oddly, it might boil down to some bottles of booze. Over the years, some of the leading advocates of SUSY have made bets with sceptics that they would be proved right by a certain date. Those bets are now coming due, and some theorists have started handing over expensive bottles of cognac.

The turning point may come when American physicist David Gross, the Nobel prize-winning theorist and staunch SUSY fan, concedes a bet he made with Ken Lane back in 1994, to buy a posh meal at a swish restaurant. It will cost him a few hundred dollars and a dented ego. But it could give a whole generation of theorists the closure that they need to move on, so they can start looking for the real keys to the cosmos.

Robert Matthews is a visiting professor in science at Aston University, Birmingham

ILLUSTRATION: ADAM GALE

tvhighlights

WILD THAILAND

Premieres 15 March. Wednesday at 7.10pm (JKT/BKK), 8.10pm (SIN/HK/MAL/TW)

Wild Thailand reveals a sacred kingdom of awe-inspiring beauty. It takes in the towering limestone cliffs, the paddy fields, the hidden temples and the teeming city of Bangkok, before visiting the forests of the north.

DANGEROUS EARTH

Premieres 10 March.
Friday at 9.30pm (JKT/BKK), 10.30pm (SIN/HK/MAL/TW)

Dangerous Earth delves into this fantastic bank of footage to uncover the latest scientific advances, with each episode focusing on a different subject – volcanoes, auroras, avalanches, icebergs, hurricanes and lightning.

ESCAPE TO THE WILD SERIES 2

Premieres 27 March.
Monday at 8.50pm (JKT/BKK), 9.50pm (SIN/HK/MAL/TW)

Each episode, Kevin travels to a far flung destination to see how others have built their lives and dwellings against the odds. Often the jaw-droppingly beautiful landscapes belie a harsh reality for the settlers who have chosen to build their lives there.

COLOUR – THE SPECTRUM OF SCIENCE

Premieres 31 March.
Friday at 9.45pm (JKT/BKK), 10.45pm (SIN/HK/MAL/TW)

This series explains how each of these colours occurs, unlocking the mysteries of nature and the forces that underpin the Universe itself.

BBC earth

/BBCEarth

@BBCEarthAsia

BBC Earth is available in Hong Kong, Indonesia, Malaysia, Singapore, South Korea, Taiwan, Thailand, Vietnam, Mongolia and Myanmar. Please call your cable operator for more details or check out our website at www.bbcasia.com

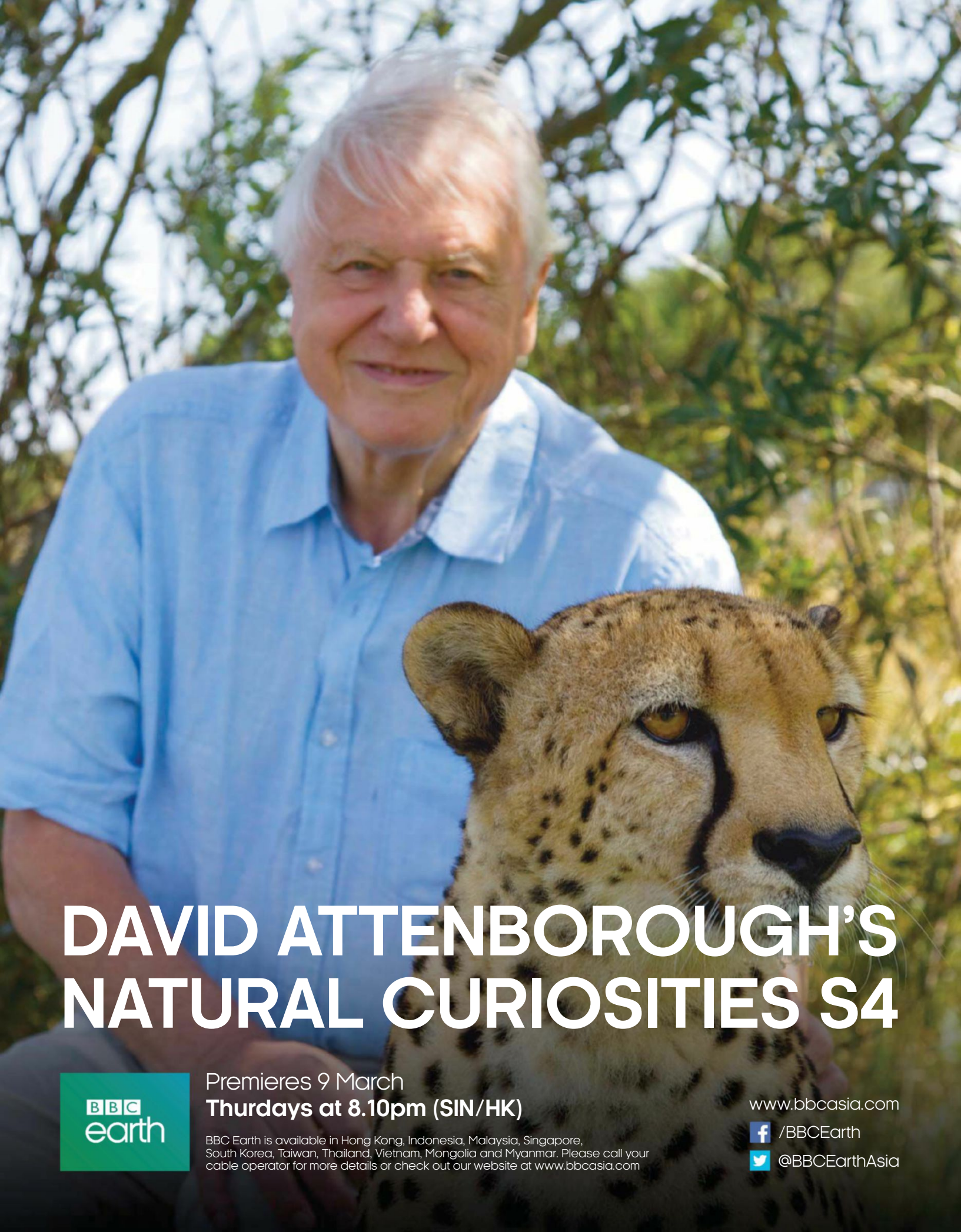
Also available on

BBC iPlayer

www.bbcplayer.com

Download on the App Store

Google play



DAVID ATTENBOROUGH'S NATURAL CURIOSITIES S4

BBC earth

Premieres 9 March

Thurdays at 8.10pm (SIN/HK)

BBC Earth is available in Hong Kong, Indonesia, Malaysia, Singapore, South Korea, Taiwan, Thailand, Vietnam, Mongolia and Myanmar. Please call your cable operator for more details or check out our website at www.bbcasia.com

www.bbcasia.com

/BBCEarth

@BBCEarthAsia