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INCORPORATING BBC SCIENCE WORLD

ANGELS OF THE FOREST
p54

ASIA EDITION | **VOL** 12 **ISSUE** 1
JAN/FEB **2020**

THE NEW SOLAR SYSTEM **SPECIAL REPORT**

THE HUNT FOR

PLANET 9

How we'll find the most mysterious object in our Solar System

PPS 1904/04/2018 (025649)
MCI (P) 134/11/2017 ISSN 2529-7503

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SGD 8.50 | THB 240 | NT 200 | RM 18

BUILDING FOR **THE FUTURE**
p46

MAGIC IN THE **MORAY FIRTH**
p34

HOW **BRITAIN** SAVED **EINSTEIN**
p42

TV HIGHLIGHTS

Japan with Sue Perkins

Join Sue Perkins as she explores a country caught between ancient tradition and dazzling technology: Japan.

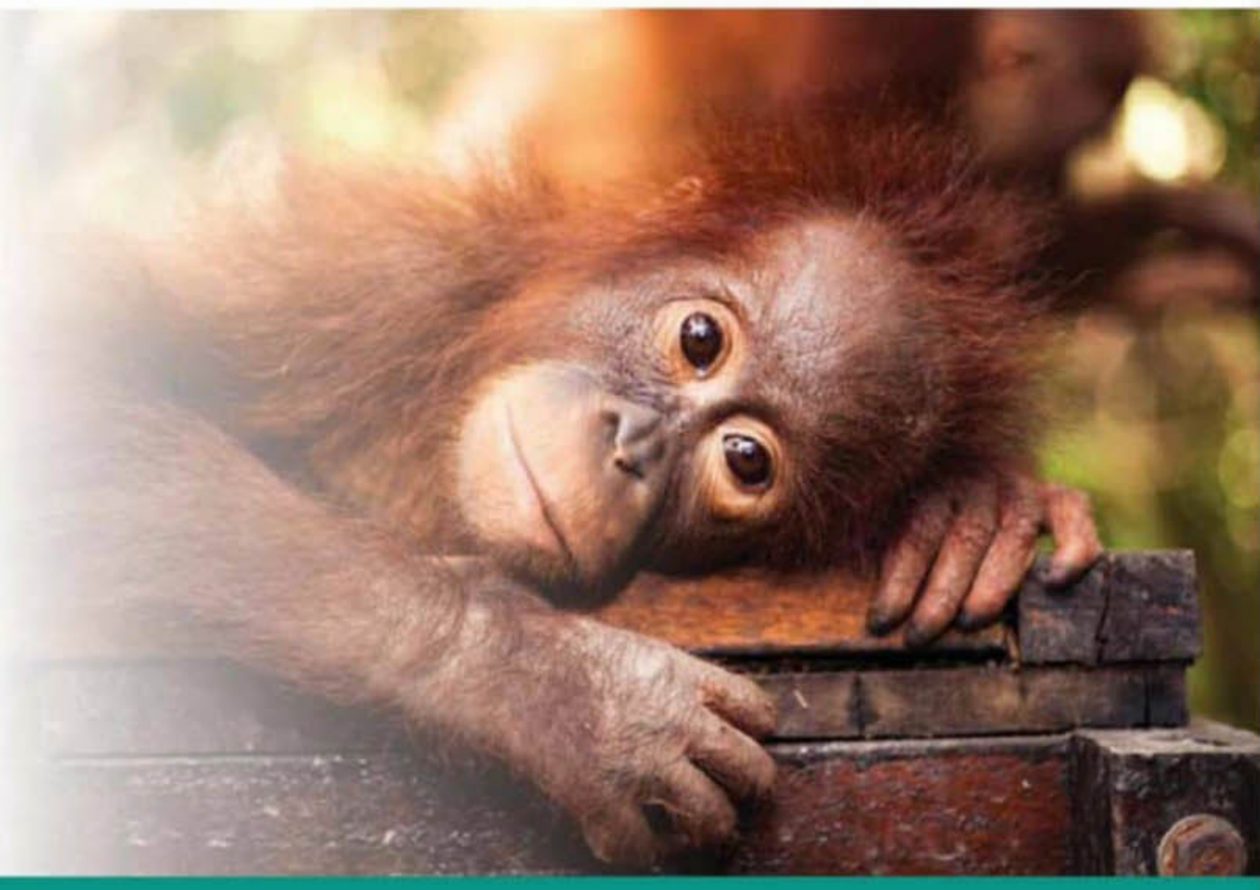
Premieres 10 January
Friday at 9:00pm (SG/HK)

North America with Simon Reeve

Author and adventurer Simon Reeve embarks on another epic journey, this time across North America.

Premieres 11 February
Tuesday at 9:00pm (SG/HK)

Red Ape: Saving the Orangutan



Combining rescue footage with contributions from experts, this documentary looks towards the future and asks what hope remains to save the orangutan.

Premieres 25 February
Tuesday at 9:55pm (SG/HK)

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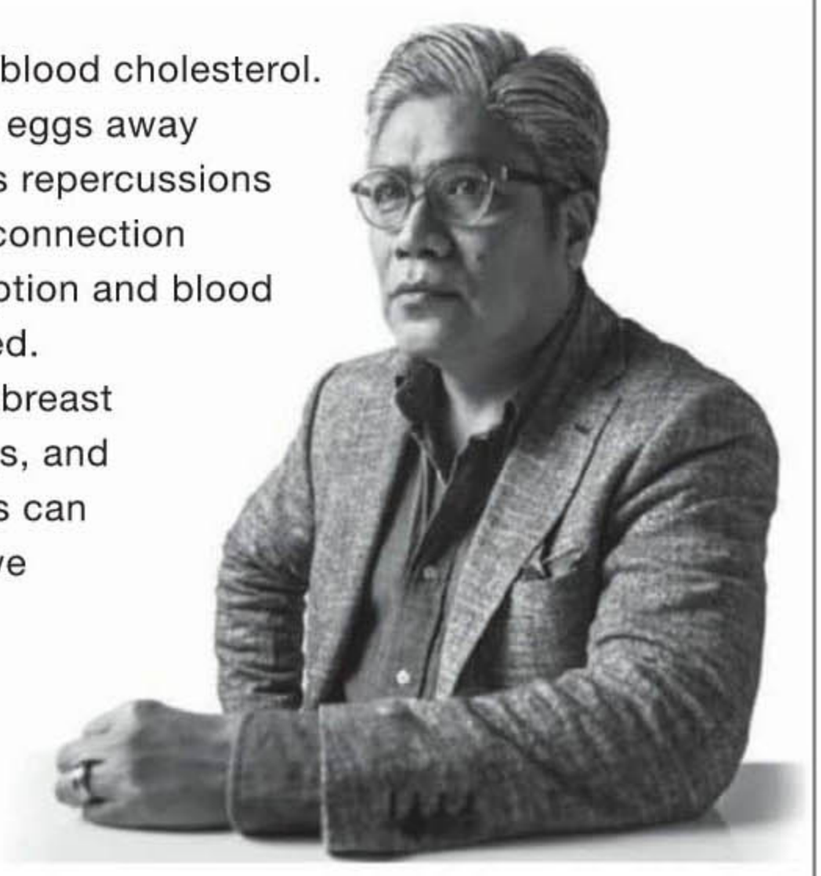
ARMED WITH THE METHOD

Many of us demand scientific evidence as ultimate requirement for accepting new ideas – and for good reason. However, scientific evidence is very often a product of interrelated systems and fields of enquiry and is therefore susceptible to any disruption in scientific methodology. As cumulative findings affect scientific evidence, it can and does change over time. For example, scientific methods can be invalidated and replaced following the development of new technologies or the rise of new theories that are able to penetrate layers upon layers of data.

Take the effect of eggs on human blood cholesterol. For the longest time, we have taken eggs away from our daily diet for fear of serious repercussions including heart disease. Today, the connection between (eggs) cholesterol consumption and blood cholesterol levels has been disproved.

It is important to keep ourselves abreast of new scientific studies and findings, and open to the reality that such findings can change. This attitude ensures that we view science as a dynamic pursuit.



Marc S. Almagro
marc@media-group.com.sg

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Experts in this issue...

COLIN STUART
An astronomy author and public speaker, he has written 16 books that have sold over 300,000 copies worldwide. (p26)

ANDREW ROBINSON
He is the author of over 25 books on science and the history of science, archaeology and scripts, and Indian history and culture. (p42)

ABIGAIL BEALL
A science/technology journalist and author of *The Art of Urban Astronomy*, she has degrees in physics and science journalism. (p46)

MIKE UNWIN
A freelance wildlife and travel writer/photographer, he spent eight years living and working in southern Africa. (p54)

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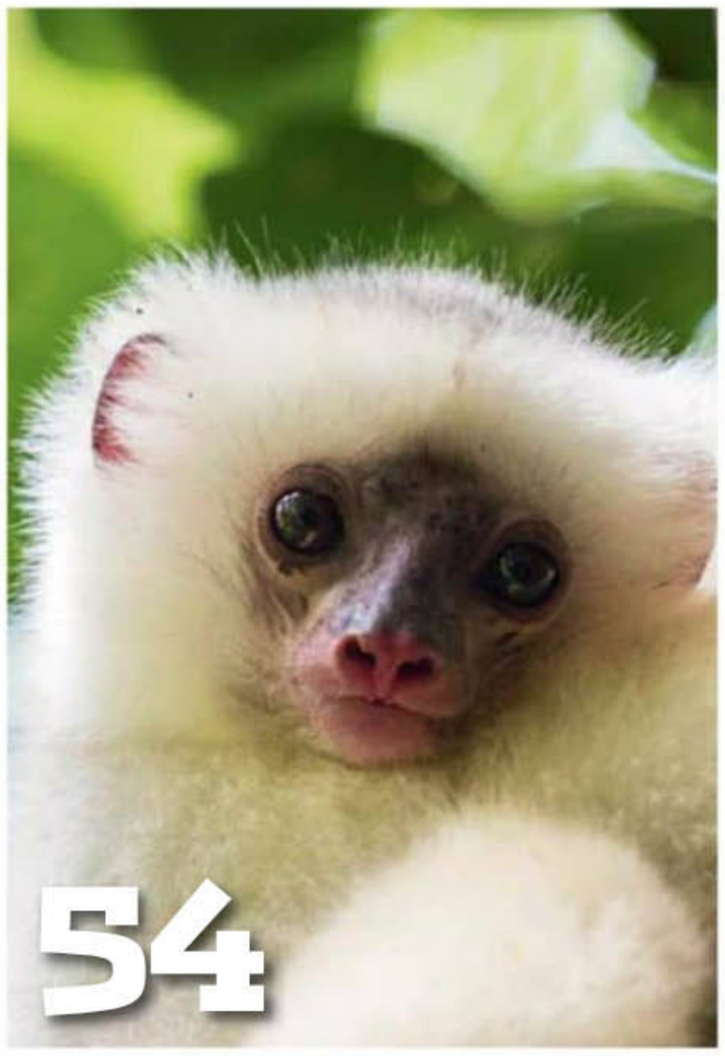

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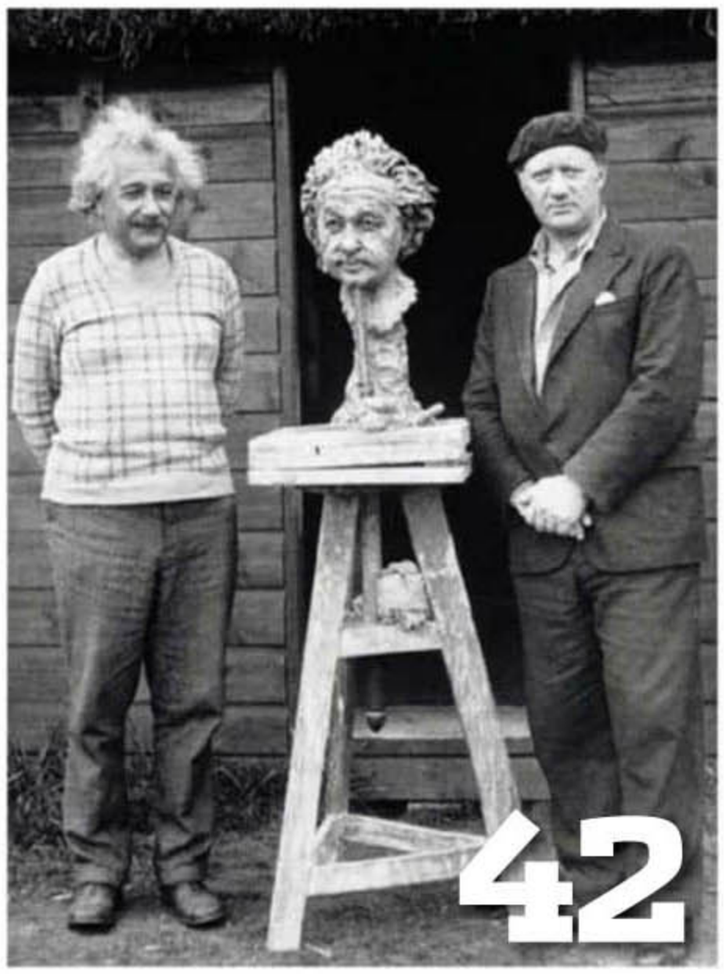

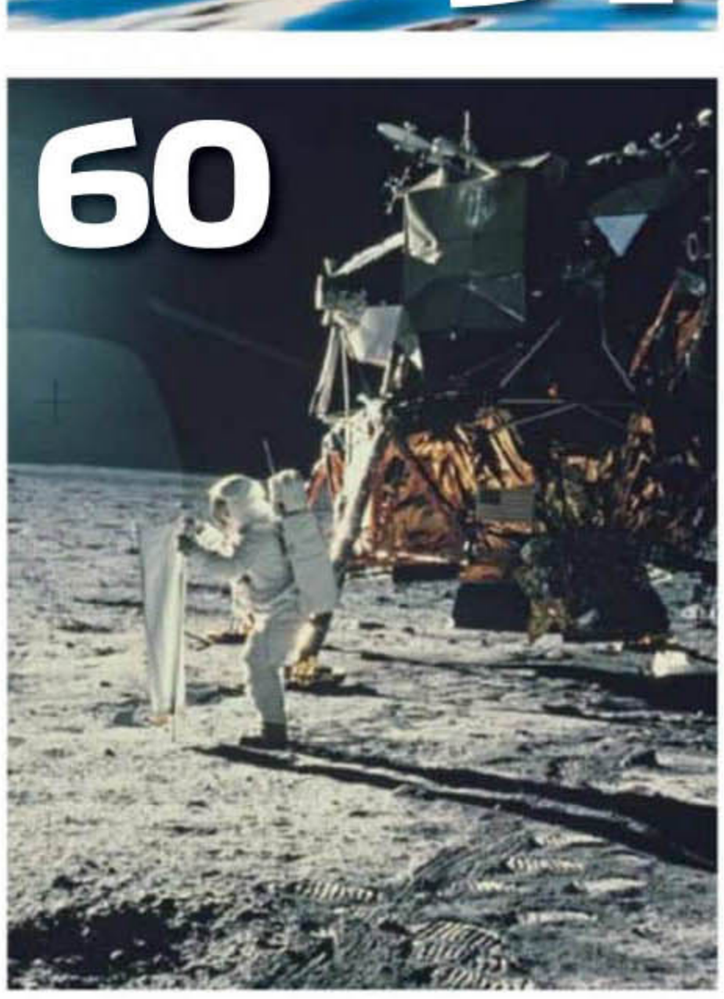

BBC earth

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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.

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Virtually there

DÜSSELDORF, GERMANY

Here, the audience at Roncalli Circus Theatre experiences the first holographic circus animals. Roncalli's founder and director Bernhard Paul, and chief digital officer Markus Strobl, led a team of 15 people to create life-sized elephants, stampeding horses, and a huge, swimming goldfish.

Bernhard wanted to include the technology in the circus after he watched a hologram of the late singer Prince during Justin Timberlake's 2018 Superbowl performance.

"I was so impressed by the holographic technique," says Paul. "As a circus, the audience is our boss, and when you feel the audience does not approve of something then you have to change it."

The 360° holograms are made by projecting 11 different laser beams onto a nylon-based screen that is set up around the ring. The projectors are connected via a cloud computer that uses as many as 3,000 processors to generate the visuals.

CIRCUS RONCALLI

Berry smart

CHICHESTER, UK

The world's first raspberrypicking robot earns its keep at a West Sussex farm. The autonomous machine is a variablestiffness robot arm that's able to replicate the movements of a human arm. The tech was developed by Fieldwork Robotics, a team from the University of Plymouth headed by Dr Martin Stoelen.

"Currently, manual harvesting represents a large portion of producers' total costs," says Stoelen. While human workers can pick around 15,000 raspberries in one eight-hour shift, Fieldwork's robot can collect more than 25,000 in a day. Stoelen is certain that there will always be jobs for people associated with agriculture. "But it might be that in a decade's time, instead of spending hours in the cab of a tractor, your role is managing robots such as those we are developing."

EYEVINE

Drone down

PARIS, FRANCE

Looking rather like props from an action film, these NEROD F5 devices are actually high-tech drone jammers, designed to scramble the signal of an enemy unmanned air system (UAS).

On 14 July, this demonstration of the NEROD F5 stunned crowds at the Bastille Day parade in Paris. When the trigger is pulled, the gun fires microwave-frequency signals towards the drone, which then disrupts any communication between the drone and its pilot. This means the pilot can no longer direct the drone.

The rifle-style design of the NEROD F5 is unlike most drone scramblers, which usually require a large battery that is worn in a backpack by the operator. Other methods of bringing down drones include sending a false GPS signal to the drone, which confuses its sense of direction and positioning, or distracting a drone's camera with a laser beam.

REUTERS

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ASIAN Geographic magazine is going through a rehaul! Featuring 2020 editorial lineup

Elements of Life, Colours of Asia

In 2019, *ASIAN Geographic* is celebrating 20 years of bringing Asia to the world, and we have an exciting lineup ahead in 2020. Our editorial calendar will be based on a philosophical approach to Wu Xing, or the five elements in Chinese philosophy – Water, Wood, Fire, Earth, and Metal – with our last issue of the year projected to focus on bringing these elements together, all through travel.

Our first five 2020 issues will be colour-coded in blue, green, red, brown, and silver, respectively, to address our concurrent themes, and each issue will include a *PASSPORT* section that will focus on a specific region in Asia. The sixth and final issue of the year will be an *ASIAN Geographic PASSPORT* special edition that will combine all these elements and their associated colours, making the entire year's publication come together in a stunning, rich hue – making up the perfect collection!

NO. 140 ISSUE 1/2020

+ PASSPORT SECTION FEATURED REGION: SOUTHEAST ASIA

Water

An inherent part of our lives, the water element is downward and inward, and its energy is stillness and conserving. This issue covers everything blue, whether by taking a plunge into the waters – where we will swim amongst issues of ocean governance, conservation, sustainability, or diving – or even just by sipping on the Asian-native butterfly pea flower tea from the pods planted in your garden.

NO. 141 ISSUE 2/2020

+ PASSPORT SECTION FEATURED REGION: WEST ASIA

Wood

Wood, sometimes translated as Tree, symbolises growth and longevity, much like the bamboo stems that are strong, flexible, and some of the fastest growing plants in the world. As the first phase of Wu Xing, it also signifies the birth and beginning of life. This issue celebrates and navigates through the most important thing known to the living: Life itself.

NO. 142 ISSUE 3/2020

+ PASSPORT SECTION FEATURED REGION: EAST ASIA

Fire

The motion of fire is upward and its energy is expansive, representing dynamism, strength, persistence, and prosperity. This issue will look at brightness, warmth, heat and the full bloom of flowers, fruits, and creativity in the arts and culture of Asia.

NO. 143 ISSUE 4/2020

+ PASSPORT SECTION FEATURED REGION: CENTRAL ASIA

Earth

Earth is a balance of both yin and yang. Its motion is inward and centering, and its energy is stabilising and conserving. Earth is associated with practicality, hard work and stability. In this issue, we look at Asia balancing sustainability, conservation, and economic growth, as well as exciting solutions that can spur a new green economy while shining a spotlight on marine and wildlife conservation.

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Readership
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A YEAR

NO. 144 ISSUE 5/2020

+ PASSPORT SECTION
FEATURED REGION: SOUTH ASIA

Metal

Metal's motion is inwards, and its energy is contracting. Metal attributes are firmness, rigidity, persistence, strength, and determination. This issue of *ASIAN Geographic* looks at all the special festivals and remembrance days that are celebrated by different countries and cultures all across Asia, as we contract and combine the things that make this continent so vast, yet so unique.

NO. 145 ISSUE 6/2020

The Colour Edition: *Passport*

TRAVEL ISSUE

This *PASSPORT* special edition will bring all the five elements together into a full circle, as it is meant to be, and we will explore all the corners of Asia through Wu Xing. Water, Wood, Fire, Earth, and Metal will encompass the largest continent in the world, and all the regions in Asia will be seen through this exceptional lens.

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Update

THE LATEST INTELLIGENCE

DISCOVERED: THE CHEMICAL THAT MAKES MEMORIES

Your brain has its own box of memories. If you were to hold it in your hand, brush off the dust and open it up, you'd be able to pull out Polaroid snaps of your most treasured memories. Your graduation ceremony perhaps, your wedding day, your child's first words – all things you wouldn't want to forget. But how does your brain keep these memories in their crystal-clear clarity? ▶

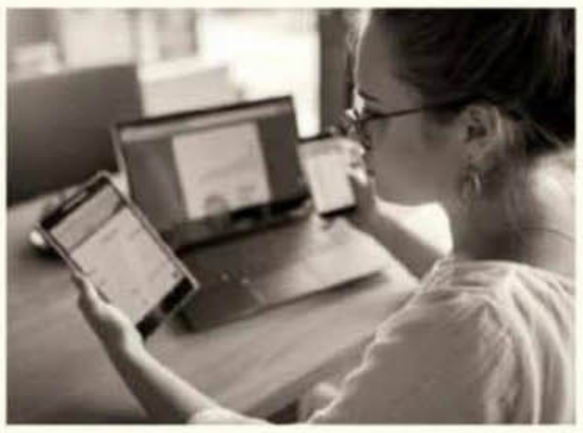
The synapse between two nerve cells (illustrated here) plays a vital role in memory formation

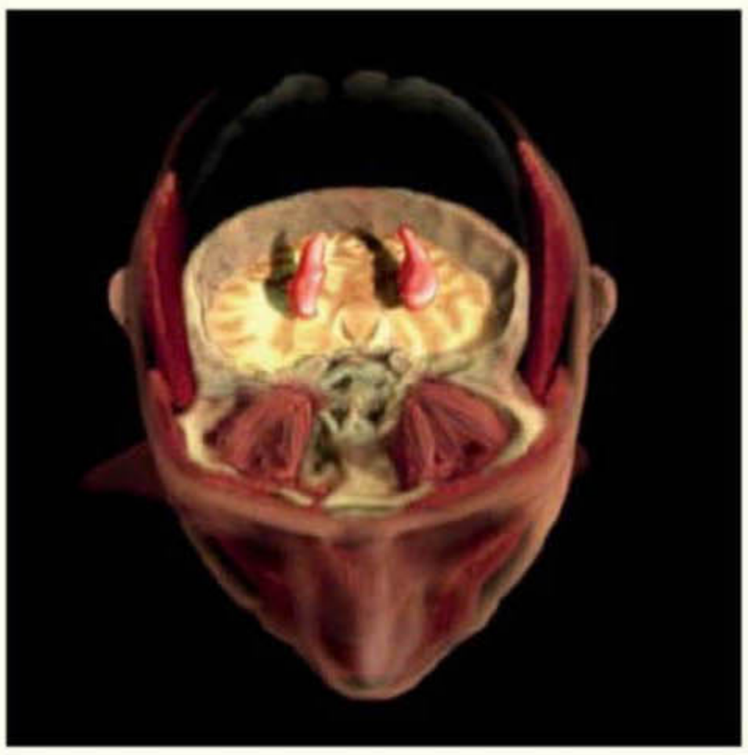
SCIENCE PHOTO LIBRARY, GETTY IMAGES

NEWS IN BRIEF

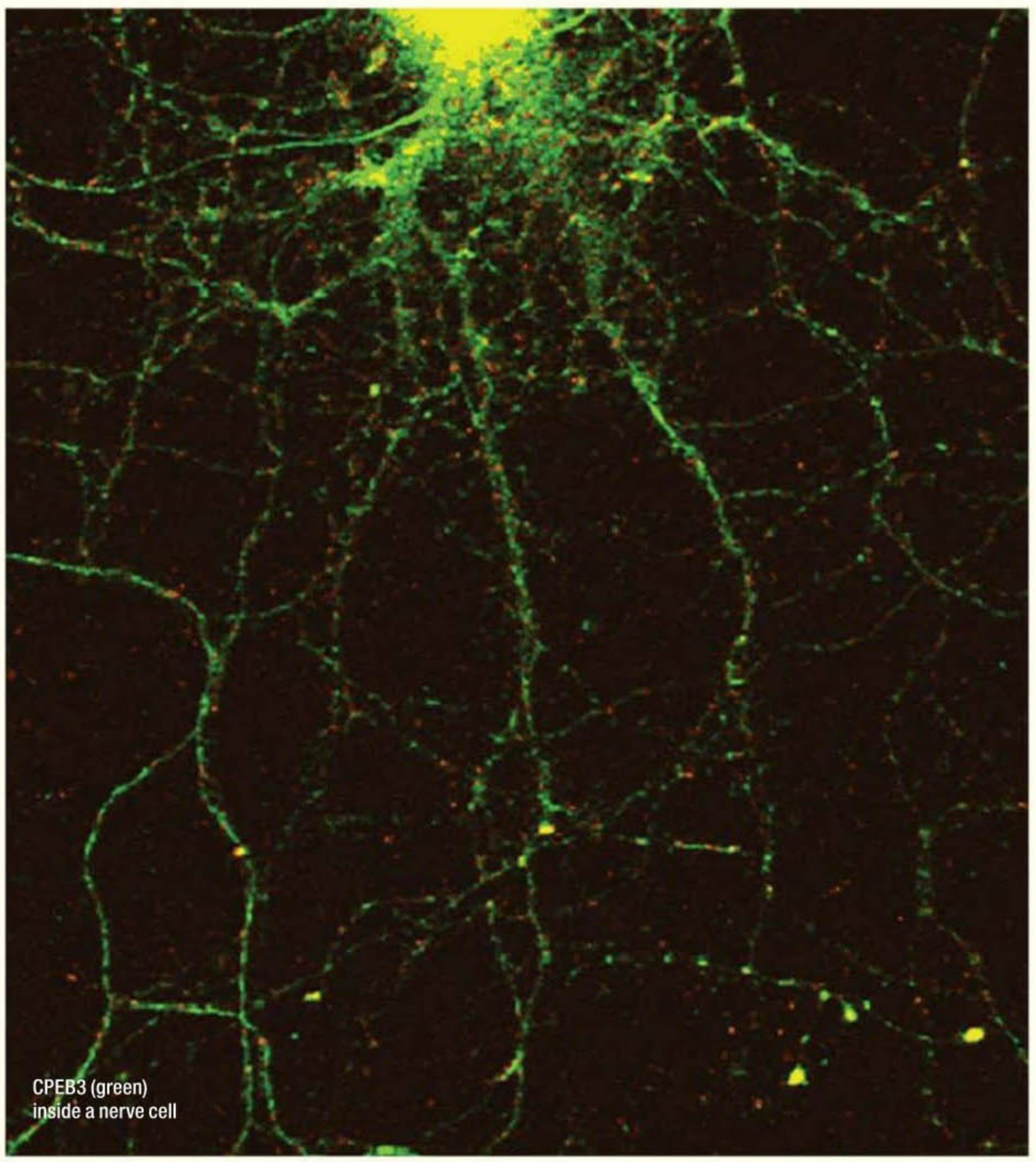
Multitasking just as hard for women as men

One of the great gender myths has, it seems, been busted for good: new research shows that men and women are equally good (or bad) at multitasking. Psychologists in Germany tested the multitasking prowess of 48 men and 48 women, using letter and number identification tasks to measure the participants' ability to pay attention to two tasks at once (concurrent multitasking), or to switch attention between tasks (sequential multitasking). Multitasking had a negative effect on both the participants' speed and their accuracy, but there was no difference in performance between the men and women.





The protein CPEB3 is created in the hippocampus (red kidney-shaped areas)



CPEB3 (green) inside a nerve cell

SCIENCE PHOTO LIBRARY, GETTY IMAGES, CARNEGIE MELLON UNIVERSITY

▶ The strength of a memory lies in its formation and upkeep. When we create a memory, the axons of nerve cells in the brain connect. The point at which two axons connect is called a synapse, and it is the strength of the synapse that determines if the memory is stored or allowed to fade away.

Now, a study in mice carried out by Nobel Prize-winning researchers at Columbia University has shown that a protein called CPEB3 plays an important role in the formation of memories. The team discovered how this protein is stored and used in the brain and hope it could lead to new methods of slowing memory loss in humans.

"The science of how synapses form and are strengthened over time is important for deciphering any disorder in which synapses – and the memories associated with them – degrade and die, such as Alzheimer's disease," said Dr Luana Fioriti, who co-authored the research.

CPEB3 is created by the brain's memory centre, the hippocampus. Once produced, it is stored in structures called P bodies that protect it from other parts of the cell. It then travels to the synapse between nerve cells where required and is gradually released to help create a specific memory.

The findings suggest that the more CPEB3 is released at a synapse, the stronger the connection and thus, the more concrete the resulting memory will be. When the protein was removed, the mice could create new memories but were unable to keep them. As a version of CPEB3 can be found in human brains, this discovery represents a promising new avenue for research into memory loss.

"Memory is what makes us who we are. It permeates our lives and is fundamental to our very existence," said Nobel Laureate Dr Eric Kandel, who co-authored the research. "But at its core, memory is a biological process, not unlike a heartbeat. With this study, we've shed new light on the molecular underpinnings behind our brain's ability to make, keep and recall memories over the course of our lives," he added.

STONE AGE HUMANS GORGED ON GIANT RATS TO SEE THEM THROUGH THE ICE AGE

Times were hard for the Stone Age inhabitants of the Bale Mountains of Ethiopia. So hard, in fact, that the plummeting temperatures of the Ice Age forced them to exist on a diet of giant mole rats, which were plentiful. Excavations of the Finch Habrea shelter, located 3,350m above sea level, have discovered stone artefacts, bits of pottery, and piles of giant rat bones (pictured right). Carbon dating suggests the artefacts are between 47,000 and 31,000 years old making the site one of the oldest high altitude settlements ever discovered.

MEDICINE

Printed hearts take shape

The dream of 3D printing whole, living human hearts for lifesaving transplants just got a little closer. A team at Carnegie Mellon University in the US has developed a technique to 3D print collagen in fine detail. Collagen, besides being the most abundant protein in the body, is a key structural element that forms the biological scaffold that gives organs their structure and strength.

Carnegie Mellon's new technique, called Freeform Reversible Embedding of Suspended Hydrogels (FRESH), deposits collagen, layer by layer, within a support bath of gel. This enables the collagen to solidify in place as the complex structure is built up. When the printing is complete, the support gel is melted away by gently heating it to 37°C – body temperature.

"If you try to print this [collagen] in air it just forms a puddle on your build platform. So we've developed a technique that prevents it from deforming," said Andrew Hudson, who co-authored the research.

The technique can print filaments as narrow as 0.02 millimetres across – around the width of a human hair. This enables researchers to print detailed structures into which living cells can be deposited to build muscle and blood vessels.

"What we've shown is that we can print pieces of the heart out of cells and collagen into parts that truly function, like a heart valve or a small beating ventricle," said Prof Adam Feinberg, a biomedical engineer at Carnegie Mellon University. "By using MRI data of a human heart, we were able to accurately reproduce patient-specific anatomical structure and 3D-bioprint collagen and human heart cells."

The FRESH technique will also work with other bio-inks that, like collagen, are soft when first printed, so the team hopes it will provide a highly adaptable tissue-engineering platform. They have also made the design of their system open source, so that other groups can use them to build 3D bioprinters at relatively low cost.

Collagen is difficult to work with in 3D printing as it starts out as a fluid. This new technique prevents it from deforming, so body parts – like this heart valve – can be made

LENZIE FORD/LUANA FIORITI/KANDEL LAB/ZUCKERMAN INSTITUTE AT COLUMBIA , GOTZ OSSENDORF ILLUSTRATION: GABRIEL SILVERA

THEY DID WHAT?

Chimps sent to the movies

WHAT DID THEY DO?
Researchers from Duke University paired up chimpanzees and had them watch a short movie. After the cinema session, they then observed their behaviour, taking note of how long it took the two apes to approach one another, how close they got, and how long they stayed together, and compared them to pairs of chimps that had watched movies alone.

WHAT DID THEY FIND?
The chimps that watched movies together approached one another more readily and spent more time together than those who had watched movies on their own.

WHY DID THEY DO THAT?
The team wanted to investigate the effect of shared experiences on social bonding. Humans have a wide variety of social activities that brings them closer together, such as listening to music, dancing, or watching films. Although only preliminary, this study suggests that apes may display similar behaviour indicating that the act of bonding through shared experiences may have deeper evolutionary roots than previously thought.

AIR POLLUTION AGES THE LUNGS

Scientists have found further evidence that breathing in polluted air damages the lungs and reduces life expectancy. Analysis of more than 300,000 people in the UK found that those who were exposed to higher levels of air pollution had reduced lung function (as measured by spirometry tests which involve exhaling in one forced breath). This reduction was equivalent to at least one year of ageing. The researchers, based in Canada, Switzerland and the UK, also found that those who were exposed to more pollutants had a higher risk of developing chronic obstructive pulmonary disease (COPD).

TRENDING

YOUR GUIDE TO WHO'S SAYING WHAT ABOUT THE HOTTEST TOPICS IN THE WORLD RIGHT NOW

#AlanTuring

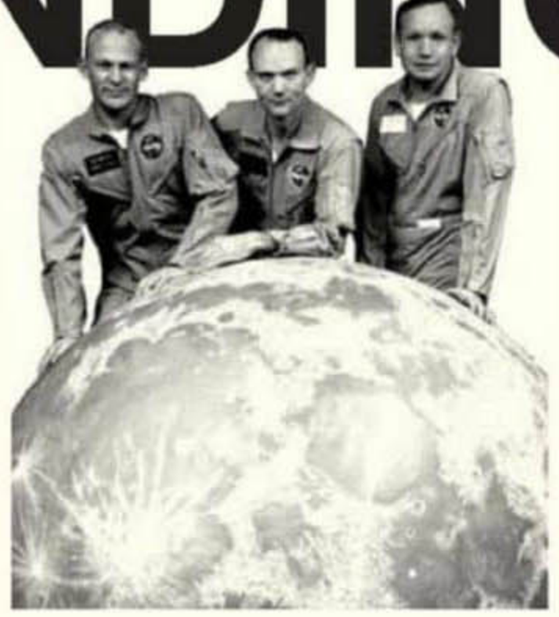
The Enigma codebreaker and computing pioneer has been announced as the face of the new £50.

MIT CSAIL
@MIT_CSAIL

The binary on the ribbon that runs across England's new 50-pound note is 23 06 1912 in decimal – Alan Turing's birthday.

Stephen Fry
@stephenfry

Well that's just great news about AlanTuring – I have been pushing for this for years, though I thought it might have been rather good for him to share the £50 note with Ada Lovelace. Both pioneers of computing science, both underappreciated in their lifetimes.



#Apollo50

On 16 July 1969, NASA made history by launching humans to the Moon. The crew safely arrived on 20 July.

Buzz Aldrin
@TheRealBuzz

50 years ago today, Neil Armstrong, Mike Collins and I launched into space on a mission of enormous importance. God bless the 400,000 Americans who helped us get to the Moon and back. Together, we Americans can do anything! Never forget July 16, 1969! #Apollo50

Scott Kelly
@StationCDRKelly

50 yrs ago today, Armstrong, Collins and Aldrin began humanity's greatest journey. #Apollo11 not only set a trajectory to the Moon but also to our future. #Apollo50

Stemettes
@Stemettes

The #Apollo50 Moon landing anniversary is a reminder of the importance of #WomenInSTEM #hackthemoon #MoonLanding50

#BigButterflyCount

This month saw the launch of the Big Butterfly Count, a nationwide citizen science project aimed at assessing the environment's health.

Chris Packham
@ChrisGPackham

I have quite a few small whites and meadow browns in the garden and yesterday a single peacock. What does this mean? Not much in anecdotal isolation! Which is why @savebutterflies #bigbutterflycount is so important – turning our observations into science.

Matt Lucas
@RealMattLucas

Being in nature can have a powerful, grounding effect, with research indicating that it can help alleviate mental health problems like depression and anxiety. Sit back, relax and take part in @savebutterflies #BigButterflyCount

#RhinoRays

Giant guitarfishes and wedge fishes, known collectively as rhino rays, are the world's most threatened marine fish, according to the *IUCN Red List*.

Meaghen McCord
@MeagAShark

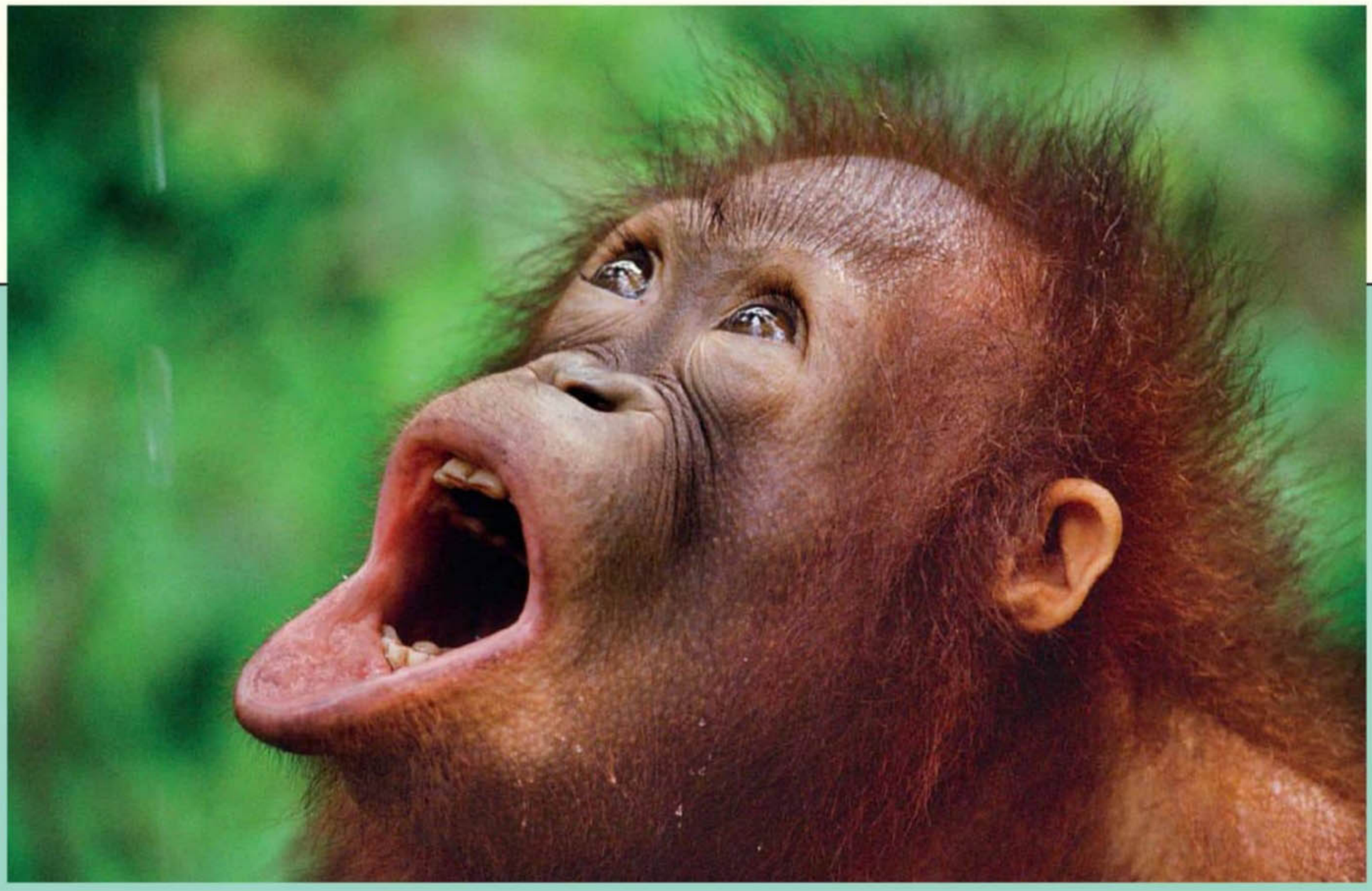
#RhinoRays set to bypass #sawfishes as the most endangered marine fish. Demand for fins and meat causing significant population declines.

Shark Advocates
@SharkAdvocates

#RhinoRays are now the world's most endangered marine fish. Most fisheries that take them are poorly monitored, essentially unregulated and increasingly intense. Immediate protections are needed to prevent extinction.

Jess Cramp
@jessaddwater

This is not a happy #flatsharkfriday. @IUCNRedList announced that #RhinoRays are the most threatened group of marine fishes in the world due to overfishing. We need better fisheries mgmt + MPAs NOW or these could go extinct. I just saw my first shovelnose ray last week.



CONSERVATION

Orangutan numbers recover in sustainably managed forests

But the primates still struggle in areas with palm oil plantations

An airborne survey of endangered orangutans in Sabah, the Malaysian state in the northeast of Borneo, has found that populations have stabilised within well-managed forests but are still in decline in areas with extensive palm oil plantations. The study was carried out by the World Wide Fund for Nature and is the biggest, most comprehensive survey of orangutans in Borneo to date. The large areas of lowland forest in Sabah is the ideal habitat for orangutans. However, over the past 50 years extensive logging and land clearance for agriculture has led to a drastic decline in their numbers.

The researchers surveyed an area almost 5,500km wide. Based on the number of tree-borne nests counted, they estimate that there are almost 10,000 orangutans living in the area. This includes more than 1,500 previously undiscovered animals spread out in small widely dispersed groups.

The bulk of the orangutans, around 5,550, were found living within sustainably managed forests or in the central uplands away from the loggers. The numbers in this area have remained stable since 2002, suggesting that conservation efforts are proving successful. In contrast, orangutan numbers in forests surrounded by extensive areas of palm oil plantations have fallen by as much as 30 per cent.

"Conservation efforts are proving successful"

"A recent survey on orangutan populations in Sabah, northeast Borneo showed a mixed picture from different regions," said the World Wide Fund for Nature's Donna Simon. "However, overall the research shows that they have maintained the same numbers over the last 15 years and can remain so as long as proper conservation management measures continue to be put in place."

GETTY IMAGES X5,

DINNERTIME SUMS HELP WITH MATHS TESTS

Children whose parents discuss maths problems at the dinner table score better on tests in secondary school, new research has found. The study, which involved over 200 German children, saw that having books around the house, reading to pre-school students and doing maths problems together all contributed to an improved performance at ages 12 and 13. Early exposure to books and language skills didn't just improve students' reading abilities – their outcomes in numeracy also improved.

NEUROSCIENCE

Our brains are tuned to hear music

Human brains are uniquely suited to hearing music, a new study suggests. Compared to macaque monkeys, humans respond much more strongly to sounds with a musical pitch, and prefer those to sounds without a pitch. Our use of language and love of music could be behind these differences.

"Humans respond more strongly to sounds with a musical pitch"

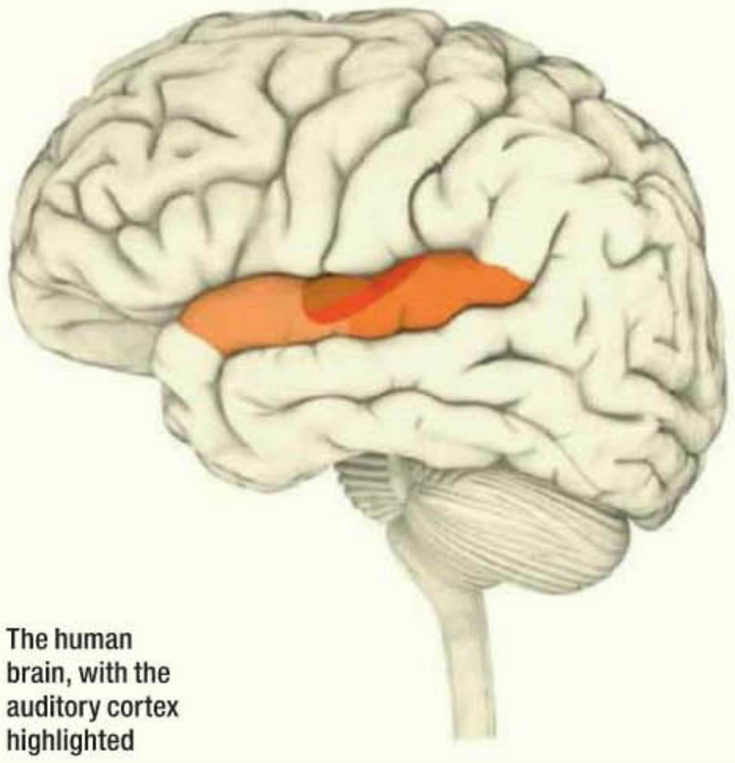
The team, based at the National Institute of Neurological Disorders and Stroke in Maryland, US, studied the differences in how humans and macaques hear the world. "We found that a certain region of our brains has a stronger preference for sounds with pitch than macaque monkey brains," said senior author Dr Bevil Conway.

The area of the brain that processes sounds is called the auditory cortex. By studying the activity of the auditory cortex in a non-invasive brain scan, the team could measure how strongly the brain responded to certain sounds.

The sounds were split into two types: noise without pitch, and pitch without noise. Specifically, 'noise' is a sound containing lots of different frequencies within a particular range, like the 'fuzzy' sound of an untuned radio. Regular human speech and macaque calls have both a pitch and a noise component. To compare how humans and macaques responded to each type of sound, the team first played the participants a series of pure tones followed by a series of noises made up of similar frequencies.

In humans, the auditory cortex lit up much more brightly when the tones were played, compared to the noises. However, macaques showed barely any difference in how they responded to these two sounds.

"These results suggest the macaque monkey may experience music and other sounds differently," said Conway. "In contrast, the macaque's experience of the visual world is probably very similar to our own. It makes one wonder what kind of sounds our evolutionary ancestors experienced. The results raise the possibility that these sounds, which are embedded in speech and music, may have shaped the basic organisation of the human brain. Since we rely so heavily on speech to communicate, and music is culturally important, our brains evolved to accommodate these."



The human brain, with the auditory cortex highlighted

IN NUMBERS

10 MINUTES

The time it took for college students' levels of cortisol, a major stress hormone, to drop after interacting with dogs and cats, in a study carried out at Washington State University.

20

The number of moves it took a robot built by researchers at the University of California to solve a Rubik's Cube. It typically takes well-practised humans around 50 moves.

151 DAYS

The time it takes the asteroid 2019 LF6 to orbit the Sun, the shortest orbital period ever discovered.

EMOJI USERS

Perhaps it's time to whack a few smileys in your dating profile. Daters that make heavy use of emojis hook up more often and have sex more regularly, a study at the Kinsey Institute has found. It may be because they are better at communicating desire.

CAT LOVERS

The stereotypical 'crazy cat lady' is a myth, a study carried out at the University of California has found. Their survey of 561 Californians found that those with cats were no more likely to be lonely, anxious, or have difficulty forming relationships than owners of other pets or those without pets.

GOOD MONTH

BAD MONTH

ATHLETES

Though they may go to great lengths to keep themselves in tip top condition, there is one area of athlete's bodies that are often in poor shape: their teeth. A study carried out at UCL has found that almost half of athletes have untreated tooth decay. Sugary sports drinks, energy bars and gels are most likely to blame, they say.

ARACHNOPHOBES

If the mere mention of the word 'spider' sends you into hysterics, it's probably best that you avoid storm-prone regions. Spiders born in areas with high incidence of hurricanes are more aggressive than those born in calmer environments, researchers at McMaster University have found.

GETTY IMAGES, TOBIAS MACHTS, MIT ILLUSTRATIONS: GABRIEL SILVERA

The robot was guided through replicas of blood vessels without causing damage

NEUROSCIENCE

Flexible robot slides through blood vessels in the brain

A thread-like robot steered by magnets could treat blood clots in stroke patients to prevent brain damage. The flexible robot was designed by researchers at MIT to slide through the brain's blood vessels without getting stuck.

The team hopes that the bot will replace the traditional method of treating blockages and lesions, which currently involves a surgeon inserting a thin wire into a major blood vessel in the patient's leg or groin and directing it into the brain by hand. Not only is this process difficult, but any wrong moves can cause further damage. It is also potentially harmful to the surgeon, because a real-time X-ray (known as fluoroscopy) is used to pinpoint the wire's location in the blood vessel, therefore exposing them to repeated doses of radiation.

"Stroke is the number five cause of death and a leading cause of disability in the United States. If acute stroke can be treated within the first 90 minutes or so, patients' survival rates could increase significantly," explained associate professor Xuanhe Zhao, who took part in the research. "If we could design a device to reverse blood vessel blockage within this 'golden hour', we could potentially avoid permanent brain damage. That's our hope."

The robot thread has a thin wire core made of a springy nickel-titanium alloy, coated in a rubbery 'ink' that's embedded with magnetic particles. Around the core is a layer of a 'hydrogel', a soft, non-toxic, water-based material that gives the robot a smooth surface to reduce the chance of it damaging blood vessels or getting stuck.

Currently, the robot is controlled by hand: the team have tested it in a silicone model of a stroke patient's brain, directing the robot thread by moving a magnet around the outside of the model. However, in the future, the surgeon could control the magnets from outside the operating room, or even from a different location.

HEALTH

Premature birth affects relationships in adulthood

Adults who were born following a gestation of less than 37 weeks have lower chances of forming romantic relationships, or having children, compared with those who were born full-term at 40 weeks, according to research by psychologists at the University of Warwick.

The study, which pulled together the results from 4.4 million adults, found that those who were born premature are 28 per cent less likely to form romantic relationships and 22 per cent less likely to become parents than adults who were born full-term. They were also 2.3 times less likely to ever have sex. Adults who were born extremely early, before 32 weeks, have even worse chances.

Other studies have suggested that premature birth is linked with being shy, withdrawn and less inclined to risky behaviour, which is why people who were born early may end up socially excluded or struggling to form relationships.

"The finding that adults who were born pre-term [early] are less likely to have a partner, to have sex and become parents does not appear to be explained by a higher rate of disability. Rather, pre-term born children have been previously found to have poorer social interactions in childhood that make it harder for them to master social transitions such as finding a partner, which in turn is proven to boost your wellbeing," said Dr Marina Goulart de Mendonça, who took part in the research.

The researchers say that as premature children tend to be more withdrawn, it is especially important for parents and teachers to encourage kids to build friendships, as this will help them to develop their social skills. But take heart: despite pre-term adults having fewer close relationships, the friendships they do form are just as good as those of full-term adults.

GETTY IMAGES X3 CONWAY LAB/NIH, ILLUSTRATIONS: GABRIEL SILVEIRA

THEY DID WHAT?

Seals trained to sing

WHAT DID THEY DO?
Three juvenile grey seals were taught to copy human speech sounds and simple melodies such as Twinkle, Twinkle, Little Star by researchers at the University of St Andrews.

WHAT DID THEY FIND?
All three seals were able to mimic some human sounds but one female, named Zola, proved to be the Beyoncé of the group. She was able to sing recognisable versions of several songs, including Twinkle, Twinkle and the Star Wars theme tune. "Copies were not perfect," said lead researcher Dr Amanda Stansbury. "But given that these are not typical seal sounds, it is pretty impressive. Our study really demonstrates how flexible seal vocalisations are."

WHY DID THEY DO THAT?
By studying how other mammals learn to produce 'human' sounds, it is thought that we can discover more about our own speech-related development and disorders. The researchers were particularly interested in 'formants': the particular vibrations of air inside the vocal tract that humans use to make vowel sounds. Non-human primates are limited in their ability to change formants, whereas pinnipeds – marine mammals that include seals, sea lions and walruses – have a similar way of producing vocal sounds to humans. Formants are an important part of the way we communicate, and studying non-human learning of formants can help us better understand the evolution of complex communication.

BRAIN ENERGY LINK TO CHILDHOOD OBESITY?

American researchers speculate that childhood weight gain may be linked to the amount of energy the brain uses. Research has shown that, in five-year-olds, the brain uses almost half of the body's energy. This has implications for weight gain, which, at its simplest, occurs when someone's energy burn is less than their calorie intake.

ZOOLOGY

Think or swim

Seals can consciously control their circulatory systems before diving

When submarine crews in movies hear "Prepare to dive!", they jump into action to get the vessel ready to submerge. A new study, led by Dr J Chris McKnight of the University of St Andrews, suggests seals use an equivalent thought to prompt the physiological changes needed to help them stay underwater for so long.

The team studied a group of harbour seals (Phoca vitulina) wearing near-infrared spectroscopy devices, which track patterns of blood circulation. These PortaSeal wearables were attached to the animals' heads and shoulders to monitor changes in their bodies while swimming and diving in a quasi-natural foraging habitat.

"Discovering that seals can seemingly actively exert control over their circulatory systems is really exciting," says McKnight.

Mammals, including humans, have a range of automatic cardiovascular responses to being submerged in water, including a reduced heart rate and constriction of the peripheral blood vessels in their limbs and extremities – a process known as the mammalian diving reflex. Marine mammals exhibit this reflex particularly strongly, but we cannot see inside their bodies before and during a dive to see the extent of changes that they undergo.

McKnight and his team wondered if near-infrared spectroscopy (NIRS), used to monitor blood flow and oxygenation levels in brains, might provide the answer. It involves shining light (of wavelengths between 800 and 2,500 nanometres) into the subject's head and analysing the spectrum of light that reflects back. Different molecular bonds absorb different wavelengths of light, so the reflected wavelengths provide clues as to the amount of blood passing through vessels in the subject's brain and surrounding tissue.

The results showed that seals constrict their peripheral blood vessels and boosted their cerebral blood volume about 15 seconds before diving. These anticipatory adjustments suggest that blood redistribution in seals is under some cognitive control and not simply a reflex response to submersion. Seals also increase oxygen in their brain at a consistent time in each dive, despite a lack of air.

ANIMAL WEARABLES

A tracking device weighing just one-tenth of a gram and small enough to be fixed to a bumble bee's back was made by a team at the University of Washington.

University of Birmingham researchers have developed sensor-packed backpacks for pigeons to collect data on urban microclimates.

A white beluga whale wearing a harness with a GoPro camera holder and label suggesting it came from St Petersburg, Russia, approached a fishing boat in Norway. A defecting spy?

PRIMER

Lightyear One

COULD THE FIRST LONG-RANGE SOLAR-POWERED CAR HERALD A NEW DAWN FOR ELECTRIC VEHICLES? PERHAPS, IF YOU WANT TO REMORTGAGE YOUR HOUSE

SOMEONE'S INVENTED A LONG-RANGE SOLAR-POWERED CAR?

Yep. The Lightyear One has been designed by Netherlands-based company Lightyear. The firm was founded by alumni of Solar Team Eindhoven, which won the Bridgestone World Solar Challenge race in 2013, 2015 and 2017. It was their success in the race that inspired them to develop the car and technology even further, working with people who've come from motor racing, Tesla and the aerospace industry. "We have a very different mindset, as a company," says CEO and co-founder Lex Hoefsloot. "We wanted to get into the mindset of making a super-efficient car. It's thinking about cars differently from how we used to."

HOW LONG-RANGE ARE WE TALKING?

Compared with other electric cars, Lightyear One is pretty competitive. Worst-case scenario: in cold weather, with the heating on, at fast motorway speeds, Lightyear claims the car can manage about 400km (250 miles). In more ideal conditions, it can travel 725km (450 miles) before it needs a charge. Lightyear wanted to get rid of the issues that concern many people about electric cars, such as 'range anxiety' and a lack of charging infrastructure, so the car will reportedly charge up to 350km (217 miles) overnight from a standard 230V outlet.

GETTY IMAGES, MONICA ARSO CIVIL/SEA MAMMAL RESEARCH UNIT

"Worst-case scenario: in cold weather, with the heating on, at fast motorway speeds, in can manage about 400km on one charge. Range anxiety begone"

YOU SAID IT WAS SOLAR-POWERED. WHY AM I HAVING TO PLUG IT IN?

In some parts of the world – like miserable old Blighty – you won't always be able to get by on solar power alone. Still, in the brightest two months of the year in the UK, you shouldn't need to charge it from an outlet as the car will be able to gain enough power from sunlight – though that depends on how far you need to go, of course. People living in sunnier climes can enjoy more solar-powered driving. For example, residents of Phoenix, Arizona, could manage 224 days.

SO IS IT COATED IN SOLAR PANELS?

Not quite. The bonnet and roof are covered in more than 1,000 solar cells. Lightyear has developed the technology to make the cells as efficient and lightweight as possible, while still being strong. They are sturdy enough, in fact, for an adult to stand on without breaking them. It will solar charge up to 12km (7.5 miles) every hour when in daylight, whether it's sitting outside your house or driving along the road. That's not bad – on a sunny day you could park up outside your work and after eight hours you'd have nearly 97km (60 miles) of charge to play with.

WHAT DOES IT LOOK LIKE?

Lightyear wanted to create a car of the future, and its sleek lines certainly deliver. From its reduced weight and drag, to a small battery, everything has been optimised to make it as efficient as possible. Plus, it's got the mod cons you would expect, like Apple CarPlay and Android Auto. There's also a 230V power outlet inside, which, according to Hoefsloot, essentially turns the car into "a power bank with solar cells on the roof". The company is also sharing its technology with other manufacturers.

HOW FAST DOES IT GO?

Top speed is 160km/h, so about 100mph.

AND THE COST?

You can reserve one for a hefty €149,000 (£133,000). Hoefsloot is optimistic that prices will drop as production increases. "If we push energy consumption down, and therefore energy cost, and maintenance costs down, then you will get to very low costs per kilometre," he says. "And this is the strategy we are using to get to super-affordable price points in 10 to 15 years."

OPEN YOUR EYES

Could a fancy pair of glasses improve our relationship with the digital world?

There is a famous fight scene in John Carpenter's iconic 1980s cult sci-fi film They Live that has to be the most over-egged conflict ever put to celluloid. The main character is a working-class guy called Nada, who is deeply frustrated by the injustice of being kept down by the white-collar workers who brush past him on their way to their daily grind. One day, he discovers a pair of black sunglasses, puts them on and sees the world as it truly is: not in beautiful technicolour, but drab black and white, with billboards everywhere that are not advertising aspirational images, but words like 'MARRY AND REPRODUCE', 'OBEY', and 'THIS IS YOUR GOD'. The sunglasses reveal a plot to control the masses. Behind the plot are some of the white-collar workers – they are not humans, but grotesque aliens.

This is when the fight comes in. Nada tries to convince his buddy, Frank, to try on the glasses and see the truth behind the facade. But Frank refuses. Like, really refuses. They spend 10 of the 94 minutes of the movie physically beating the heck out of one another. "Put on the glasses!" <PUNCH> "Take a look! Put 'em on!" <PUNCH>. Nada is truly the world's most persistent sunglasses salesman.

I unabashedly love this film. It represents the length we will go to ignore the fact that we are being sold desires and lifestyles that serve nobody except those who sell them. Nada desperately wants his friend to open his eyes. Frank stubbornly refuses to. They are both sides of us in our relationship with our technological world.

"We are being sold desires and lifestyles that serve nobody except those who sell them"

We have all been told a million times what the true price of free is. We know that our incredibly rich behavioural data is being sold by everyone who runs a web service to people who want to sell us stuff. It is written in black and white, but it's covered up by filters that drive us to produce identities that never cry, always have amazing holidays and constantly consume.

Some people, though, want us to put on the sunglasses. I'm usually one of them, often on news programmes explaining tech companies' loose interpretations of privacy. But as in Nada and Frank's epic screen fight, talk doesn't always hit home. Sometimes you have to force the glasses on.

Artist Ivan Cash's interpretation of this mission is to block out screens entirely. He recently released his first batch of 'IRL glasses' that turn most digital displays black. Added bonus: they are designed to look like the glasses in They Live. But like my incessant talking, they aren't the solution either. In the recent Crutch episode of Digital Human he says as much, describing the IRL glasses as a catalyst that he hopes will spark debate about the problem surrounding screens.

The Hollywood version of this story ends with the aliens being revealed to the rest of us. But in the real world version, we already know the aliens are there. And what happens after the credits roll? Well, that's our sequel to write.

PORTRAIT: KATE COPELAND ILLUSTRATION: JUANJO GASULL

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *Digital Human*.

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❍ Female	❍ 31 - 40	❍ Management	❍ $50,001 - $100,000
	❍ 41 - 50	❍ Professional	❍ $100,001 - $150,000
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NEPTUNE

NINE

Beyond Neptune, a handful of small worlds are moving in harmony. Astronomers think they might be dancing to the tune of a third world lurking in the darkness, one that's four times bigger than Earth and significant enough to be named our Solar System's ninth planet. Now they think they know exactly where to look for it...

by **COLIN STUART**

ILLUSTRATION: MAGIC TORCH

Look up at the night sky and find the famous three stars of Orion's Belt. Then extend the line between them up and to the right towards the constellation of Taurus, The Bull. Halfway between them sits a small patch of otherwise unremarkable sky that could well be home to one of the most famous finds in astronomical history – a ninth planet orbiting the Sun. It isn't every day a new planet is discovered in the Solar System. In fact, by one measure, it has only happened twice before in all of human history with Uranus (1781) and Neptune (1846). All the other planets have been known since antiquity and were never really 'discovered'. Objects such as Ceres (the largest asteroid) and Pluto were once deemed part of the planet club, but have since had their membership revoked. William Herschel, Urbain Le Verrier, Johann Gottfried Galle and John Couch Adams are the only astronomers to ever find a new planet that is still considered as such.

That elite list may soon be about to grow. CalTech astronomers Mike Brown and Konstantin Batygin are among the frontrunners to join it. Back in 2016 they went public with the radical notion that the roll call of planets orbiting the Sun isn't finished. They had noticed a handful of small worlds beyond Neptune behaving mysteriously, and considered that perhaps a ninth planet could account for their strange motion. "We were confident that another planet could explain the features of the outer Solar System," says Batygin. They've been scouring the sky for this object, but so far it has escaped them. For now, this potential world goes by the moniker of Planet Nine. If and when it is discovered, it will be named after a Roman or Greek deity, just like the other planets.

LONG-DISTANCE RELATIONSHIP

Planet Nine's suggested existence is based on observations over the last decade with telescopes big enough to peer into the murky environs beyond the eight known planets. Studying this under-explored wilderness is a real challenge. We only see thanks to reflected sunlight, and for these trans-Neptunian objects (TNOs) that light has to undergo quite a journey. The odyssey starts at the Sun, then travels out to a distance of more than 4,500,000,000km, before bouncing off an object and making the return trip to the Earth almost all the way back to the start. That light is also fading all the while, making it very faint and requiring a big telescope to collect it. Take the 600-kilometre-wide object known as 2012 VP113. It sits 80 times further from the Sun than the Earth, meaning the light we see reflected from it is around 40 million times dimmer than normal sunlight. Despite travelling at 300,000 kilometres per second, light takes nearly a day to cover the full distance from the Sun to VP113 and back to the Earth.

It was the discovery of VP113 by astronomers Scott Sheppard and Chad Trujillo in 2014 that first flagged up the possibility of an undiscovered planet. They are another team currently hunting down Planet Nine. Closer scrutiny of VP113's path around the Sun showed that it shared orbital characteristics with another TNO

ALAMY, SCIENCE PHOTO LIBRARY X2

"WE WERE CONFIDENT THAT ANOTHER PLANET COULD EXPLAIN THE FEATURES OF THE OUTER SOLAR SYSTEM"

called Sedna. The angle at which they approach the Sun is eerily similar. Our best theories of Solar System formation say that for each object this tilt should be random. So the fact that these two objects match arouses suspicion. “They’re like the fingerprints and broken glass of a crime scene,” says Megan Schwamb from the Gemini Observatory in Hawaii and co-discoverer of several TNOs. “Who did it?”. One explanation is to point the finger at a ninth planet, whose gravity is pulling on these objects and organising their orbits. To be doing that it would have to be several times the mass of the Earth. It wouldn’t be the first time we’ve found a new planet this way. After Uranus was discovered, discrepancies in its orbit were put down to the tug of another planet even further out. Sure enough, when astronomers calculated where this planet would be they discovered Neptune. Now teams of astronomers including Brown, Batygin, Sheppard and Trujillo are trying to do the same with Planet Nine.

HIDE AND SEEK

So far the planet remains stubbornly out of view, but the search has cemented the evidence that it is really there. In the process of trawling the outer Solar System, astronomers have uncovered new TNOs. We now know of 14 objects clustered together more than 230 times further from the Sun than the Earth. This includes an object nicknamed The Goblin, discovered by a team of astronomers including Sheppard and announced in October 2018. It’s a 300-kilometre-wide TNO on a highly elongated 40,000-year loop around the Sun. The more of these objects that we find sharing similar tilts, the stronger the case for Planet Nine becomes.

But there are alternative explanations. The leading one is that these copycat orbits are nothing more than observational bias. There are thought to be millions of TNOs out there that we haven’t found yet, all with random orbits. It could just be a fluke that we’ve happened upon the handful that do share similar paths around the Sun. ▶

TOP: The five confirmed dwarf planets in our Solar System and their moons. From left to right: Pluto; Eris; Makemake; Ceres; Haumea

MIDDLE: The region of sky between Orion’s Belt (yellow circle) and Taurus (white circle) is the search area for Planet Nine

BOTTOM: Artist’s impression of Planet Nine

FAMOUS OBJECTS BEYONAD NEPTUNE

SEDNA

Discovered by Mike Brown, Chad Trujillo and David Rabinowitz in 2003, Sedna was one of the objects that forced astronomers to re-evaluate Pluto's planethood. It takes 11,400 years to orbit the Sun, crawling along at an average speed of just one kilometre per second. Sedna will make its closest approach to the Sun in 2075–2076, providing a once in an 11,400-year opportunity to get the best view of this world named after the Inuit goddess of the sea.

2012 VP113

This object is often nicknamed 'Biden' after Joe Biden, who was the US vice-president at the time of its discovery at the Cerro Tololo Inter-American Observatory in Chile. At 600 kilometres wide, astronomers believe its pink colouration is due to the way cosmic radiation has shaded its surface, which is made of water and/or methane ice. It doesn't get as close to the Sun as Sedna, nor as far away. Sedna and Biden were the original basis for the Planet Nine idea.

If this were true, Planet Nine would be a figment of our imaginations. But in January 2019 Brown and Batygin published new research attempting to quantify how likely this is based on the latest TNO discoveries. Their answer? Just 0.2 per cent. "That's our most conservative estimate," says Batygin. A ninth planet, they claim, is the only existing explanation for what we see in the outer Solar System.

SCOURING THE SKIES

That doesn't mean finding it is easy. All searches so far have failed to spot the planet. The hunt is not helped by the fact that there are only a handful of telescopes in the world capable of seeing it. Not only do you need a large aperture telescope to collect the faint light, you also need one equipped with a camera with a wide field of view. Brown is using the 8.2-metre Subaru telescope in Hawaii to hunt for it, while Batygin is busy crunching the numbers. "The search area is 800 square degrees of sky," says Brown. That's about the same as 3,200 full Moons. A telescope with a narrow view would just take too long to cover this vast expanse.

It's not a two-dimensional patch of sky either, but three-dimensional. We also don't know Planet Nine's exact distance from the Sun. If it is near it will be brighter and if it's further away it will be dimmer. When it comes to the brighter end, Brown says they've already covered nearly all of the sky where it might be hiding without success. "That's surprising to me," he says. "That would have been the most reasonable guess of what Planet Nine would be like."

The findings are all the more unexpected when Batygin's latest computer modelling is taken into account. "We've performed thousands of new computer simulations in the last 18 months," he says, all to understand more about where Planet Nine could be. According to Batygin, the

GETTY IMAGES

"A NINTH PLANET, THEY CLAIM, IS THE ONLY EXISTING EXPLANATION FOR WHAT WE SEE IN THE OUTER SOLAR SYSTEM"

THE GOBLIN

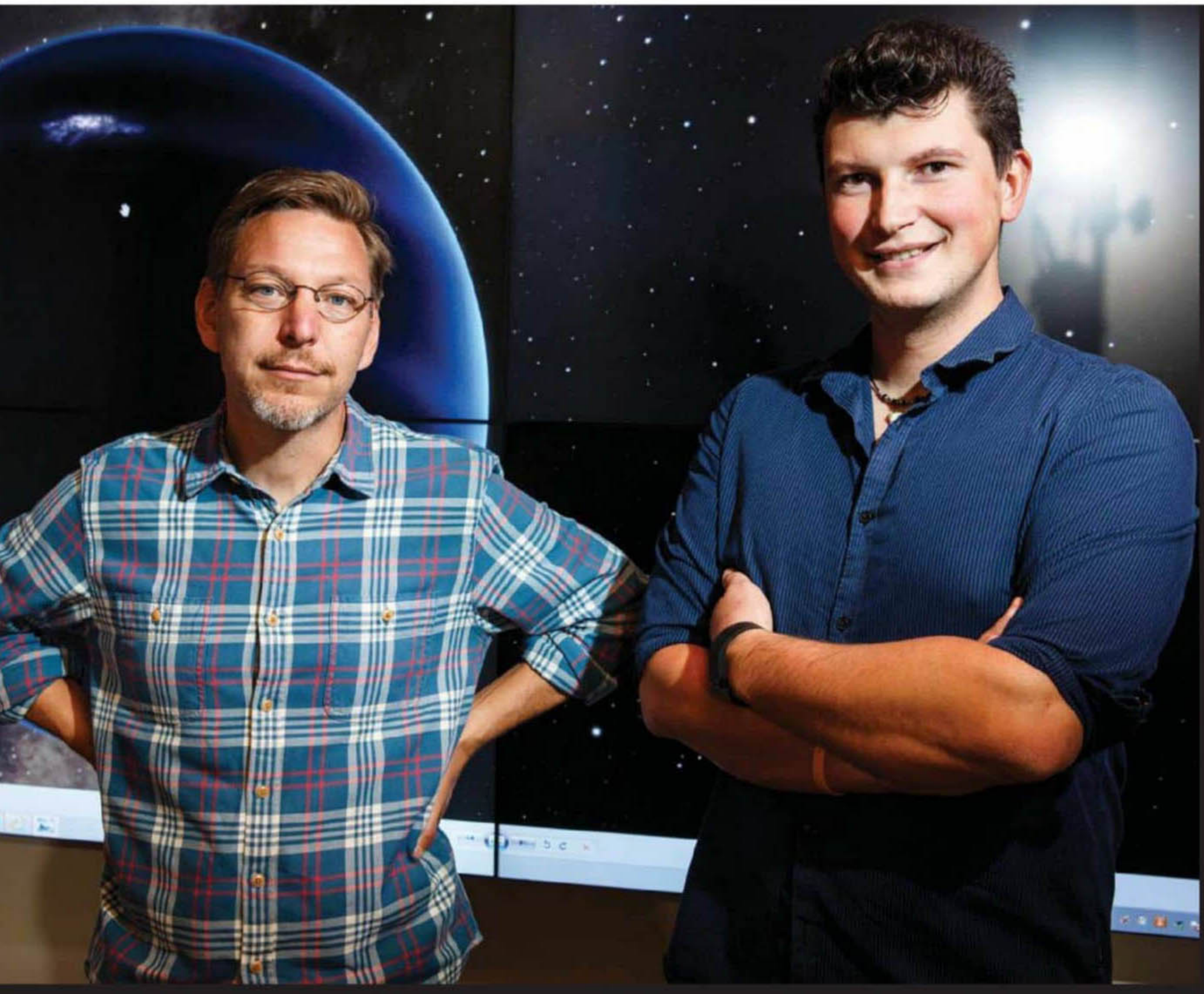
Named because it was discovered close to Halloween, The Goblin was first observed on 13 October 2015 using the Mauna Kea Observatory in Hawaii. It took three years to track it in sufficient detail to pin down its orbit and announce the discovery to the public. The Goblin's highly elongated orbit carries it from roughly twice Pluto's distance from the Sun all the way out to 30 times further than that. It's about as bright as one of Pluto's smaller moons.

FAROUT

Astronomers like to keep things simple where they can, as illustrated by the nickname of this object found on 10 November 2018. A name like FarOut marks that, at the time of its discovery, it was the furthest object ever found in the Solar System. Unfortunately this won't be its official name. Looking back at older photographs actually shows that FarOut had been captured before in 2015 and 2017. Like VP113, it appears to be pinkish in colour.

FARFAROUT

FarOut didn't hold its crown as a record breaker for long. In February 2019 a team led by Scott Sheppard announced the discovery of an object even further out – nicknamed FarFarOut. This time it is 140 times further from the Sun than Earth (or 21 billion kilometres). Both objects have been found so recently that their orbits are still being determined to see if they support the Planet Nine theory.



Mike Brown (left) and Konstantin Batygin (right) are searching the skies for objects beyond Neptune, including Planet Nine

HEAD IN THE CLOUDS:
The Subaru Telescope on top of Hawaii's Mauna Kea is being used to search the skies for Planet Nine

> "NATURE HAS NO OBLIGATION TO YOU. LOOK AT GRAVITATIONAL WAVES – THEY TOOK 100 YEARS TO FIND"

upshot of those calculations is that "Planet Nine is smaller in all parameters by a factor of two compared to our original estimates". Its orbital period is now thought to be 10,000 years rather than 20,000. It is five times the mass of the Earth, not 10. Despite being smaller, its shorter orbit would make it about two and half times brighter than the original 2016 estimates.

THE NET IS CLOSING

So how come Brown still hasn't found it, despite trawling the whole area at the brighter end? "We don't know its albedo and that's the key parameter," says Brown. An object's albedo is a measure of how much sunlight its surface reflects back into space. "It could either be a super-cloudy, bright object or a dark ice ball covered in junk with a low albedo." The fact it hasn't been found yet suggests it is the latter. If a dull surface is making it dimmer, finding Planet Nine will take more time. "We've covered about 50 per cent of the sky in that range," he says.

So the net is closing, but it is a laborious process. "The main difficulty is sustaining such an intense search for many years," says Brown. Planet Nine's predicted position out between Orion's Belt and Taurus is both a blessing and curse. Orion is part of the winter sky, which means that astronomers are restricted to searching for it during that season. In the summer it is part of the daytime sky and therefore undetectable. On the plus side, winter nights are longer, but the emphatic downside is that in recent years the winter weather in Hawaii has been horrendous. Batygin recalls one occasion where he was driving up the volcano to the telescope with hailstones the size of golf balls slamming into the car. On another occasion the weather looked clear, but Brown arrived at the telescope to find the door to the telescope was frozen shut. "We've had every sort of obstacle you can imagine," says Brown. Other roadblocks have included volcanic eruptions, earthquakes and sulphur dioxide fumes. "It's frustrating," he says. "[I'd] like to find it and move on to something else." With winter now over, this season is done and the search will have to wait until the Earth moves back round to the favourable side of the Sun. Batygin sums it up nicely: "Nature has no obligation to you," he says. "Look at gravitational waves – they took 100 years to find."

Hopefully we won't have to wait quite that long. If the current searches fail, there's hope on the horizon in the form of the Large Synoptic Survey Telescope (LSST). Currently under construction in Chile, its 3.2 billion pixel camera will be capable of photographing an area of sky the size of 49 full Moons at once. It's due to start operation in 2022. Even if it doesn't find Planet Nine right away, it is expected to discover hundreds of new TNOs. If their orbits also share the tell-tale alignment, then that would both strengthen the case for Planet Nine and point astronomers towards where to find it. According to Schwamb, the Planet Nine hypothesis is an answerable question. "It is not going to be a mystery forever," she says.

A deeper puzzle is how Planet Nine got there in the first place. How does a planet five times the mass of the Earth end up marooned up to 20 times further from the Sun than Neptune? The most likely explanation is it formed in the inner Solar System with the other eight planets, before some event threw it out into the depths of space. Even before astronomers found evidence for Planet Nine, computer simulations of the Solar System's formation were hinting at a missing planet. Starting with five giant planets resulted in a Solar System that looks more like ours today than those that started with just four. The only trouble was that there was no other evidence that this extra planet ever existed. Yet if the current frenzy of activity confirms the existence of Planet Nine, it is almost certainly this missing world. Its discovery would mean more than just another planet on the list: it could be the key to understanding why our Solar System looks the way it does today.

by **COLIN STUART**
(@skyponderer)
Colin is an astronomy author. Get his weekly space newsletter at colinstuart.net/newsletter

ALAMY

Magic in the Moray Firth

Photo story

The waters off north-east Scotland are famous for hosting the world's most northerly population of bottlenose dolphins. In spring and summer, these energetic cetaceans come bounding into view.

The Moray Firth – the vast channel east of the Highlands' Black Isle – is one of the best places in the world for encounters with bottlenose dolphins, particularly in spring and summer, when their pursuit of migrating salmon brings them close to shore. Bottlenoses are common across the globe, but the 195 or so individuals that occur in these waters are substantially bulkier than those in warmer climes, thanks to an extra-thick layer of blubber that not only insulates against the Scottish chill, but also provides a reserve, should food become scarce.

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RIGHT Over time, bottlenose dorsal fins can become heavily scarred and nicked, a result of bites and nips dished out during friendly tussles and serious fights for dominance, females and territory. These unique markings are a useful identification tool; this conspicuous fin belongs to a male known as Denoozydenzy.

BELOW Winter, before the salmon glut, is a quieter time for the dolphins. Sighting are likely to be opportunistic glimpses of individuals travelling in search of fish such as herring, mackerel, sprat and cod. Bow-riding – a skill acquired from an early age – enables a bottlenose to be propelled forward by a ship's wave, thus conserving strength on its daily commute.

ABOVE Bottlenoses swim fast in pursuit of prey, but have also perfected an alternative, more energy-efficient strategy known as against-current foraging. The dolphins position themselves against the current, moving just their tails to remain stationary, and simply wait for salmon to be delivered on the incoming tide.

RIGHT Dolphins have about 100 teeth, all uniform in size and shape (homodont), with which they seize and crush their prey. As they can't 'cut up' their food, the cetaceans must manage their meals carefully: chasing a fish they can't process wastes energy. To avoid gills becoming lodged in the throat, prey is gulped down head-first; an orientation achieved by flipping the item in mid-air.

BELOW Being air-breathing mammals, bottlenoses must surface to breathe. The spray that follows the exhale is an expulsion not of water from the lungs, but of surface water covering the blowhole. Slow travel requires one or two breaths per minute; deep dives or sprints involve rapid venting cycles to charge the bloodstream with oxygen.

RIGHT Dolphins are highly social creatures, and the bottlenoses around the Black Isle usually travel in pods of up to 12 individuals. Some males establish close alliances that last for life and can be mutually beneficial in various situations. Social bonds are reaffirmed by posturing, breaching, body rubbing and flipper touching.

LEFT Females and their single calves swim in tight formation; a baby will rarely leave its mother's side for the first six months. Besides providing protection, this close contact allows the youngster to ride its mother's slipstream. At around 18 months, hunting tuition is stepped up as breastfeeding begins to wind down.

LEFT Demonstrating the curiosity of his species, a young bottlenose approaches a boat on the Cromarty Firth, which flows north of the Black Isle. Calves are not particularly threatened by predation, as these cold waters host considerably fewer sharks than tropical seas, but mothers will summon their babies with signature whistles if they stray too far. The oil rigs on the firth's shoreline are not operational, but parked here for maintenance.

ABOVE The Moray Firth dolphins could be expanding their home range – sightings have been recorded as far as Scrabster (near John o' Groats) in the north to Scarborough in the south. Such movement up and down the coast is likely to be linked to seasonal food resources.

CHARLIE PHILLIPS is field officer for Whale and Dolphin Conservation, and has been photographing bottlenose dolphins in the Moray Firth for 25 years.

ABOVE Oblivious to the crowd, a male awaits an influx of salmon on the rising tide at Chanonry Point – a renowned location for onshore dolphin-watching. He is just 10m from the beach, but the water is deep enough to prevent stranding.

Young male bottlenose dolphins regularly engage in boisterous bouts of play to establish pecking orders. One particularly rowdy posse in the Moray Firth has become known as the 'Bad Boys Club', with members frequently causing mayhem and mischief. Older members sometimes spend time away from the tussles, to seek females.

How Britain saved Einstein

Exiled, homeless and on the run from Nazi assassins, 1933 was a grim year for Albert Einstein. Yet not all was lost, writes **Andrew Robinson**, as the famous physicist discovered during his visits to Britain

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ILLUSTRATION BY **HUGH COWLING**

In late July 1933, six months after the Nazi regime came to power in Germany and forced many distinguished German Jews to leave their native land, Albert Einstein paid his one and only visit to the House of Commons in Britain. Born Jewish in Germany in 1879, the world's most famous scientist had observed closely the rise of Nazism from his home in Berlin in the 1920s while enduring vitriolic public criticism and even death threats. In March 1933, he had anticipated the German-Jewish exodus and, returning to Europe from the US, gone into voluntary exile in Belgium with his second wife, Elsa. Now he found himself in London on a political mission to help Germany's Jews, looking down from the Distinguished Visitors' Gallery of the House and listening to a speech under the parliamentary 10-minute rule. It proposed the motion: "That leave be given to bring in a bill to promote and extend opportunities of citizenship for Jews resident outside the British empire."

The speaker was a dashing, upper-class, rightwing Conservative member of parliament, Commander Oliver Locker-Lampson, who was personally – soon to be intimately – known to Einstein. A former admirer of Adolf Hitler, Locker-Lampson now opposed the Nazis because of their anti-Jewish policy. He had first contacted Einstein in late March out of the blue, offering his home in London as a refuge: an offer declined by Einstein in favour of Belgium. A few days before his speech, the MP had arranged a private meeting between Einstein and Winston Churchill – then a backbencher – at Churchill's country house, Chartwell in Kent, where scientist and politician had agreed on the seriousness of the new Nazi threat to world peace. Churchill "is an eminently wise man", Einstein wrote immediately to his wife in Belgium. "It became quite clear to me that these people have planned well ahead and will act soon." Shortly after, Locker-Lampson had introduced Einstein to a former British prime minister, David Lloyd George. In the latter's house, the MP witnessed Einstein sign the visitors' book, after pausing for a moment at the 'Address' column to write "Ohne" – German for 'Without'.

Opening his speech, Locker-Lampson noted that he himself was neither Jewish nor anti-German. Indeed, after the end of the world war in 1918 (in which the commander had fought on the Russian front in support of the tsarists and against the communists, with the backing of Churchill) he noted that he had pleaded in the House of Commons for fair play for Germany, on the grounds that the German people had been misled by their leaders in 1914. Now, however, German leaders seemed to be repeating the earlier misdirection of their countrymen, he said. Then Locker-Lampson made reference to the House's current distinguished visitor: "[Germany] has even turned upon her most glorious citizen – Einstein."

He continued: "[Today] Einstein is without a home. He had to write his name in a visitors' book in England, and when he came to write his address, he put 'Without any'. The Huns have stolen his savings. The road-hog and racketeer of Europe have plundered his place. They have even taken away his violin. A man who more than any other approximated to a citizen of the world without a house! How proud we must be that we have afforded him a shelter temporarily at Oxford to work, and long may the tides of tyranny beat in vain against these shores."

During the business of 'questions', MPs found themselves constantly glancing upwards towards their almost-legendary visitor, as diffused lighting from above threw into relief the white-suited Einstein's world-famous aureole of grey hair. The House voted to support Locker-Lampson's bill on its first reading. Afterwards, as Einstein stood with Locker-Lampson in the lobby, "Members eagerly came forward to be introduced to the greatest scientist of the age", wrote the Jewish Chronicle. The Nazi newspaper Völkischer Beobachter took note in its report headlined, "Einsteinish Jewish theatre in British parliament", which accused Locker-Lampson of having staged the performance for the purposes of self-publicity in the foreign press. His combative references to the predatory "Hun" naturally provoked a bitter Nazi denunciation of the MP.

MPs glanced upwards towards their visitor, as lighting from above threw into relief the white-suited Einstein's world-famous aureole of grey hair

HATEFUL WEAPONS

Einstein returned to Belgium, but soon extremists were targeting him for assassination. The fury of the Nazi leadership had been provoked by two acts of Einstein in August. First, he had publicly repudiated his militant faith in pacifism by calling for European rearmament against the German threat.

"I loathe all armies and any kind of violence; yet I am firmly convinced that, in the present world situation, these hateful weapons offer the only effective protection," he informed a severely disappointed Lord Arthur Ponsonby of War Resisters' International in London.

Secondly, Einstein had very publicly endorsed a communist-compiled book, The Brown Book of the Hitler Terror. This eyewitness report from Germany with horrifying photographs noted that "the National Socialist leaders… have organised the pogroms and lynchings, the burnings and the pillories, the tortures of the first, second and third degrees". Although the book officially had no author, Nazi leaders were convinced (wrongly) that Einstein had written it.

Belgian policemen, on instructions from the Belgian king, protected Einstein night

Campaign trail Einstein near parliament with Oliver Locker-Lampson, July 1933. He went there to throw his support behind the MP's campaign to offer citizenship to Germany's exiled Jews

GETTY IMAGES

and day. But he was plainly at risk, especially after the murder by Nazi agents of an Einstein associate, Jewish philosopher Theodor Lessing, in Czechoslovakia on 30 August. On 7 September came international press announcements that a secret Nazi terror organisation, the Fehme (associated with the murder of Germany's foreign minister, Walther Rathenau, a friend of Einstein, in 1922), had placed a price on Einstein's head: £1,000 according to the London Daily Herald; 20,000 marks said the New York Times.

"Whether the story is true or not we do not know," warned the Sunday Times on 10 September, but if it were, "the Nazi hotheads" should "take fair warning and think twice of this folly before it is too late. If they should commit this crime against humanity, the conscience of the whole civilised world will rise against them, and the German government will find itself execrated and isolated as no German government has been before or since the war."

By the time this comment appeared, Einstein was again in England. On 9 September, at his wife's insistence, he had packed a few bags with vital books and papers and caught a boat and train from Belgium to London. He was heading not for Oxford – whose university had welcomed him in 1921 on his first visit to Britain, and again in 1931 and 1932, then sheltered him as a refugee in May–June 1933 – but instead a wooden holiday hut belonging to Locker-Lampson on a remote heath in Norfolk. There he could supposedly concentrate on theoretical physics, away from prying eyes.

HOVERING GUNMEN

In reality, a bizarre mixture of secrecy and publicity surrounded his four-week British visit in September and October – no doubt partly calculated by Einstein's publicity-hungry host, Locker-Lampson. On 12 September, the front pages of British national newspapers carried a dramatic photograph (shown overleaf) of Einstein sitting outside his hut with a "private guard of friends": the commander in the foreground with a wind-blown Einstein, and a local gamekeeper hovering in the background – the two Englishmen holding guns – plus one of the commander's two female secretaries, apparently attentive to the mathematical calculations of the professor. The secret location on Roughton Heath was given only as "near Cromer", but without too much detective work any Nazi agent worth his salt could have worked it out.

In early October, after the sculptor Jacob Epstein had visited the Norfolk encampment to model a bust of the physicist (held by the Tate, but not on display), Einstein headed back to London. There Locker-Lampson had organised a public

Call to arms Einstein (second left) at a 'No More War' rally in 1923. A decade later, confronted by Nazi militarism, the scientist renounced his pacifism and urged European rearmament against the German threat

Marked man
With the mathematician Walther Mayer on the beach at Le Coq-sur-Mer, Belgium, his home in exile. In September 1933, amid rumours of a bounty on his head, Einstein fled to Britain

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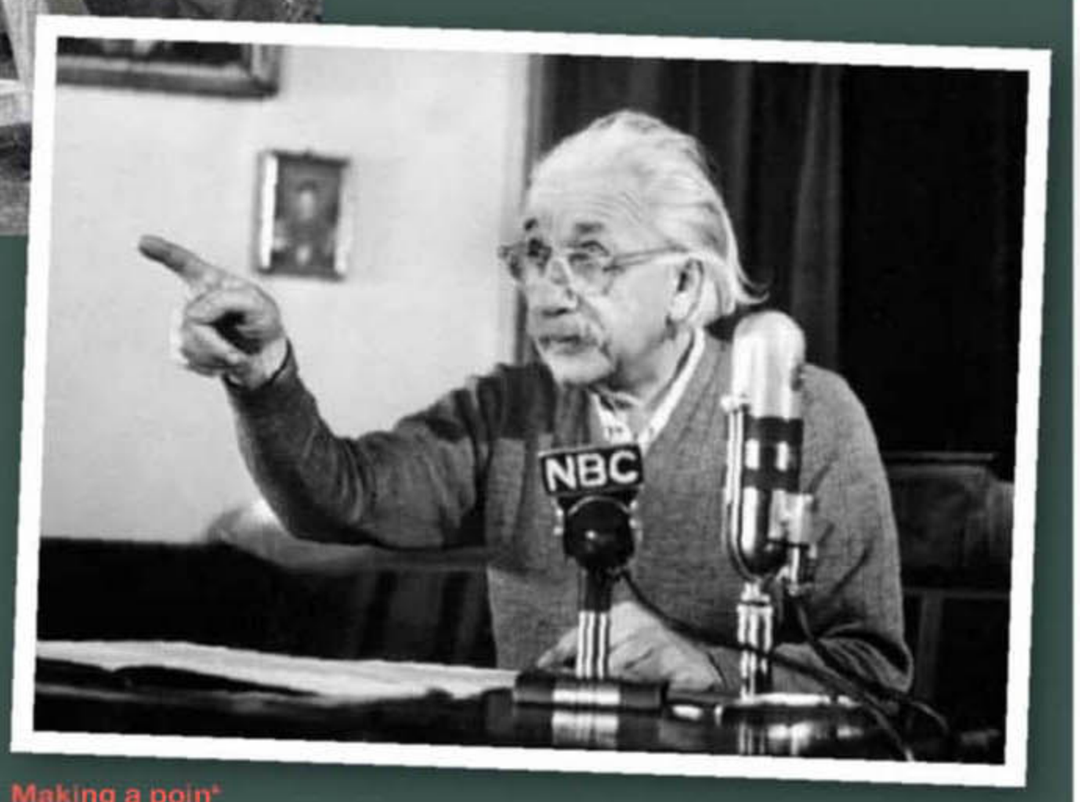
Armed guard
Einstein at Commander Locker-Lampson's holiday hut in Norfolk. With him are Locker-Lampson (left), a local gamekeeper and one of the commander's secretaries

"No matter how long I live I shall never forget the kindness which I have received from the people of England," Einstein told a reporter



Seeing double
With the sculptor Jacob Epstein in the Norfolk hideout. Epstein's bust of Einstein is part of the Tate's collections

Making a point
Arguing against the production of the H-bomb in 1950. Einstein warned of the existential threat posed by nuclear war until his death five years later

meeting at the Royal Albert Hall at which the German physicist and British speakers might raise charitable donations for academic Jewish refugees from Germany. Einstein, as the star attraction, spoke on "Science and civilization" in his hesitant, peculiar and touching English, to massive applause from an overflowing audience – other than a group of Blackshirts from the British Union of Fascists who were in attendance. Without the "intellectual and individual freedom" won by our ancestors, said Einstein, "there would have been no Shakespeare, no Goethe, no Newton, no Faraday, no Pasteur and no Lister" – and of course no Einstein. As William Beveridge, another speaker, remarked in his live broadcast on BBC radio that evening: "I had never seen him before. Einstein was a legend to me. It is like seeing Christopher Columbus or Julius Caesar."

Afterwards, on the steps of the hall, Einstein told a newspaper reporter: "I could not believe that it was possible that such spontaneous affection could be extended to one who is a wanderer on the face of the earth. The kindness of your people has touched my heart so deeply that I cannot find words to express in English what I feel." He concluded: "I shall leave England for America at the end of the week, but no matter how long I live I shall never forget the kindness which I have received from the people of England."

Einstein kept his word. Although he would live the rest of his life in America, based at the Institute for Advanced Study in Princeton – deeply involved with both physics and Cold War politics – and would never return to Europe, he remained at heart an anglophile. The only scientists portrayed on the walls of his house in Princeton were British: Isaac Newton, Michael Faraday and James Clerk Maxwell.

In July 1955, three months after Einstein's death, the British philosopher and mathematician Bertrand Russell announced the Russell-Einstein Manifesto to an audience in London. Signing this stirring document, which presciently warned the world of the dangers of a nuclear war, had been Einstein's last public act. It was a fitting end to his long association with the British people.

Andrew Robinson is the author of 25 books in the arts and sciences. His latest, *Einstein on the Run: How Britain Saved the World's Greatest Scientist*, was published by Yale in September

GETTY IMAGES/BRIDGEMAN

BUILDING FOR THE FUTURE

by **ABIGAIL BEALL**

As overpopulation and climate change take their toll on our cities, engineers and urban planners are adapting their designs to cope with an uncertain future

STEFANO BOERI ARCHITETTI

GOING UNDERGROUND

To cope with surging populations, city planners are starting to look beneath their feet for space

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SINGAPORE

As the world's population continues to rise, space is becoming scarcer, and cities are looking for new places to host their residents. For Singapore – the world's third most densely populated country and home to nearly six million people – the answer is to head downwards.

Climate change and rising sea levels mean that reclaiming land is no longer a sustainable option for Singapore. Instead,

"MOVING TRANSPORT BENEATH THE SURFACE WILL HELP PEOPLE ESCAPE SINGAPORE'S WEATHER"

Jurong Rock Caverns in Singapore are 130m beneath the surface and will be used to store liquid hydrocarbons such as crude oil

the country is looking to create an underground city. Earlier this year, Singapore's Urban Redevelopment Authority published its draft master plan, setting out what the next 15 years are going to look like. So far, the equivalent of £10.7m has been invested in the research and development of underground tech. Laws have been changed regarding home ownership, so people only own the land as far down as their basement, to free up space beneath houses for development.

People won't be living underground at first, the authority says. Instead, the city will start by moving storage, utilities, transport and industrial facilities underground, freeing up space above ground for residential and commercial uses.

Currently, Singapore uses underground spaces for transport and cooling systems, which go down to 20m. A deep tunnel sewage system for transporting waste water and sewage is planned for 20m to 50m. "For deeper space of more than 100m, more heavy-duty functions such as ammunition storage and caverns for petrochemical storage could be created," says Sing Tien Foo, director of the Institute of Real Estate Studies at the National University of Singapore. One major planned development is the Jurong Rock Caverns, which can hold about 1.5 million cubic metres of crude oil and petroleum.

At the country's airport, Changi, a four-in-one transport hub will host three train depots and one bus depot by 2024, all underground. This will help the country to double its train network by 2030, with all additional railways underground. Moving transport beneath the surface will also help people to escape Singapore's weather, which is seeing rising heat, humidity and rainfall as a result of climate change.

In order to make the most of its subsurface environment, Singapore first needs to understand what's down there at the moment. Currently, Singapore's Building and Construction Authority is developing a 3D geological model using laser scanning, which will be collated into a central database to help map and plan the underground space.

Prof Kevin Curran, a cyber security expert at Ulster University, says that technology is going to be key in allowing this kind of eco-city to develop. For example, air quality will become an important factor that will need constant monitoring, as underground air isn't circulated as easily as air above the surface. "Sensor-enabled devices are already helping monitor the environmental impact of cities around the world, collecting details about sewers, air quality, and garbage," say Curran. Underground cities might have smart rubbish bins, for instance, which send an alert when they need to be emptied, and smart lighting, which only comes on when traffic or pedestrians are approaching.

Although much of Singapore might be underground by 2030, it will be a little longer before people are living there. "Deep underground construction is costly," says Foo. "There's complexity associated with access, ventilation and fire safety.

"The use of the underground space for residential and commercial uses has not been planned yet," he adds, "but the feasibility could be evaluated in the future, if more land is required." ▶

LIFE AT SEA

OCEANIX

As sea levels encroach on the land, could we move people to the oceans?

In 2007, Marc Collins Chen was working as the minister for tourism in French Polynesia when reports started to emerge that the Pacific islands would be under threat from rising sea levels in the coming decades. "There wasn't consensus around when this would happen," he says. "But there was a sense of doom."

Today, Chen is CEO of Oceanix, a company based in Hong Kong that's developing concepts for floating cities. He's now been working on the problem for 12 years. "If you're a Pacific Islander and many of your islands are at sea level, you have to look at a solution," he says.

Earlier this year, Oceanix announced a collaboration with the Bjarke Ingels Group (BIG) and MIT's Centre for Ocean Engineering, creating a concept for a city of 10,000 people. It was unveiled as part of the UN's New Urban Agenda, a plan to create ways for the world's growing population to live more sustainably.

The 10,000 figure is an estimate, says Chen, and the way the city works means it will be able to host as few or as many people as necessary. The city will be made up of floating, roughly triangular platforms, each around two hectares in area and home to 300 people. Each platform, or 'neighbourhood', will generate its own renewable electricity from the waves and Sun, and the population can be increased by adding more of these modular platforms.

Alongside renewable energy, the city will grow its own plant-based food, and treat and reuse all waste water. "If you wanted to feed everybody with beef and chicken, you'd need so much surface area and freshwater," says Chen. "It'd become economically unfeasible."

The platforms will be secured to the seabed with biorock, which is a material already being used to create artificial reefs around the world. A low-voltage electrical current is passed through a steel frame, which electrolyses the seawater around it and causes charged particles ('ions') to build up on its surface, coating the steel in a rocky substance that's as strong as concrete.

Making sure the cities have a positive impact on the environment is crucial, Chen says. The UN uses 'ecological footprints' to measure the impact people have on the natural world, measured in global hectares per person. At current population levels, our planet has only 1.7 global hectares (gha) of biologically productive surface area per person. At the moment, the UK has a footprint of 7.9 gha per person, which means we're using more than we have. As the world's population increases, we need to be reducing our individual footprints. Chen says that Oceanix could have a footprint of as little as 0.5 gha per person, helping to reduce the strain on our ailing planet.

This might all sound quite far-fetched, but Chen believes it will happen, and soon. The company is aiming to have a prototype of the floating city in place within the next two and a half years, although the location has not yet been pinned down. ▶

BJARKE INGELS GROUP

All buildings will be lower than seven storeys (to windproof them) and made from locally-sourced materials such as bamboo

Six villages will connect to form a city of 10,000 residents, spread across 75 hectares

A large, protected harbour will be formed in the heart of the city. The six innermost neighbourhoods will include a public square, marketplace and centres for spirituality, learning, health, sport and culture

Individual platforms, or neighbourhoods, will be two hectares in area and home to up to 300 people

Each neighbourhood will generate its own renewable electricity through technologies such as solar roofs and wave energy converters

Villages will be composed of six platforms around a small, central harbour

GARDEN STATE

Can forest cities help to mop up our pollution?

LIUZHOU, CHINA

Traditionally, the more people in a city, the fewer trees there are. To create space for houses, offices and other buildings, nature takes second place. But, if the architect Stefano Boeri has anything to do with it, this will soon be changing.

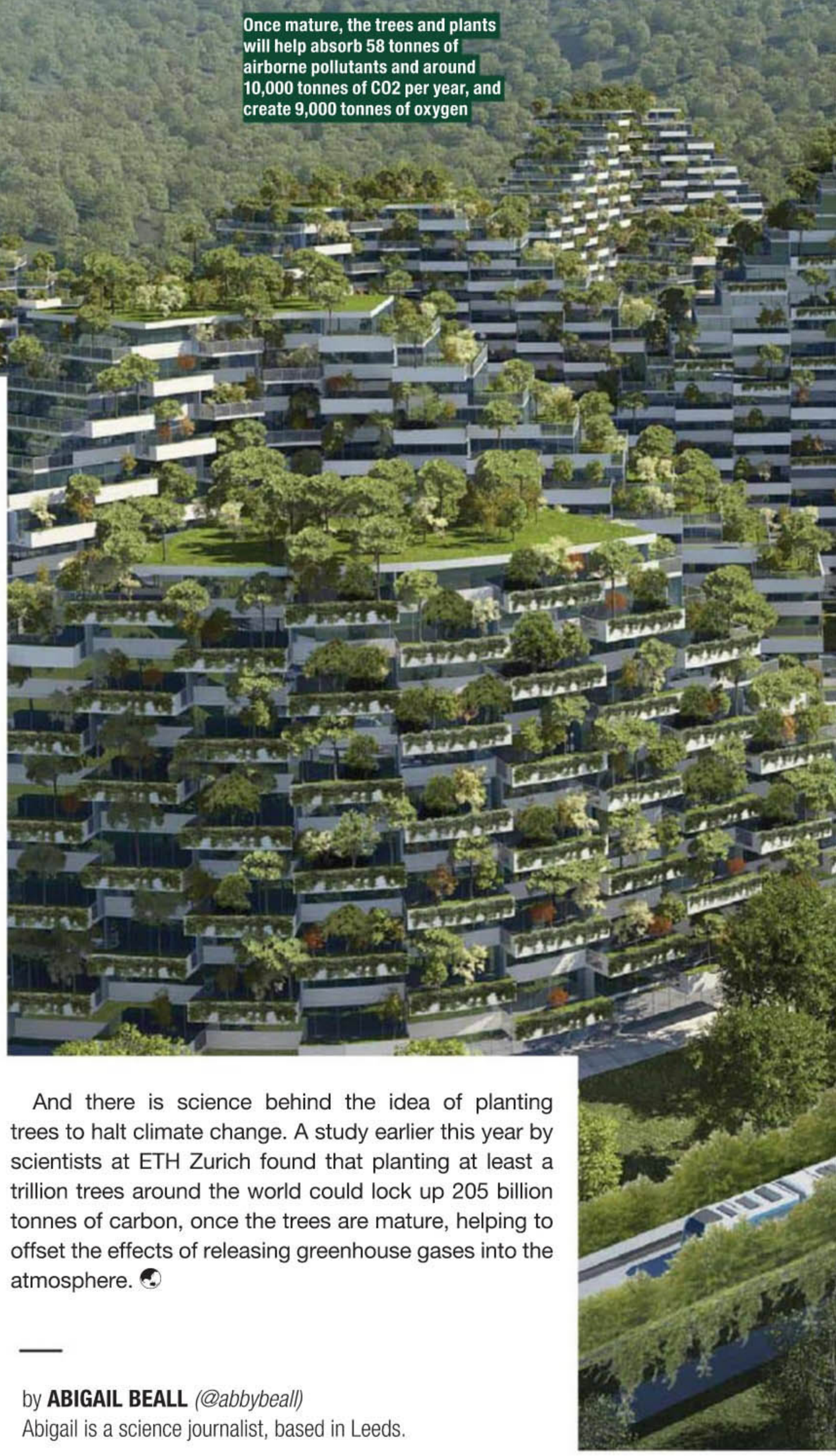
Boeri has designed a forest city, to be created in the north of Liuzhou – a metropolis in the Guangxi region in southern China. This mountainous area was chosen to be "a city where living nature is totally intertwined with architecture," according to Boeri. Instead of completely getting rid of the trees to build houses, the city's design accommodates the surrounding greenery. Homes and commercial buildings will be covered with trees, with gardens on the balconies of every floor, and rooftops that are home to miniature forests.

"I have been working on the idea of urban forestation for years," says Boeri. "In those areas of the planet where it is still necessary to build new cities, we are planning real forest cities for a maximum of 150,000 inhabitants."

The Liuzhou Forest City will be connected to central Liuzhou via a railway line and a road. It will be home to 30,000 people, and include commercial and recreational spaces, two schools and a hospital. On top of this, the vegetation will absorb carbon dioxide and pollutants, as well as releasing oxygen into the atmosphere.

Development is well underway for the forest city. "Our masterplan for a forest city in Liuzhou has been approved by the local government," says Boeri. Now, the government is starting the process of selling land to interested developers. "The current phase is still ongoing for land selling," says Boeri. Building is expected to begin in 2020. At the same time, the firm has replicated the concept in Lishui, a city in the southeast of China. The masterplan has also been given the thumbs-up by local governors here, and the developer is collecting funds to launch the project.

If the Chinese cities prove successful, Boeri hopes that the idea will take hold across the world. "We are developing the same concept in other places with different climate conditions, such as Mexico and north Africa," he says.



Once mature, the trees and plants will help absorb 58 tonnes of airborne pollutants and around 10,000 tonnes of CO2 per year, and create 9,000 tonnes of oxygen

STEFANO BOERI ARCHITETTI

And there is science behind the idea of planting trees to halt climate change. A study earlier this year by scientists at ETH Zurich found that planting at least a trillion trees around the world could lock up 205 billion tonnes of carbon, once the trees are mature, helping to offset the effects of releasing greenhouse gases into the atmosphere.

by **ABIGAIL BEALL** *(@abbybeall)*
Abigail is a science journalist, based in Leeds.


Geothermal energy will be used for interior air-conditioning, while solar panels on the roofs will provide renewable electricity
The city will host 40,000 trees and almost one million plants of over 100 species
The greenery will create a habitat for birds, insects and small animals, increasing biodiversity in the region
The city will be connected to central Liuzhou by a railway line and road

As one of the world's 25 most endangered primates, silky sifakas are facing loss of habitat through deforestation. Today, there are thought to be no more than 250 mature individuals.

ANGELS OF THE FOREST

Madagascar's mountain forests are haunted by one of the world's rarest and most beautiful primates, the snow-white silky sifaka.

By Mike Unwin Photographs Ugo Mellone

Left to right: a sociable species; females bear one infant every two years; males scent mark by rubbing against trees, staining their chests brown.

When the dawn mist lifts from the sacred slopes of Mount Marojejy, movement catches your eye: a flash of startling white travelling at speed through the dense forest canopy. It flits in and out of view like a wraith and only when it comes to a halt, framed in a gap, can you bring binoculars to bear. There's no mistaking those long, slender limbs and pure white coat: it's a simpona, or – to scientists – a silky sifaka. The rising sun illuminates the animal with a radiance that feels ethereal. No wonder locals know it as the 'angel of the forest'.

It's not always so easy to spot, however, especially when you're craning up from the steep forest floor. "I was always hoping for cloudy skies," admits photographer Ugo Mellone, who captured the rare images on these pages. "The animals are so white that an untrained eye can easily overlook them against the sky holes in the canopy."

It doesn't help that the silky sifaka's home comprises some of the most challenging terrain on Madagascar: the Marojejy Massif, in the island's north-east, rears to a height of 2,132m and its steep slopes are cloaked in dense forest. For years, this elusive animal and its hidden world remained shrouded in mystery, even to the few scientists who ventured there.

For years, this elusive animal and its hidden world remained shrouded in mystery.

"It was like being transported to a different world," says Patricia Wright, conservation biologist at Stonybrook University.

MISTAKEN IDENTITY

It was not until this century that the silky sifaka gained proper recognition. First described to western science in 1871 by French zoologist Alfred Grandidier, it was initially classified as a white race of the diademed sifaka, Propithecus diadema. Indeed, by 1931 all Madagascar's sifakas were thought to be races of either Verreaux's sifaka or the diademed sifaka.

During a 2004–07 study, however, researchers noted key distinctions between the silky sifaka and other races of diademed sifaka. Molecular studies backed these up, and when the second edition of Lemurs of Madagascar (Mittermeier et al) was published, the silky received full species status, deriving its species name candidus from the Latin word for white.

Today, zoologists recognise nine species of sifaka. The name comes from the group's explosive 'shee-fak!' alarm calls, and the genus as a whole is noted for its acrobatic upright leaping through the canopy and, on occasion, across terra firma. The silky sifaka is one of the largest, weighing 5–6.5kg and measuring some 48–54cm in head-body length, with a tail roughly the same again. In the field, the almost pure white of its luxuriant coat marks it out immediately from other lemurs, and is relieved only by its darker face, which becomes pinker as the animal loses pigmentation with age.

Finding silky sifakas means an early start, slogging up the tangled, muddy trails before dawn. The lemurs awake in their sleeping trees from about 5.30am, and reaffirm bonds with low contact calls while tucking into their first snack of the day. This is when the trackers aim to locate a troop, allowing them to keep tabs on the lemurs as they set out for the day's feeding.

In Marojejy, silky sifakas occupy a home range of some 34–47ha. Each day is spent criss-crossing this territory in search of food, covering around 700m in 24 hours and up to 500m in altitude. Using powerful back legs to bound through the canopy at speeds of up to 30kph, they can make rapid progress. But the pace is generally leisurely, stopping whenever they find productive feeding grounds. On average, some 44 per cent of the day is spent resting and 25 per cent feeding, with the rest spent in social behaviour.

SOCIAL NETWORKS

Research at Marojejy has found that troops vary in size from two to nine individuals, and in composition from a single pair to a mixed male-and-female group or a single male with several females. Though permanent dominance hierarchies are not known, females may take priority over males when feeding. Most interactions are gentle, with much social grooming and playful antics among younger members.

Silky sifakas are highly vocal lemurs. Researchers have identified seven different calls, which include low hums to keep in contact while foraging, a bird-like twittering to signal submission during conflict and a high repeated 'where are you?' howl when lost. The usual alarm call in response to danger is an explosive, sneeze-like 'zzuss',

Getting a grip

Sifakas have limbs uniquely adapted to getting around their arboreal home. Their hind legs are some 35 per cent longer than their forelegs, and propel them in upright leaps of up to 10m from one tree trunk to the next. At high speed, this technique is known as 'ricochetal locomotion', the sifakas moving so fast they appear simply to ricochet from tree to tree. Each leap is secured, however briefly, by means of a strong grip. Like all lemurs, sifakas have divergent digits on their narrow, elongated hands and feet that help grasp vegetation, and soft pads that both cushion their landing and provide some adhesion. The enlarged big toe (hallux) on the hindfoot functions as a semi-opposable thumb, allowing a tong-like grip of tree limbs.

Like other primates, sifakas' digits are equipped with nails rather than claws – except for the second toe, which has an elongated 'toilet claw' for personal grooming. This is one of several features that distinguish lemurs – together with lorises, bushbabies and other prosimians – from monkeys and apes. The sifakas belong to the family Indridae – one of eight lemur families on the island, which together comprise more than 100 species.

Silky sifakas have a rich olfactory language, using scent to get their message across, like many lemurs.

HOW TO SEE

Silky sifakas

As a visitor, the only realistic way to see silky sifakas is to visit one of the habituated troops at Marojejy National Park. The best time of year is during the Malagasy spring and summer, from the very end of August to late December, when the weather is most conducive to wildlife-watching. There's another short window of opportunity in April to May. At other times, rain can be heavy and the going very tough.

TOUR OPERATORS

Rainbow Tours 0207 666 1250, rainbowtours.co.uk offers tailor-made trips that combine three nights at Marojejy with three nights at Andasibe-Mantadia National Park, where you can go in search of indris and other lemurs. Other tour companies offering guided trips to Marojejy include Naturetrek 01962 733051, naturetrek.co.uk; Wildlife Worldwide 01962 302086, wildlifeworldwide.com; and Natural World Safaris 01273 691642, naturalworldsafaris.com.

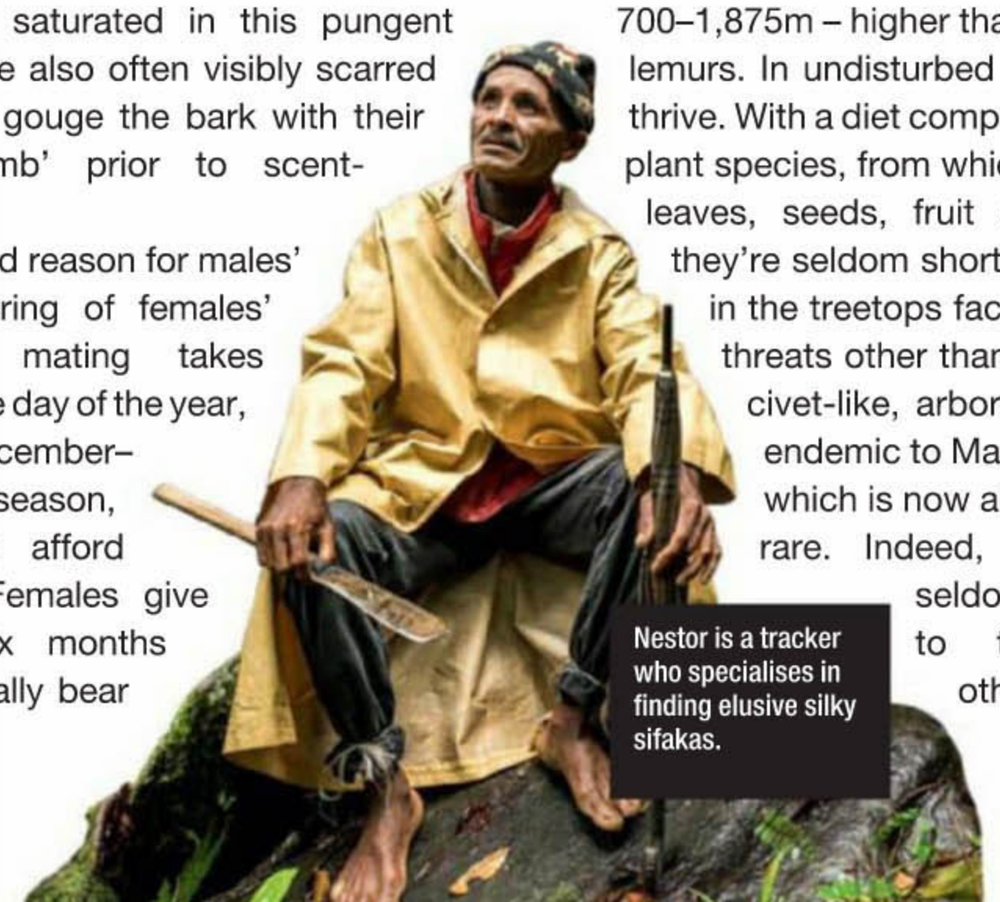
but the appearance of a large bird overhead may also prompt a deeper, monkey-like chattering – suggesting that the species has an inherited fear of raptors, even though the Madagascar buzzards pose no real threat.

Like many lemurs, silky sifakas also have a rich olfactory language, using scent to get their message across. Males are especially industrious, and during the breeding season can be distinguished from females by the brown stains on their chest left by rubbing their sternal gular gland against tree trunks. They will also constantly check female scent markings, often overlaying them with their own scent. Strategic trees, known as totem trees, become saturated in this pungent perfume and are also often visibly scarred by males, who gouge the bark with their front 'toothcomb' prior to scent-marking.

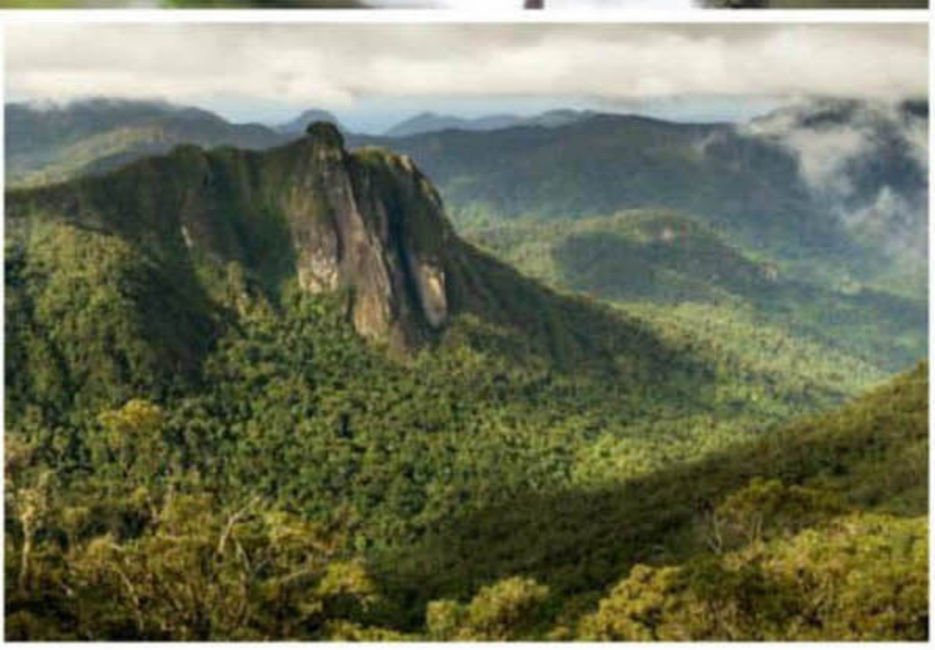
There's a good reason for males' zealous monitoring of females' receptiveness: mating takes place on just one day of the year, during the December–January rainy season, so they can't afford to miss out. Females give birth some six months later and generally bear a single infant once every two years. The youngster clings to its mother's chest for the first four weeks then rides on her back as it begins to explore the world more widely. Other troop members join in with childcare, playing, grooming, carrying and occasionally even nursing an infant that isn't their own – a practice common to all sifakas. Upon reaching sexual maturity, at two to three years, they disperse to find new troops.

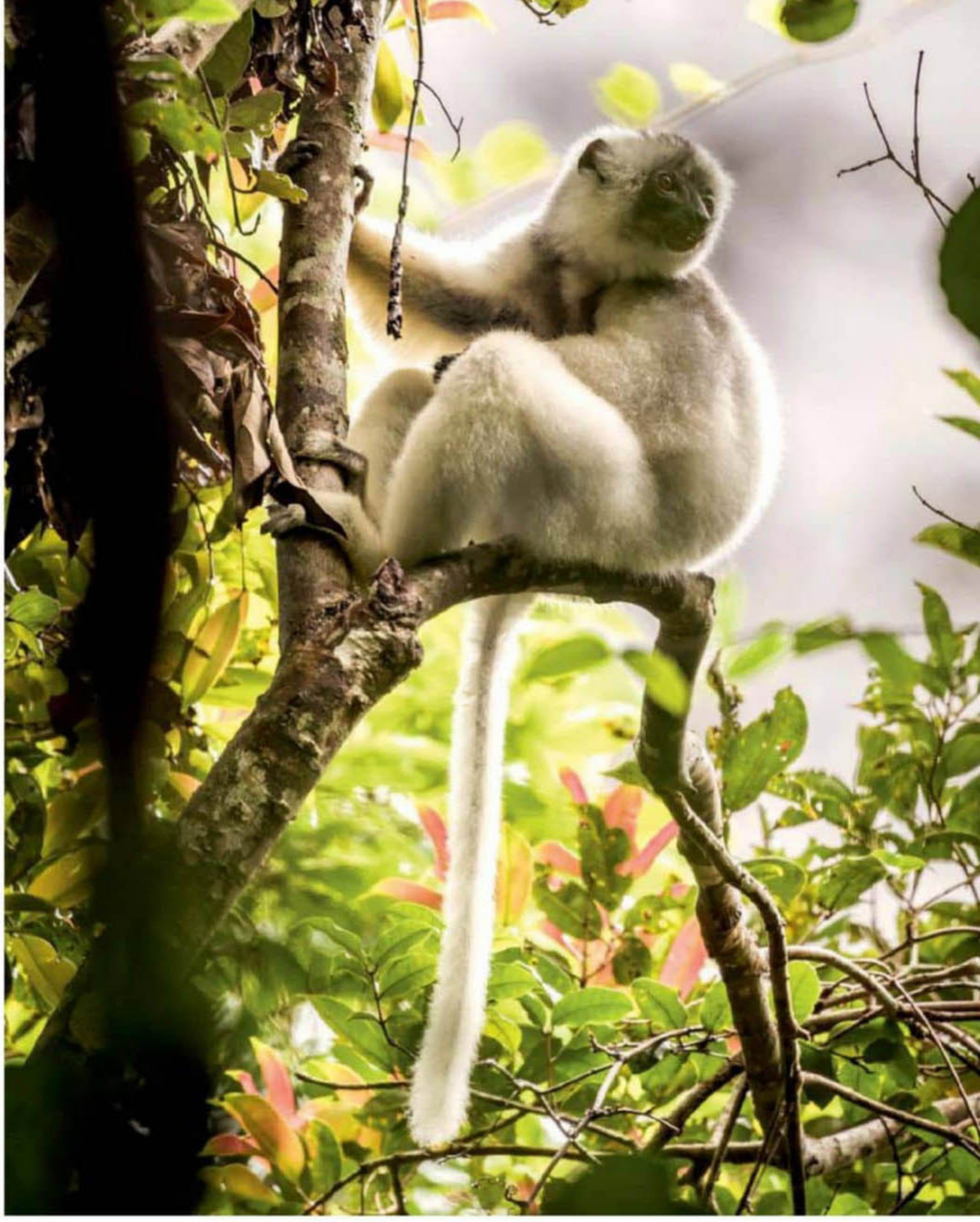
HEAD FOR HEIGHTS

Mount Marojejy provides ideal habitat for silky sifakas. These are essentially animals of montane rainforest, typically found at 700–1,875m – higher than most other lemurs. In undisturbed habitat, they thrive. With a diet comprising over 76 plant species, from which they glean leaves, seeds, fruit and flowers, they're seldom short of food, and in the treetops face few natural threats other than the fossa, a civet-like, arboreal carnivore endemic to Madagascar but which is now also extremely rare. Indeed, the sifakas seldom descend to the ground other than for



Nestor is a tracker who specialises in finding elusive silky sifakas.





Clockwise from top left: pigmentation is lost with age, with faces becoming pinker; these not-so-fussy eaters take their pick of over 76 plant species; few threats are encountered in the treetrops, apart from the fossa; some 80 per cent of native forest has been lost over the last century and is at further risk of deforestation.

occasional mouthfuls of soil to supplement their green diet with important mineral salts.

Sadly, ideal habitat is in short supply. Madagascar has lost some 80 per cent of its native forest over the last century. Today, silky sifakas are confined to a narrow forest strip in the north-east, with the bulk of the population found in Marojejy National Park and Anjanaharibe-Sud Special Reserve. A few groups also survive in nearby Makira Forest Protected Area and in a few adjacent unprotected forest fragments.

The IUCN lists the species as Critically Endangered – it is one of the world's 25 most endangered primates. Researchers believe there are likely to be no more than 250 mature individuals in the wild today – and there are none in captivity.

Habitat loss remains the chief threat to the silky sifaka. Even protected areas, including Marojejy National Park, which covers some 55,000ha, remain at risk of deforestation. Furthermore, there are no local taboos (known as fady) that prohibit the eating of this species – unlike with, say, the golden-crowned sifaka – so individuals are also vulnerable to the bushmeat trade.

MAKING NEW CONNECTIONS

But hope is not lost. With Marojejy now part of the Rainforests of Atsinanana World Heritage Site, the silky sifaka has become a flagship species for the area. While research continues, with radio-collared individuals revealing ever more about the species' movements and behaviour, conservation groups are working with government to expand and safeguard existing reserves, and to link the sifaka's few remaining retreats, by using protected forest corridors.

Most important, the message is now reaching local people. Conservationists within the community are boosting knowledge of silky sifakas. And now, with several habituated troops, they can even take schoolchildren into the reserve to see the sifakas for themselves. Such encounters build a sense of pride and connection and this thrill also extends to visitors, who are able to stay at a local lodge and hire an expert guide to enjoy their own sightings.

With ecotourism comes employment. And, for local people who have revered Marojejy's forests for generations, this demonstrates that when it comes to creating livelihoods and preserving the sacred mountain, silky sifakas might just turn out to be guardian angels.

MIKE UNWIN writes about wildlife and travel and counts Madagascar among his most exciting destinations.

A space odyssey

The moon landing is one of the crowning glories of American history but, for much of the preceding 25 years, it looked like the US might be eclipsed by its Soviet rivals. On the 50th anniversary of this iconic moment, **Kendrick Oliver** tells the story of the race to the moon, from the hunt for Nazi Germany's rocket men to Saturn V's fiery launch

GETTY IMAGES

Man on the moon
Buzz Aldrin sets up a 'Solar Wind Composition' experiment in front of the lunar module during Apollo 11's moon landing, July 1969

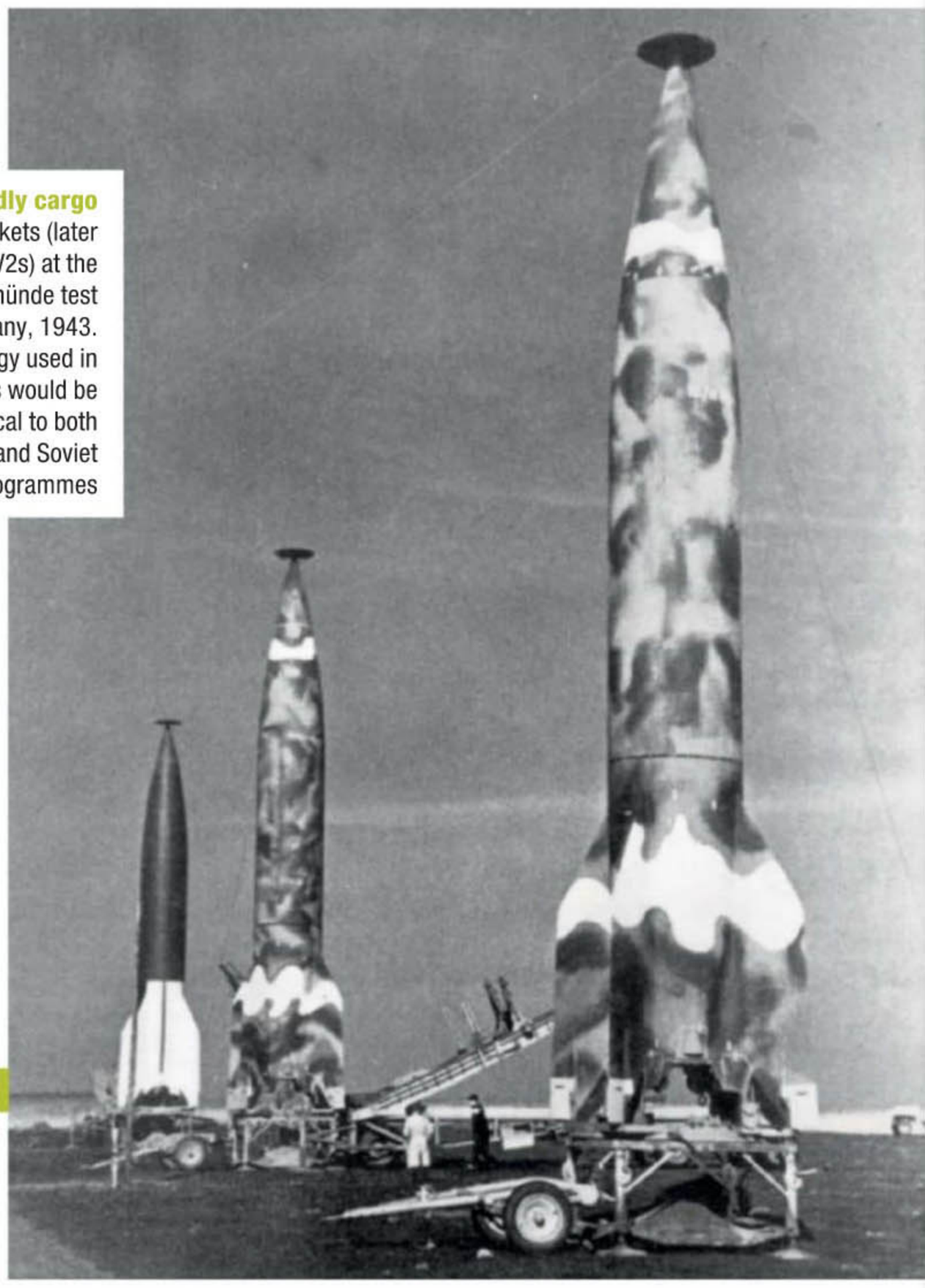
America holds its breath

It was the evening of 15 July 1969, and the acclaimed novelist Norman Mailer was driving along US Highway 1, in Brevard County, Florida, surveying the gathering of Americans – "an encampment of every variety of camper" – on the shoreline across from Merritt Island, site of the Kennedy Space Center. They were there in their many thousands to witness the launch, the following morning, of Apollo 11, the spacecraft that would deliver the first humans to the surface of the moon and then return them to Earth.

Mailer contemplated the diverse hopes and fears drawing these people to the scene: pride in their country, certainly; concern for the safety of the astronauts, yes. But was there something else, some fascinated projection of the Faustian bargain that all Americans – space pioneers and ordinary folks alike –had made with technology, some apprehension that a new machine age was now carrying everyone on a common path to a bleak and dangerous destination? As Mailer put it: "Had we been getting ready to go to the moon out of some deep instinct that already we had killed the nerve which gave life to the Earth?"

Mailer thought back to the event he had just left, a private banquet attended by Wernher von Braun, who had led development of the Saturn V rocket that would lift the considerable weight of Apollo 11 into orbit. At the banquet, von Braun had presented a visionary perspective of the mission – "We are expanding the mind of man" – but a ripple of embarrassment had preceded his remarks, when the banquet host made passing reference to the fact that von Braun had begun his rocketry career in service to the Third Reich. Americans often discussed the enterprise of landing a man on the moon in moral, idealistic terms – "we came in peace for all mankind" – but there was not much about the space age that genuinely transcended partisan politics and earthly ambition. The long countdown to the launch of Apollo 11 was punctuated by conflict and competition, both between nations and within national space establishments…

Rapt audience
Some of the thousands of Americans who converged on Brevard County, Florida to witness the launch of Apollo 11, July 1969



Deadly cargo
A-4 rockets (later known as V2s) at the Peenemünde test centre, Germany, 1943. The technology used in these rockets would be critical to both American and Soviet missile programmes

MORE FROM US

Listen to our podcast interview with Kendrick Oliver on the race to the moon at historyextra.com/podcast

Priceless assets Wernher von Braun (arm in cast) and fellow members of the German V2 rocket team, pictured after their surrender to US forces, May 1945

T-MINUS 26 YEARS, 9 MONTHS, 13 DAYS

The spaceship is born

"Do you realise what we accomplished today? This afternoon the spaceship was born!" On 3 October 1942, an A-4 missile left its test stand at the joint Luftwaffe-army rocket centre at Peenemünde, on the Baltic island of Usedom, rose up into the thermosphere to a height of 56 miles, and then arced back into the Baltic Sea 118 miles away. Colonel Walter Dornberger, head of the German army's rocket programme, was elated, but he told Wernher von Braun, who directed the group responsible for the development of the A-4, that their work was just beginning.

The army would now expect the A-4 to move rapidly into production, a formidable task given the still experimental nature of the rocket and the complexity of its design. Soon, reverses in the German war effort would intensify the pressures upon von Braun. By the end of 1943, the SS was using slave labourers from concentration camps in order to speed up assembly of the A-4s, as von Braun undoubtedly knew. Thousands died from overwork, starvation and disease.

The A-4, now renamed the V2, was first fired in anger on 8 September 1944. One of its targets was Paris, liberated two weeks before. With the Allies already advancing on Germany from east and west, the V2 (though it killed hundreds of people in London and Antwerp) made little difference to the outcome of the war.

T-MINUS 24 YEARS, 2 MONTHS, 14 DAYS

The Allies harvest German rocket men

The Allies had crossed the Rhine, the Red Army was in Berlin, and Hitler was dead. The V2 programme had disintegrated. On 2 May 1945, von Braun, recovering from a car accident at a hotel on the German-Austrian border, decided – together with other members of his team – to surrender himself to a US Army intelligence unit headquartered nearby. Interrogations over the next few weeks revealed to the Americans the value of the expertise possessed by the V2 engineers. US Ordnance forces raced to collect V2 rockets and components, and documents from the programme, before major installations were handed over to the Red Army under the Yalta agreement.

The Soviets were intent on a similar harvest, an effort that continued into early 1946 (about 150 German rocketeers were taken to the USSR late that year). In March 1946, the Soviets established a programme to reproduce V2 rockets for flight testing, under the leadership of Sergei Korolev (pictured below). By that time, von Braun and around 100 other German rocketeers were in the United States, at a secret facility in Fort Bliss, Texas, seeking to do the same thing.

In October 1942, a German A-4 missile rose to a height of 56 miles and arced back into the Baltic Sea

T-MINUS 13 YEARS, 11 MONTHS, 17 DAYS

The Americans enter the race to launch a satellite

As young men, both Korolev and von Braun had been enthused by the possibility of using rockets for space travel, but their professional lives had been dedicated to weapons development. In 1950, amid increased concern about American military readiness following a successful Soviet atom bomb test, the US army established an Ordnance Guided Missile Center at Huntsville, Alabama, with von Braun installed as project director. Over the next four years, von Braun's group would produce a more advanced version of the V2 in the form of the Redstone short-range ballistic missile and begin work on the intermediate-range Jupiter missile.

Korolev had also been extrapolating the design of the V2, developing the nuclear-armed R-5 missile and initiating a programme to build a ballistic missile – the R-7 – that could reach the United States. But on 29 July 1955, the US government announced an intention to launch a scientific satellite during the International Geophysical Year (an international scientific project that ran from July 1957 to the end of 1958). The Soviets swiftly announced that they would also do so, with Korolev managing to convince the Kremlin that he could adapt the R-7 for this purpose without compromising its development as a weapon. In contrast, von Braun, much to his chagrin, was cut out of the US satellite programme, with the Pentagon instead lending its support to the navy's Vanguard launcher.

Out of the loop Von Braun explains the theory of satellite flight, 1957. Despite his rocketry expertise, he was initially frozen out of the US satellite programme

ALAMY/AKG IMAGES/GETTY IMAGES/BRIDGEMAN

T-MINUS 11 YEARS, 9 MONTHS, 12 DAYS

Sputnik spurs the US into action

Before 4 October 1957, everything that had been fired into space had swiftly fallen back to Earth or burned up upon re-entry. The Soviet launch of Sputnik (pictured right), an orbiting satellite atop Korolev's R-7, augured a new age. Possibilities long confined to works of science fiction seemed close to realisation. It was not hard to imagine that the rocket technology that had lifted a metal beach ball into orbit might soon be capable of carrying a man there too; it might also lift a space-based surveillance instrument, and components for a weapon or a permanent space station; it might even throw a probe beyond Earth's gravitational well to the moon or another planet.

But for Americans, much of the excitement that followed Sputnik's launch was edged with concern. How had the Soviet Union, a nation using crude command economics to will itself from backwardness into modernity, made it into orbit first? In December, an attempt to deliver an American satellite into space, by means of the Vanguard rocket, was a spectacular failure: Vanguard blew up on the launchpad, live on national television.

There seemed a danger that audiences in the rapidly decolonising 'Third World' might read Sputnik as evidence that a communist-style system offered the quickest route to modernisation. It was in the context of such apprehensions that von Braun and the army finally received permission to try to launch a satellite, Explorer 1, using a version of the Redstone rocket. The launch, on 31 January 1958, was successful. The United States had entered the space age.

Crash and burn The Vanguard rocket, America's riposte to Sputnik, blows up on its launchpad, December 1957

Might audiences in the 'Third World' read Sputnik as evidence that a communist-style system offered the quickest route to modernisation?

T-MINUS 10 YEARS, 11 MONTHS, 17 DAYS

Nasa enters the fray

Until 1958, America's activities in space were dominated by its military. Many of the launches that took place during the late 1950s were carried out under the aegis of the Pentagon for classified military and intelligence purposes. As far as most Americans working on US rocket and satellite development were concerned, that would continue to be the case in the 1960s.

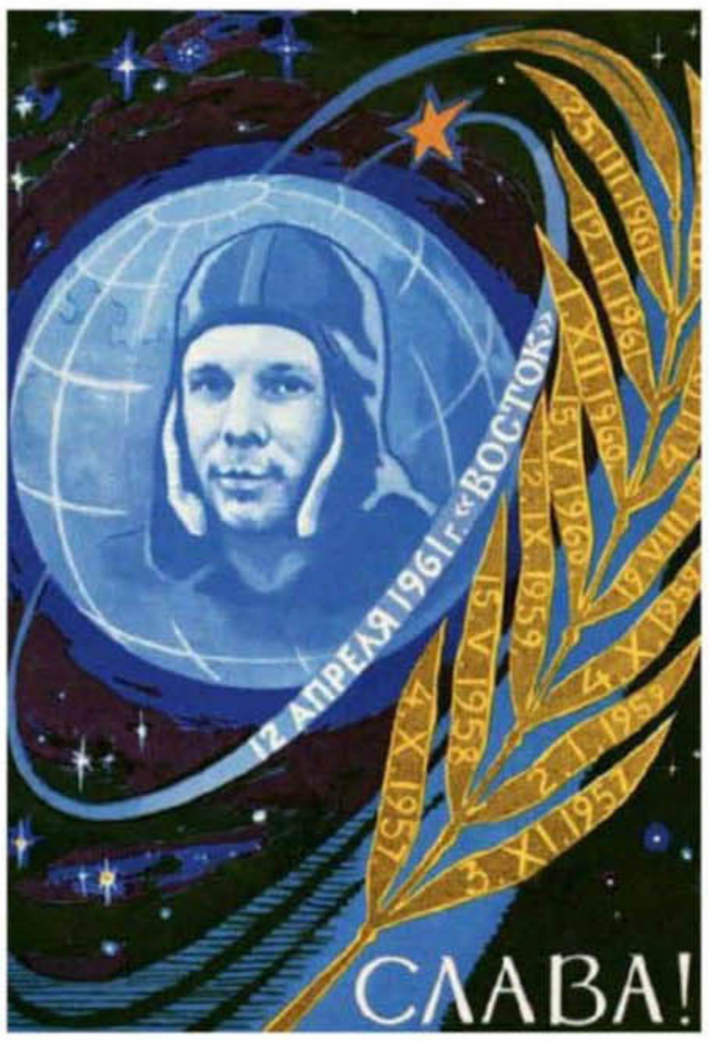
But as the 1950s drew to a close, there was a change of direction. The desire to draw a distinction between the American and Soviet approaches to space led President Eisenhower to establish a civilian agency. That agency – the National Aeronautics and Space Administration (better known as Nasa) was given responsibility for the "expansion of human knowledge of the phenomena in the atmosphere and space" and the development of non-military vehicles "capable of carrying instruments, equipment, supplies and living organisms through space".

Nasa came into existence on 29 July 1958. By the end of 1959, von Braun had transferred his Huntsville operation to the new agency, lured by Nasa's interest in his plans for a next generation heavy-lift booster, and the Pentagon's decision to place all military rocket programmes under the control of the air force.

Both the USSR and United States had by then committed to launching a man into space; they had also both attempted to send probes to the moon. But the project of a manned lunar landing still seemed too costly and ambitious for either government to adopt it officially, even as a long-term objective.

GETTY IMAGES

Mission accomplished
Alan Shepard shortly after becoming the first American to travel into space, aboard Freedom 7, May 1961. The success of Shepard's mission dispelled any lingering American doubts over sending men to the moon



Communist triumph
In April 1961, Yuri Gagarin became the first man in space, an achievement celebrated in this Soviet illustration. The Washington Post described the feat as "a psychological victory of the first magnitude for the Soviet Union"

GETTY IMAGES/ALAMY

T-MINUS 8 YEARS, 1 MONTH, 21 DAYS

Kennedy promises the moon

"I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth." It was 25 May 1961, and John F Kennedy was delivering a special address to the US Congress on "urgent national needs".

April had been a cruel month for the new US president. Korolev had scored another space spectacular, as Vostok 1, atop a rocket derived from the R-7 missile, carried Yuri Gagarin into orbit and into the pantheon of Soviet heroes. The mission was, according to the Washington Post, "a psychological victory of the first magnitude for the Soviet Union". Soon after, a US-trained force of Cuban exiles had landed at the Bay of Pigs in an attempt to overthrow the regime of Fidel Castro and been defeated within three days.

Kennedy had until then been ambivalent about the plans that Nasa had developed for a manned mission to the moon; now, however, he began to see the adoption of this goal as a means of demonstrating his personal capacity for vigorous leadership, giving the space programme new momentum and, should the effort be successful, proving to a worldwide audience the superiority of the American capitalist system.

The Soviets had not yet invested any major resources into a lunar landing project of their own, so there seemed a reasonable chance of American success. When, in early May, Alan Shepard returned safely to Earth following a sub-orbital flight aboard Freedom 7, the last lingering reservations faded. Kennedy was ready to ask Congress, in his special address, to fund the work needed to accomplish the lunar mission, to be termed 'Project Apollo'. Congress, sharing the president's view that pre-eminence in space was key to the effective prosecution of the Cold War, was happy to say "yes".

President Kennedy believed that a successful moon landing would confirm the superiority of the US capitalist system

Meeting point John Houbolt demonstrates his space rendezvous concept for lunar landings, July 1962

T-MINUS 7 YEARS, 5 DAYS

Nasa reveals how it will get to the moon (and back)

What had not been fully worked out, at the time of Kennedy's announcement, was how to actually accomplish the task of a manned lunar landing. Over the following months, Nasa officials assumed that two or more of von Braun's large Saturn boosters would be required to haul the entire Apollo spacecraft system with its three-man crew into orbit, along with sufficient fuel to send it on to the moon, lift it back up off the lunar surface and return it to Earth.

But then there was a change of tack. On 11 July 1962, Nasa announced that it had opted for a different method: in lunar orbit, a lightweight lander containing a two-man crew would detach from the main command module and travel down to the surface; landing accomplished, it would then ascend to 'rendezvous' with the command module, which would carry the whole crew home.

The use of a separate lunar module involved certain risks – if rendezvous failed, the two astronauts inside would be stranded, drifting around the moon. But it also offered such substantial fuel savings that the complete Apollo apparatus could be launched atop a single Saturn V. The adoption of the lunar-orbit rendezvous method afforded Apollo's engineers an early conceptual focus that their Soviet counterparts lacked. It was only in 1964 that the Kremlin approved the objective of a manned lunar programme; what's more, the limited budget it allocated to the programme was divided between Korolev, who was developing a new, large N1 booster to facilitate landing missions to the moon and Mars, and his rival, Vladimir Chelomey, who had proposed an alternative circumlunar voyage using a converted intercontinental ballistic missile (ICBM).

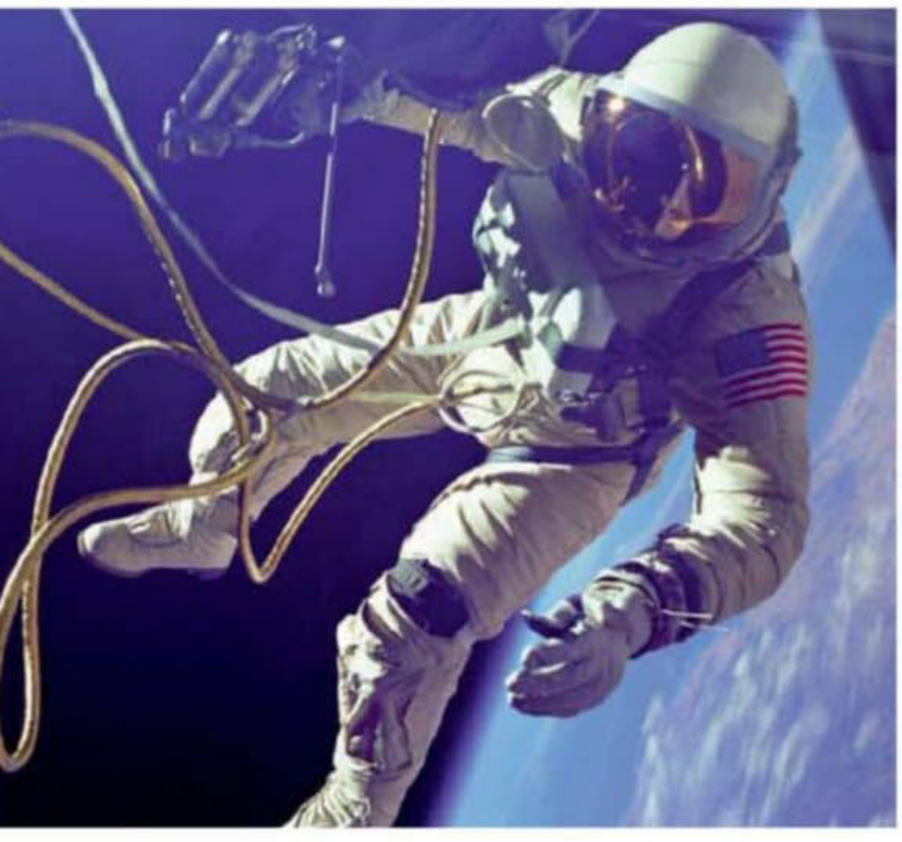
T-MINUS 2 YEARS, 5 MONTHS, 19 DAYS

Death stalks the space race

By the end of 1966, America had leapfrogged the USSR to take a clear lead in the race to the moon. Nasa had just successfully completed a series of 10 two-man missions – the Gemini programme – using a Titan ICBM, which had offered its astronauts vital experience of long-duration spaceflight, rendezvous and excursions outside the spacecraft.

Unmanned launches of von Braun's Saturn rockets had generally gone well. The first crewed Apollo mission, intended to test the command module in Earth orbit, was scheduled for February 1967. But on 27 January, a fire broke out within the module during a systems test, with the crew sealed inside. All three astronauts died. The Apollo programme was placed on hold. The investigation into the fire prompted a redesign of the command module, while Nasa managers sought to refocus the attention of their own staff and the agency's contractors on quality control and safety over the drive – at all costs – to beat the Soviets to the moon.

Meanwhile, the Soviet lunar programme itself continued to stutter. In January 1966, during a hospital operation, Korolev suffered a haemorrhage and died. In April 1967, a mission to test the Soyuz command module, a core component of Soviet plans for the moon landing and other space projects, ended in tragedy when the module's descent parachute failed to open upon re-entry. The module crashed into the ground, killing the cosmonaut inside.



Tragic fate Edward White becomes the first American to walk in space in 1965. He was killed two years later when Apollo 1 caught fire

Iconic image Earth rises above the lunar horizon in a photograph taken from Apollo 8, December 1968. By now, the US was way out in front in the race to the moon

T-MINUS 6 MONTHS, 22 DAYS

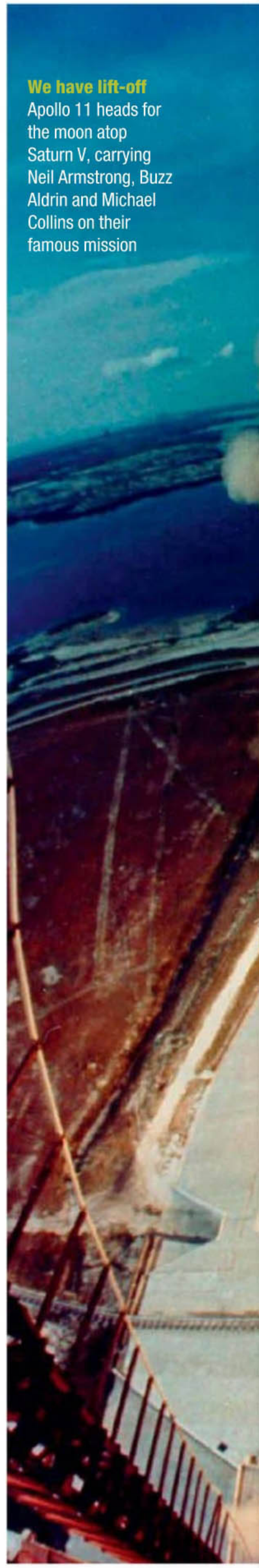
Humanity gets its first view of Earth

"We are now approaching lunar sunrise, and for all the people back on Earth, the crew of Apollo 8 has a message that we would like to send to you." It was Christmas Eve 1968, and an Apollo command module was in orbit around the moon. The manned Apollo programme had resumed two months previously, when the crew of Apollo 7 fully flight-tested the command module by circling the Earth 163 times.

Apollo 8, however, represented an achievement of a different order: its astronauts were the first to be launched atop the Saturn V and the first to voyage to the vicinity of the moon. While there, they captured an iconic image of the Earth rising above the lunar surface and delivered a live broadcast to a huge radio and television audience, concluding with a reading of the Bible's account of the creation of the cosmos.

Although the complete Apollo system, including the lunar module, would not be certified for a landing mission until after the flights of Apollo 9 (in March) and Apollo 10 (in May), Apollo 8 signalled to the world that Nasa was back on track to meet the deadline set by President Kennedy back in 1961.

Conscious that their own N1 booster had yet to be launched successfully, Soviet spokesmen started to downplay the significance of the lunar landing goal. After Apollo 8, it was evident that, barring some major new disaster in the American programme, the Americans would beat their Soviet rivals to the moon.



We have lift-off Apollo 11 heads for the moon atop Saturn V, carrying Neil Armstrong, Buzz Aldrin and Michael Collins on their famous mission

BRIDGEMAN/GETTY IMAGES/ALAMY

"The lift-off seemed to partake more of a miracle than a mechanical phenomenon," wrote the novelist Norman Mailer

T-MINUS 8.9 SECONDS

Saturn V's engines begin to accelerate to full thrust

Norman Mailer was watching from the Kennedy Space Center Press Site three-and-a-half miles away as von Braun's Saturn V engines ignited and began to accelerate to full thrust. A few seconds later, the hold-down arms retracted and the massive rocket, the Apollo 11 spacecraft at its head, lifted slowly from the launchpad. The noise from its engines only reached the press site six seconds after launch. "Therefore," Mailer wrote, "the lift-off itself seemed to partake more of a miracle than a mechanical phenomenon, as if all of huge Saturn itself had begun silently to levitate and was then pursued by flames."

Afterwards, Mailer did not know how he felt. The men who had made Apollo did not share his politics and belonged to a conformist culture that he habitually disdained, but the launch they had conjured had nevertheless been a wondrous thing. "A ship of flames was on its way to the moon."

KENDRICK OLIVER is professor of American history at the University of Southampton.

THE TRANSPORT REVOLUTION

FROM HYPER-FAST TRAINS TO FLYING TAXIS, WE LOOK AT THE VEHICLES THAT ARE SET TO TRANSFORM HOW WE GET AROUND

Words: **ANDY RIDGWAY**

GOING LOOPY

↑ HYPERLOOP

There's been a lot of hype, but this sleek capsule built by California-based Hyperloop Transportation Technologies (HyperloopTT) shows that super-fast hyperloop travel is on its way, promising speeds of up to 1,223km/h (760mph) for city-to-city travel – faster than a commercial jet.

The full-scale, 30m capsule is being prepared for testing at HyperloopTT's 320m test track in Toulouse, France. If all goes well, the first passenger trials will take place next year, with the aim of having the first commercial system up and running by 2022, probably in Abu Dhabi.

Hyperloop capsules will reach their high speeds by gliding through sealed tubes from which most of the air has been removed by vacuum pumps, reducing drag. The capsules are levitated just above the track using magnets, reducing friction, and powered by a 'linear induction motor' that also uses magnetic forces.

The Hyperloop has been hailed as the first new mode of transportation in over 100 years, but there are still significant technological challenges to overcome, such as the complexity of maintaining the vacuum in the tubes over such long distances. Nevertheless, plenty of engineering brainpower is being invested, and companies including Virgin Hyperloop One, Hardt Hyperloop and TransPod are all working on their own systems.

HELLO VERA

↓ VOLVO VERA TRUCK

Lorries of the future may be barely recognisable from the ones pounding up and down motorways today. Say hello to Volvo's self-driving truck Vera, which does away with a driver's cab entirely.

In spite of its sleek, futuristic looks, Vera is not just a concept vehicle. Volvo is working with shipping and logistics company DFDS on a system that would use these driverless trucks to haul goods five kilometres from a transport hub to a port terminal in Gothenberg, Sweden – a route that takes in public roads. It's expected to be up and running within five years. Vera navigates using onboard cameras and a system that builds up a 3D laser map of its surroundings. There's also a safety backup, enabling staff in the control centre to take control remotely if needs be.

"Driverless lorries are most likely to be used where you have a high volume of short, repetitive journeys," says Mikael Karlsson, vice president of autonomous solutions at Volvo Trucks. Longer, more complex journeys will still be left in the hands of human drivers – at least for now.

GETTY IMAGES, JEREMY BIDON

FLOATING INTO THE FUTURE

← ENERGY OBSERVER SHIP

It was once a racing catamaran that won trophies and broke world records, but this boat – now called ‘Energy Observer’ – has taken on a new life as a floating laboratory aimed at revolutionising how we power ships.

Its traditional sails have been replaced by a skin of cutting-edge solar panels that power electric motors. It’s also the first ship to feature a hydrogen power generation system, using an electrolyser to split seawater into hydrogen and oxygen. The hydrogen is compressed and stored in tanks until it’s needed, when a fuel cell converts the hydrogen back into water, releasing electrical energy in the process. Meanwhile, two rigid, 12-metre-tall ‘Oceanwings’ sit on either side of the 30-metre-long craft, providing extra wind propulsion when required.

Energy Observer is currently two years into a six-year world tour, the goal of which is to demonstrate how this green energy production and propulsion technology could be harnessed in future ships – important given that 90 per cent of global trade is transported by the sea.

↑ CONTROL CENTRE

It’s from this cockpit that the crew steer Energy Observer and communicate with the outside world. Doors from the cockpit lead to the brains of the boat: the Energy Management System. Because different energy sources ebb and flow as conditions at sea change, the system is routinely switched between power sources to keep the craft running. For example, when solar power runs out at night, the hydrogen fuel cells are brought into action to convert the stored hydrogen into electricity.

YELLOW CAB

↑ CORA AIR TAXI

How often have you been sat in traffic, wishing you could just fly above it all? Well, Cora, a flying electric taxi, could be the answer.

It's piloted autonomously, which means that pretty much anyone could fly in it without training. Twelve lift fans get Cora off the ground vertically, before it flies like an aircraft using a single propeller at the rear. This means it could take off from a car park or the roof of an office building, carrying its two passengers home – as long as they live within its 100-kilometre range.

Kitty Hawk Corporation, the California-based company behind Cora, envisages that you would book a trip aboard much like you do with an airline or a ride share. But how soon we'll be able to do that is unclear – Cora still needs regulatory approval before it can operate commercially. There's good reason to believe it will happen, though: Kitty Hawk is funded by billionaire Google co-founder Larry Page and is working with both Boeing and Air New Zealand.

TELEPATHIC TRANSPORT

→ MERCEDES-BENZ FUTURE BUS

Bus rides are set to get a 21st-Century makeover. The Mercedes-Benz Future Bus is fitted with a GPS system, cameras and radar, so it can drive itself along its route, stopping to pick up passengers along the way. All the driver needs to do is watch out for hazards, intervening with a dab on the brake or a touch of the steering wheel.

Future Bus has other tricks up its sleeve, too. Perhaps the most impressive is its ability to 'talk' with traffic lights using its 'vehicle to infrastructure' system, so it can find out when they are about to change, gently slowing down if necessary. All of this technology is designed to provide passengers with a smoother service and relieve the workload on drivers.

Although Future Bus was successfully tested on a 20-kilometre route from Schiphol Airport in the Netherlands, it will still require several million kilometres' more testing before it can go into production. But Mercedes owner Daimler says that these kinds of technologies will be increasingly built into its buses in order to assist drivers.

by **ANDY RIDGWAY**
(@AndyRidgway1)
Andy is a lecturer and science writer based in Bristol.

THE MYSTERIES OF SLEEP

The clocks have gone back, leaving many of us reaching for the coffee as our body clocks struggle to realign. But there are many aspects of sleep that still leave experts scratching their heads...

Words **Ginny Smith**
Illustrations **Victor Soma**

HOW DID SLEEP EVOLVE?

Imagine two animals, of the same species, living in a dangerous environment where food is scarce. Animal A spends the day searching for food and mates, while avoiding predators. When night falls, she rests, remaining still but watchful until daybreak. Animal B follows the same pattern, but while resting, she becomes unconscious, and almost entirely unaware of the world around her. Which animal do you think would have the best chance of survival?

If you answered A, congratulations! You have discovered the paradox that surrounds the evolution of sleep.

Debate rages over why all but the simplest of animals have evolved to spend so much of their lives unconscious. One idea is that sleep conserves energy, but studies have shown we burn almost as many calories snoozing as we do when we are awake, so that seems unlikely. Evolution tells us that if something is a risk, as sleep is, then there must be a benefit outweighing that risk. So what is the benefit that sleep brings?

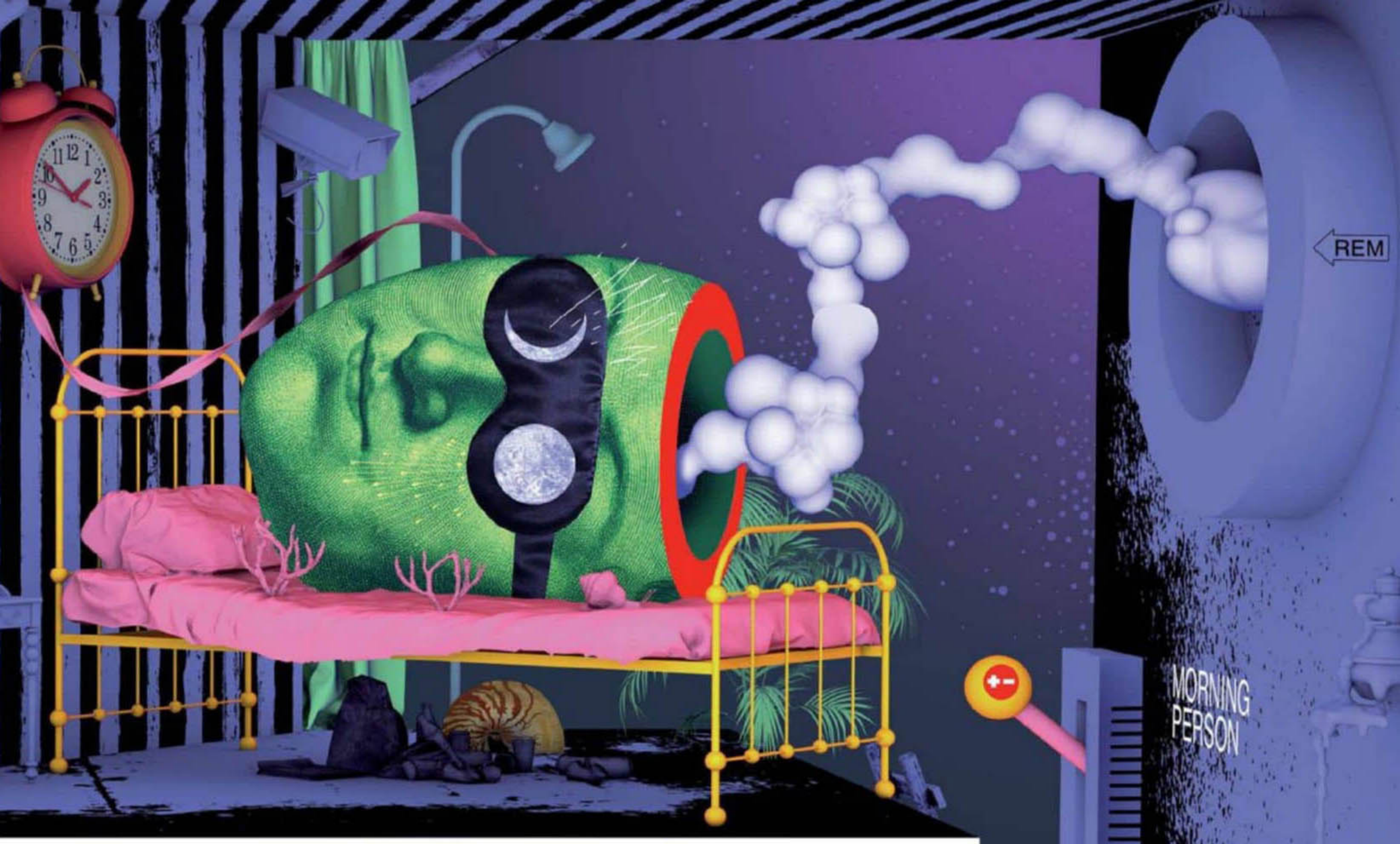
Decades of research have linked sleep with memory processing, emotional stability and even the brain's 'rinse cycle'. But what we don't know is whether we sleep because these processes need to happen, or whether we evolved to carry them out while sleeping because it's more efficient than doing them during the day.

What's clear is that the Earth has a rhythm, a cycle of light and dark, and almost all animals have their own circadian rhythms, or body clocks. Most set them based on light levels, but even blind cave fish in Mexico, which have lived underground for millennia, have body clocks.

Dr Andy Beale, a postdoctoral scientist at the University of Cambridge, studies these animals. He says that every cell in the body has a rhythm, so it is vital for organisms to have a way to sync these, even if they don't use the Sun to do so. So perhaps sleep arose as a way to group the body's processes, ensuring that cells all carried out their maintenance simultaneously, rather than in conflict with one other.

Unfortunately, however, evolutionary theories are hard to prove, so for the moment we are left wondering how sleep emerged in the first place.

> "SLEEP IS A RISK, SO THERE MUST BE A BENEFIT THAT OUTWEIGHS THAT RISK"



WHY IS SLEEP DEPRIVATION DANGEROUS?

A handful of families appear cursed. Around middle age, many of the members develop strange symptoms: sweating, tremors and – most troublingly – complete and devastating insomnia. These are signs of an extremely rare disease called Fatal Familial Insomnia (FFI).

A genetic mutation in FFI sufferers causes misshapen proteins to build up in the brain, damaging the thalamus – the control switch between wake and sleep. Without this brain area, sleep is impossible. And without sleep, sufferers fall into a kind of waking coma. From the onset of their symptoms, they rarely live longer than a year.

While there are many theories about why we need sleep, how sleep deprivation can kill you is still a mystery. But a recent study may have found a clue. Researchers discovered that cells in the brains of sleeping mice shrink, allowing cerebrospinal fluid – the colourless liquid that circulates in the brain and spinal cord – to flow more easily, sweeping away debris that builds up around active cells during the day. This is carried to lymph glands and flushed out of the body. So perhaps sleep is vital because without it, these toxic by-products build up in the brain.

The idea that sleep cleans up our brains is hard to test, and studying people with FFI can't give us all the answers. We can't even know for sure if it's the sleep deprivation itself, or the brain damage that causes it, that kills sufferers. Animal studies provide another clue. Experiments have shown that sleep-deprived rats die within a month, but again, proving lack of sleep killed them is tricky – it could instead be the stress of being repeatedly woken.

The longest recorded period of wakefulness in a healthy human is 11 days, by student Randy Gardner. By the end, he suffered declining cognitive functions, mood swings and even hallucinations. Despite this, he recovered within a day or two, and didn't experience any long-term health problems. But he might not have been fully awake for all 264 hours. Research has shown that sleep-deprived humans experience 'microsleeps', of which they are unaware. These can last for just microseconds, and can even happen in one part of the brain while the person is 'awake' and functioning.

So can sleep deprivation kill a healthy person? Or will the brain fight back to protect itself? The answer is, we just don't know…

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WHY DO WE DREAM?

Dreaming has fascinated scientists and philosophers for millennia, and still baffles us today. Originally, it was thought that dreaming only occurred during REM (rapid eye movement) sleep, and it does seem this is where most complex dreams happen. But you can dream during other stages as well – these dreams tend to be more like snapshots, associated with strong emotions. But why do we do it?

One idea is that dreaming helps with sleep's memory-processing function. After learning a maze, the brains of sleeping rats activate the same neurons they used during the day, as if they were practising or reliving the maze. We think the same happens in humans: in fact taking a nap, particularly if it includes REM sleep, can improve problem-solving abilities. During sleep, our brains sort through information taken in during the day, decide what to store, and make connections between new facts and memories. It is possible that dreams help with this, which might explain why dreaming about recent experiences is common, but also why dreams often involve weird links that your waking brain would never make.

Another theory is that dreams help with emotional processing. When we first store a memory, the associated emotions are vivid, but over time they lessen. This is why losses and traumas become more bearable with time (unless this process is disrupted, as in PTSD). Perhaps dreaming helps this dissociation,by allowing memories to be processed and removing some emotional associations.

Alternatively, dreams may provide a safe way of testing the brain's reactions to negative or threatening events, which might be why dreams are often emotional. By practising running away from a dream monster, you know what to do if it happens in real life!

Or it might be sleep that is important, and dreams are just the by-product of a brain starved of external input – like a screensaver on your computer. Interestingly, some drugs suppress REM sleep, and patients report fewer dreams, but don't seem to experience any negative effects… so the mystery of dreaming lives on.

IS BEING A NIGHT OWL BAD FOR YOUR HEALTH?

Another mystery is why some people bounce out of bed at 7am, ready to face the day, while others repeatedly hit the snooze button before stumbling blearily towards the coffee pot.

This is the question being studied by Dr Sam Jones, a sleep researcher at the University of Exeter. By investigating the genetics and behaviour of around 700,000 people, he and his team discovered more than 300 genes that seem to play a role in making you a morning or evening person. But your disposition isn't set in stone. Previous research suggested only about 25 per cent of whether we are early-rising 'larks' or evening 'owls' is down to our genes.

"It looks like it's predominantly habitual and environmental," Jones says. "It's not genetics that determines your 'chronotype' to a great extent, but your habits, your lifestyle, what you eat, how much stimulation you get in the evening, etc. It seems to be rather a modifiable thing."

As well as understanding the chronotypes themselves, Jones investigates how they affect people's lives, and early research provides tantalising hints. For example, evening people seem to be more likely to develop schizophrenia later in life. And careful analysis shows this isn't just down to genes having multiple effects – something about living the owl lifestyle puts you at greater risk of the illness. On average, owls also have lower wellbeing and are more likely to develop depression. We don't know for sure why this is, but Jones believes it probably isn't being an owl itself that is damaging – it is trying to fit in to a society that's set up for larks. This means owls are experiencing constant jet lag, which may put their bodies and brains under stress. Because of this, some people are promoting the idea of a more flexible working day. But until further research is carried out, we don't know whether this will actually improve the lives of owls, or make them less likely to suffer health problems.

WHY DO SOME PEOPLE NEED LESS SLEEP?

We've all met them. People who do more in a day than seems humanly possible. When asked their secret they smugly say, "I only sleep for four hours a night – it's all I need," with a superior look on their face. But do they really only need half the sleep most of us do? Or are they storing up problems for later life?

In 2009, researchers led by Prof Ying-Hui Fu from the University of California, San Francisco, found that carriers of a particular gene slept for two hours less than non-carriers, on average. But then they discovered a family with three generations of short sleepers who didn't carry this gene. By sequencing their genomes, the team discovered another mutation that appeared to be linked with short sleep. And mice bred with this same genetic change were easier to wake. These natural short sleepers don't seem to suffer from the health problems normally associated with getting so little sleep.

But a note of caution here. The new study investigated a single family, and a team led by sleep researcher Dr Sam Jones at the University of Exeter has come across the same mutation but found no link to sleep length. Jones and his team are writing a paper to challenge Fu's results, although Jones agrees that natural short sleepers do exist.

"It does look like some people might get away with less sleep, simply because of genetic factors which predispose to shorter or longer sleep," he says. "I think there's probably a limit, maybe somewhere between six-and-a-half to eight hours, but any more than that, I would be doubtful."

Again, genetic factors are likely to play only a small role, and environment is vital too. It may be that short sleepers are actually efficient sleepers. Most people don't spend all night in deep, restorative sleep. Racing thoughts delay dropping off, or you might be awoken by noise, light or your bladder. Eating late or drinking alcohol before bed can reduce sleep quality, and staring at screens might have an impact too. Perhaps these people aren't amazing in their ability to sleep less, but in their ability to sleep well.

This doesn't make them any less worth studying, however. In fact, it might make them more important. We don't know why some people fall asleep the moment their head hits the pillow, while others spend hours tossing and turning, or why some can sleep anywhere, anytime, while others need pitch-black perfection to get a moment's shuteye. Perhaps learning more about these short, efficient sleepers could help us all improve the quality of the sleep we get each night.

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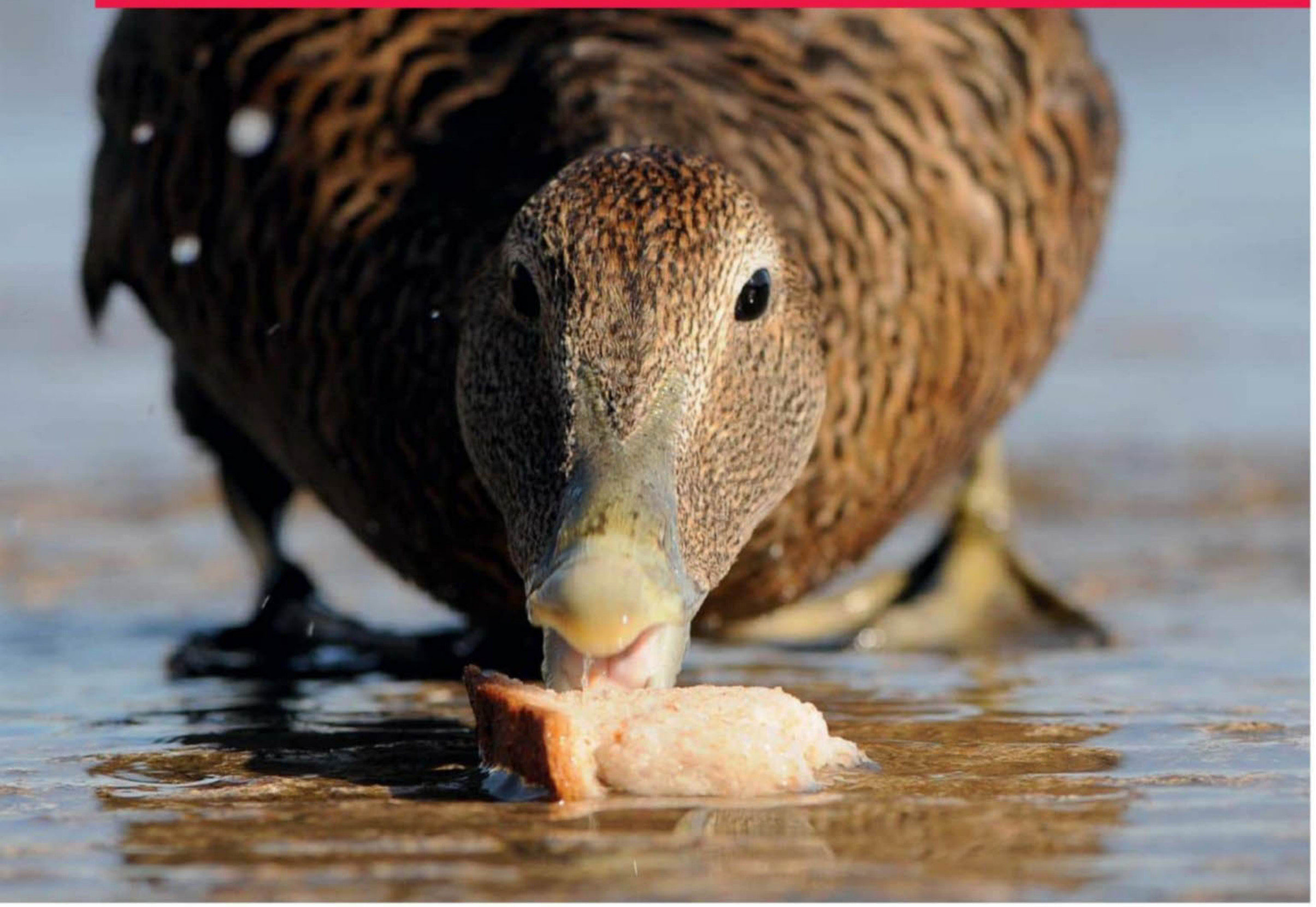
by **Ginny Smith** *(@GinnyFBSmith)*
Ginny is a freelance science writer and presenter, with a background in psychology and neuroscience. She presents the British Psychological Society's PsychCrunch podcast.

REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Feeding ducks | Heading footballs | Eco-anxiety



ANALYSIS

FEEDING WILDLIFE: CAN IT DO MORE HARM THAN GOOD?

In October, a handmade sign went viral. It claimed that ducks were starving because people were no longer giving them bread, due to concerns that it could make them ill. But is feeding ducks and other birds a harmless pastime, or should we leave them to fend for themselves?

"Just like us, birds need a varied diet to stay healthy"

WHY ARE PEOPLE WORRIED ABOUT FEEDING BIRDS?

Throwing handfuls of bread to ducks is a childhood rite of passage that many, myself included, have long seen as harmless enough. But in recent years, some scientists have suggested that bread might not do birds' digestive systems any good. Organisations such as the UK's Canal and River Trust have also recently discouraged it. They say that as uneaten food decays, the water quality deteriorates and algal blooms can occur. Plus, by encouraging ducks to congregate in one place, the build-up of droppings and outbreaks of disease such as botulism may become a problem too. Meanwhile, many cities have signs telling us not to feed pigeons and gulls, which are deemed a 'nuisance' due to the mess they make, and because scattering bread inevitably attracts rats and mice.

It seems that the public has heeded these warnings, and that fewer of us now feed birds this way. In October, a homemade sign went up in a Derbyshire park claiming that the local mallards and other quackers were dying of starvation, and imploring visitors to carry on feeding them as before. When online posts about the notice went viral, feathers flew as ornithologists and conservationists debated the merits of doling out bread to wildfowl. So who is right?

LEFT This handmade sign appeared in a park in Derbyshire, sparking a viral debate about whether it was okay to feed bread to ducks

HOW DOES BREAD AFFECT BIRDS?

Paul Stancliffe of the British Trust for Ornithology (BTO) points out that there's scant scientific evidence for bread harming birds, adding that, as little research has been done, it could even turn out to be beneficial. "We just don't know," he says. So although bread is a heavily processed 'unnatural' foodstuff intended for humans, that alone may be insufficient grounds for not feeding it to birds.

In the 1980s, the Wildfowl & Wetlands Trust (WWT) carried out a comparative study of different flocks of mute swans, and the birds that guzzled the most bread had weaker muscles, implying that a bread-heavy diet might be the cause. "Our official line is that bread is okay for ducks, geese and swans, but only in moderation," says WWT's Peter Morris. "However, this advice comes with several other caveats." The first is that it's best offered in winter, when there is less plant and insect food around. In spring and summer, too much artificial food may not be a good idea, since young wildfowl have to learn how to fend for themselves and natural food will contain a wider range of nutrients to help them grow.

"Just like us, birds need a varied diet to stay healthy," says a spokesperson for the Royal Society for the Protection of Birds (RSPB). "Although ducks, geese and swans can digest all types of bread, too much can leave them feeling full without giving them all of the important vitamins, minerals and nutrients they need."

When bird feeding first became popular in the UK in the 19th Century, some Victorians preached tough love, arguing that such handouts would only make our feathered friends lazy and dependent on welfare. Such moralising sounds old-fashioned nowadays, but may have a grain of truth. Morris says that there is a theory that wildfowl can get 'hooked' on easy meals, losing interest in other types of food. Another danger, he says, is that birds fed regularly end up tame and habituated to humans, placing themselves at greater risk of predation. ▶

GETTY IMAGES X2

IS THERE A WAY TO SAFELY FEED THEM?

Both the RSPB and WWT point out that, even if everyone feeds bread in only small amounts, that still adds up to quite a lot. We have no way of knowing what else a duck, goose or swan at the local park has been eating. So what can we safely give these birds instead? "We encourage people to use things like sweetcorn, porridge oats, crumbled biscuits and defrosted frozen peas, as well as bird seed," the RSPB spokesperson says. The WWT agrees, and additionally recommends chopped green vegetables.

WHAT ABOUT THE BIRDS IN MY GARDEN?

One thing is certain: feeding birds is now big business, with UK consumers spending between £150m and £200m a year on bird food. The vast majority goes on seeds, peanuts and fat balls for garden birdfeeders, rather than birdseed for ducks and other wildfowl. "We are a nation of gardeners who have become a nation of garden-bird lovers," wrote naturalist Stephen Moss in his 2011 book Birds Britannia. This national obsession has had a dramatic effect on bird numbers, boosting those of species such as the goldfinch and long-tailed tit. It has even influenced evolution itself. Some populations of an insectivorous warbler called the blackcap have started to visit gardens in southern Britain in winter, attracted by the food on offer. They have even begun evolving a longer, narrower bill better suited to feeding on sunflower seeds.

Whether in a garden or park, feeding birds is for many of us our first memory of interacting with nature in the wild. As the RSPB says: "This experience can be an important step towards understanding our natural world and appreciating that we all play a role in caring for it. And, as we all become more concerned about becoming increasingly disconnected with our natural world, it is important we encourage people to feed the birds and enjoy the wildlife around them."

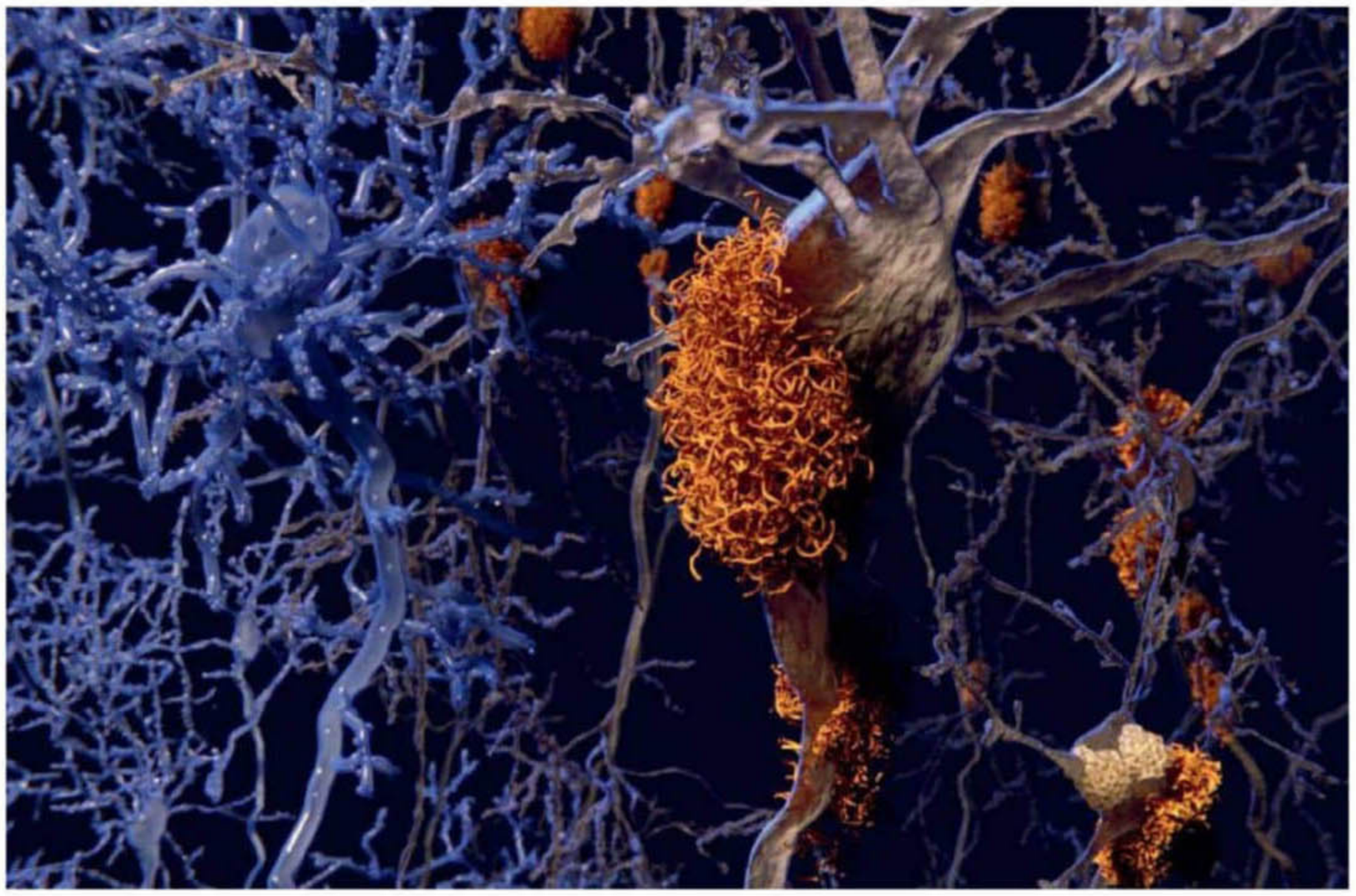
by **BEN HOARE** *(@benhoare5)*
Ben is a science and nature journalist, and the features editor of BBC Wildlife magazine.

REVIEW

HEADING AND DEMENTIA: ARE FOOTBALLERS PUTTING THEMSELVES AT RISK?

A new study has revealed that footballers are more likely to die of degenerative brain disease than non-players. Former pro footballers have called for a ban on heading, and the Scottish Football Association announced last month they were considering a ban for children under 12. But what does the research say?

Back in 1970, Jeff Astle played for England at the FIFA World Cup. In 2002, after suffering with a dementia-type brain disease for a number of years, he died at his daughter's home, aged just 59.



Later analysis in 2014 of Astle's brain revealed he'd suffered from chronic traumatic encephalopathy (CTE), a brain disease often seen in boxers. The neurosurgeon who performed the examination, Dr Willie Stewart, concluded that much like powerful blows to boxers' heads, Astle's repeated heading of the ball had caused his CTE.

Now, Stewart has been part of a team that has revealed that former professional footballers are five times more likely to have a dementia-type illness, and three and a half times more likely to die from it than members of the general public.

Since the findings were published in October, former players and football fans have called for a change in the rules around head injuries and heading the ball. At time of writing, the Scottish Football Association is considering a ban on children under 12 heading the ball. But does the science support this?

Stewart's study looked at data from over 7,000 former professional players and 23,000 controls from the general population, matched on the basis of sex, age, and socioeconomic class. The findings were based on mortality rates and prescriptions of drugs for dementia symptoms. "Out of those 1,180 footballers in our study who died, 222 had died of neurodegenerative disease-related cause. Two hundred and twenty-eight members out of the control group [of 23,000 people] died of a neurodegenerative disease," explains Stewart. "Considering there had been three times as many people in the control group, we expected to see three times the number of deaths."

"We don't know how many concussions or head impacts a player had. It's just not documented"

The study set out to determine whether professional footballers are at greater risk of getting and dying from dementia. But within this, there's another factor at play: was heading the ball or collisions between players to blame?

"That's very difficult to determine with the data we had," says Stewart. "We don't know how many concussions or head impacts a player had. It's just not documented."

To attempt to tease out a conclusion from the data, the team compared outfield players to goalkeepers.

GETTY IMAGES X2

"Although we saw a slightly lower mortality in goalkeepers than in outfield players, statistically we just couldn't prove it wasn't chance," says Stewart. "But when we looked at prescriptions, goalkeepers were less than half as likely to have been prescribed a dementia drug, which would imply that goalkeepers' rates of dementia were about half that of outfield players."

Currently, the research that's looked at the pathology of dementia in footballers and other sports suggests to Stewart that exposure to head injury is the most likely risk factor. There have been suggestions that the heightened numbers could be related to the amount of drugs or alcohol that professional players have been exposed to.

"These arguments don't stack up," argues Stewart. "We're talking about something that is a common agent to boxers, American footballers, rugby players, footballers, wrestlers, victims of domestic violence, road traffic accidents… there isn't one common risk factor that you can draw through all of these other than head injury."

"In rugby, for instance, if there is a suspected head injury the player goes off and is assessed for up to 10 minutes at the side of the park. That doesn't happen in football"

THE BRAIN AFTER HEADING

So how exactly does head impact and concussion lead to dementia? Dr Magdalena Ietswaart, senior lecturer in psychology at the University of Stirling, has spent the last few years finding out.

In 2016, Ietswaart and her team discovered that there are detectable changes in the brain after heading the ball just 20 times.

"We know that there is a link between traumatic brain damage, such as concussion, and long-term damage," says Ietswaart.

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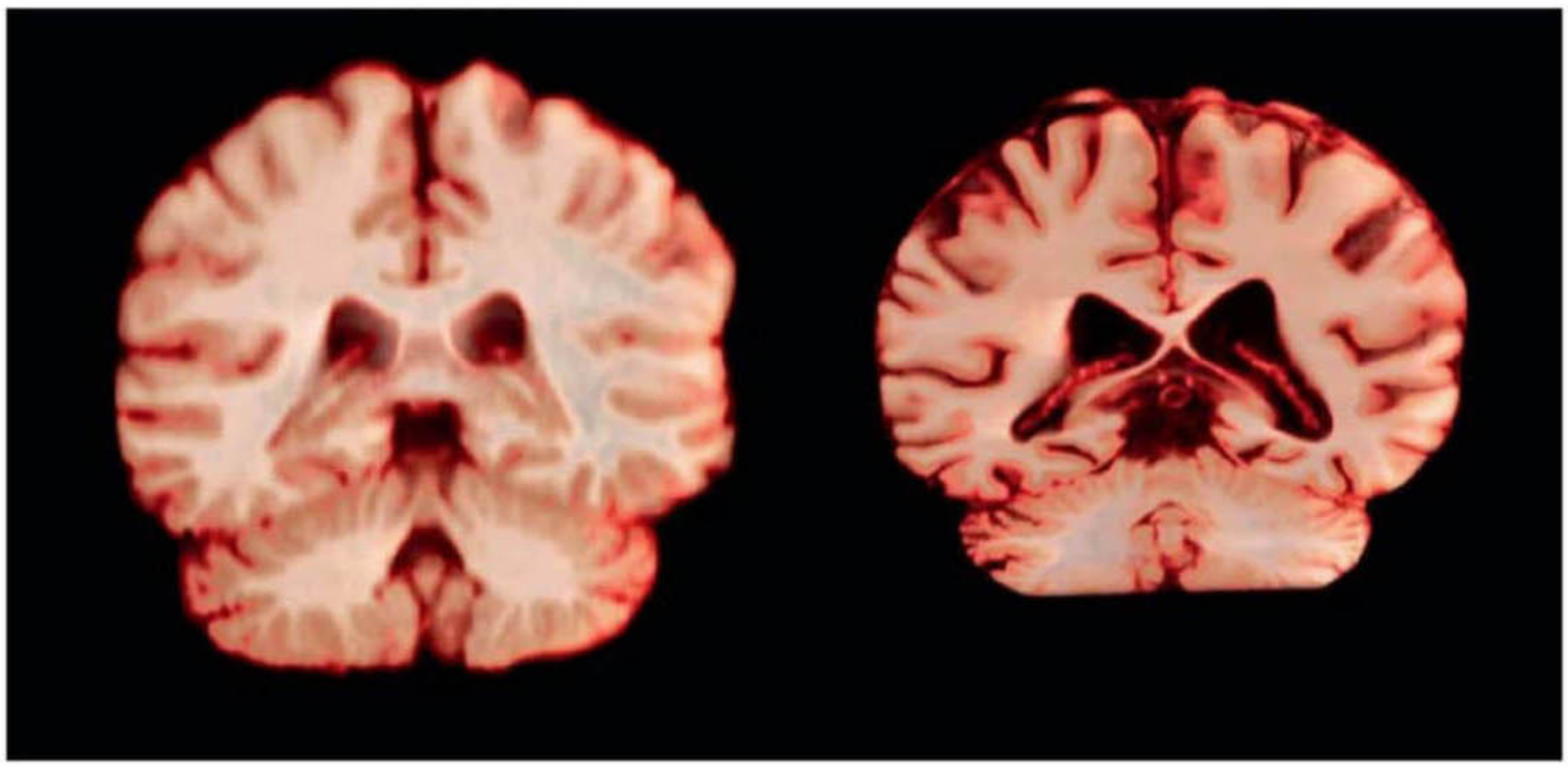


LEFT Just 20 headers over the course of a football practice had a temporary impact on the brain

ABOVE Healthy brain (left) compared to a brain with Alzheimer's. The Alzheimer's brain is smaller, due to the degeneration of nerve cells

To measure how brain chemistry is affected by heading, Ietswaart and her team looked at how long it took for a signal to travel from the brain to, say, a muscle in the leg. The team found that the communication between the brain and muscle slowed after just one session of practice headers.

"We also found effects on memory after heading the ball, which is interesting," says Ietswaart. Scientists know that a healthy brain chemistry is needed for processes of plasticity (the ability of the brain to change and adapt), which is essential for things like learning and memory.

The participants' inhibited brain-to-muscle communication levels returned to normal after 24 hours, but Ietswaart warns that the long-term consequences remain unknown.

The study faced criticism from some quarters. "People have said to me that footballers head the ball [during a game] much less now, but there is no science to say that less heading is then going to be fine." says Ietswaart. "Similarly, people said that it was 'extreme' that we had people heading the ball 20 times. But that was the number of times that local football players would practice heading the ball during training. And there's nothing to say that if you just head the ball 10 times, everything is fine."

One concern that both Ietswaart and Stewart share is when people blame the old, leather-style footballs of bygone days, they'll think the new plastic ball is safer. In fact, Ietswaart's 2016 study was done with the modern ball.

"We certainly have no evidence whatsoever to say that anything that has happened in the game in the last 10 years, 20 years, or longer, will have changed the risk of neurodegenerative disease for footballers," says Stewart. "My concern would be that if we assume – with no evidence or data to back that up – that technology in the modern game has changed and that there's no risk any more, we may be putting our footballers at risk of carrying on with a high chance of getting the disease."

According to Stewart, there needs to be better management of head injuries in the modern game. "In that regard, football is woefully inadequate. If you look at rugby, for instance, if there is a suspected head injury the player goes off and is assessed for up to 10 minutes at the side of the park. That doesn't happen in football. There might be a passing few minutes allowed on-field for an assessment, but it's nothing like adequate. It's the same injury. But it's being managed in quite different ways."

BAN OR NO BAN?

With regards to a ban, both researchers are reluctant to call it a decision informed by science. "The truth is we don't know whether a developing brain is more at risk," says Ietswaart. "We do now know that the brain is still under construction until the age of 23. Particularly between the ages of 14 and 23, the frontal lobes in the brain get a complete rewiring. Nobody wants to know that a player in their prime still has a developing brain."

"We've been doing some work looking across youth groups, and it turns out that younger kids – under 14s – barely, if ever, head the ball during a match," comments Stewart. "Are we training kids during the week by repetitively hitting the ball off the head, for that one rare occasion where they might head the ball during a match? I don't think they're losing anything from the game to say children will not head the ball any more. But going further than that into adults and professionals… we'll need to get some science and take that forward before making decisions on heading."

by **AMY BARRETT**
Amy is the editorial assistant at BBC Science Focus.

COMMENT

ECO-ANXIETY: HOW DOES THE HUMAN MIND DEAL WITH EXISTENTIAL THREATS?

From plastic pollution to climate change, there's a lot of environmental news that can cause existential angst. Is it possible to think helpfully about these issues or are they too big for our minds to cope with?

Faced with a big problem, it's normal to try to think our way out of it. While sometimes problem-solving can be helpful, it can tip into repetitive worrying over things that we can't solve in our own heads. A similarly repetitive thinking style, but one focused on the past, is ruminating – chewing over and over things that have already happened. This can be problematic, as it's a thinking style linked with depression. Another way of coping with existential threats is to avoid thinking about them altogether because they feel so massive. But this can mean that they seem even more overwhelming when we do eventually think about them.

Brain scan studies suggest there is a particular brain region involved in the processing of existential threats: the anterior cingulate cortex (ACC). This area is also involved in our behavioural inhibition system (BIS) – a system that encourages us to stop doing, and pay attention to something. Researchers have suggested this brain area is related to common behavioural reactions to existential threats: that feeling of being paralysed to act in the face of something looming, and the tendency to consume a lot of information about the threat without changing our behaviour.

ECO-ANXIETY

'Eco-anxiety' is a term that's been used by the American Psychological Association (APA) in a report about the effects of climate change on mental health, but it's not an official diagnosis. Psychologically speaking, anxiety about anything arises from how we perceive a threat, and so 'eco-anxiety' makes sense, even though the threat it relates to is real. Since it's not a specific mental health problem, eco-anxiety can't be 'treated' as such. However, if worries about climate change are creating significant distress, there are things that can help. Often it's a case of doing the opposite of what our anxious state of mind might be encouraging us to do, instead of letting our worry thoughts paralyse us. For example:

"'Eco-anxiety' is a term that's been used in a report about the effects of climate change on mental health"

ALAMY

→ Working out what things we can control and taking step-by-step action on those things can increase our sense of agency. For example, thinking about our recycling habits, energy consumption, travel and diet to minimise our environmental impact.

→ Balancing worst-case scenario news with other information and activities, like spending time in nature and with others.

→ Staying connected with people we love and caring communities, so we feel less alone with our worries.

→ Paying attention to the effects of how we are thinking about the problem so we can change this if it's unhelpful.

When we're really scared about something, it's common for our sleep, diet and exercise to suffer. Making sure we're eating healthily, and that we have a regular sleep and exercise routine, can make a difference to how overwhelmed we feel. Though this might feel selfish, we won't be able to do much about climate change if we don't take care of ourselves.

It's important to recognise if anxious or depressed thoughts, feelings and behaviours have become an overly large feature of your life. There are evidence-based treatments for anxiety and depression if you think you might be experiencing them, and it's worth reaching out to seek help. There is also information on how you can reduce your environmental impact, which may help you to feel less helpless.

by **DR LUCY MADDOX**
Lucy is a consultant clinical psychologist and writer.

Q&A

ALL YOUR QUESTIONS ANSWERED

THIS ISSUE'S EXPERTS

DR ALASTAIR GUNN
Astronomer, astrophysicist

ALEX FRANKLIN-CHEUNG
Environment/ climate expert

ALOM SHAHA
Science teacher, author

PROF ALICE GREGORY
Psychologist, sleep expert

DR HILARY GUITE
Former GP, science writer

CHARLOTTE CORNEY
Zoo director, conservationist

DR HELEN SCALES
Oceans expert, science writer

DR CHRISTIAN JARRETT
Neuroscientist, science writer

DR EMMA DAVIES
Chemistry expert, science writer

LUIS VILLAZON
Science/tech writer

JULES HOWARD
Zoologist, science writer

PROF ROBERT MATTHEWS
Physicist, science writer

GETTY IMAGES

STEVE GRANTHAM, PRESTON

WHAT'S THE MOST DANGEROUS SPORT?

This is surprisingly hard to answer, as it depends both on how the risk is measured – per participant, say, or per event – and the availability of reliable data. But according to a 2014 analysis by Prof Sir David Spiegelhalter at Cambridge University, the UK's leading authority on risk, mountaineering is probably the most dangerous sport, carrying a risk of death of around 1 per cent per climb. By comparison, running a marathon is around 1,000 times safer. ***RM***

NYE LEWIS-DAVIES

WHAT DOES THE WORLD LOOK LIKE OUTSIDE OF OUR BRAINS?

Your question has echoes of the American philosopher Thomas Nagel's classic paper "What is it like to be a bat?" – a creature that is able to navigate using echolocation (by bouncing sounds off the environment). Nagel wrote that we can never step outside of our own brain and take the bat's perspective on the world because we lack their sensory equipment. Likewise, one could argue that we can never know what the world 'looks like' free from our brains because we can only perceive objective reality through the veil of our senses, such as via wavelengths of light hitting our retina, or odorous molecules stimulating nerve cells in our nose.

We can't even ever truly know if the world looks the same from the perspective of another human brain. For instance, the colour that I label 'red' may subjectively look different to you than it does to me.

We know as a matter of fact that there are aspects of physical reality that we cannot detect ourselves – such as radio waves, ultraviolet light (detectable by birds and bees, among other creatures) and high-pitched ultrasound (used by bats). And of course, there are likely many other aspects of reality not yet detectable by any creature or our most advanced technology – a possibility that fuels the imagination of science fiction writers and mystics alike.

But while our take on the world is restricted by the limitations of our own neurological systems, it would be a mistake to underplay their potential. For starters, we have way more than five senses (among the other are balance, hunger and proprioception – the sense of where our body is in space). What's more, recent research suggests that it may be possible for us to learn a form of echolocation, by making clicks with our mouths. Indeed, some blind people can already do this, using the echoes to piece together their environment as a bat would. ***CJ***

MARTIN OGILVIE, NORWICH

WHERE DO SMELLS GO?

Smells 'disappear' when the aroma molecules disperse in the air to a concentration below your detection threshold. Your nose is more sensitive to some compounds than others: the eggy smell of hydrogen sulphide is detectable at concentrations of two parts per billion, while nail varnish remover (acetone) needs to be 50,000 times more concentrated before you can smell it. Some aroma molecules may also chemically react in the air to form a different compound that you are less sensitive to. *LV*

JULIUS CENTIK, PIEŠTANY, SLOVAKIA

WHY DOES THE CLINKING SOUND GO DOWN IN PITCH WHEN I STIR SUGAR INTO MY COFFEE?

When adding sugar into coffee – or any hot drink – the 'clink' of the spoon striking the mug's sides becomes lower in pitch. The explanation is surprisingly subtle, and lies in the effect of the sugar on the liquid. The rough surface of the sugar granules traps molecules of air dissolved in the liquid, creating tiny bubbles. These make the liquid in the mug more 'squashable' – the technical term is 'compressible' – allowing it to mop up more of the energy in the sound waves created by the spoon, which in turn makes them travel more slowly through the liquid. As the speed of the sound waves in the mug is proportional to their frequency, the reduced speed lowers their frequency, which we hear as a drop in pitch. ***RM***

DIY SCIENCE

HOMEMADE LAVA LAMP

WHAT YOU'LL NEED

- A tall, open container such as a plastic drinks bottle or a glass
- Cooking oil
- Water
- Food colouring
- Fizzy vitamin tablet or Alka-Seltzer

WHAT TO DO

1. Fill the container about a third of the way up with water.

2. Pour cooking oil on top of the water until the container is nearly full.

3. Wait for the oil and water to separate.

4. Add a few drops of food colouring and wait for the water to become coloured.

5. Break the tablet in half and drop it into the container.

6. Watch the lava lamp do its thing!

7. Add more pieces of the tablet to keep the reaction going.

WHAT'S HAPPENING

The key to how the 'lava lamp' works is the fact that oil and water don't mix. Whether two liquids mix depends on the interactions between their molecules and also their freedom to move around – the stronger the attractive forces, and the greater the possibilities of movement, the more likely they are to mix.

Water molecules are 'polar' – one end is negatively charged, and the other is positively charged. This means that water molecules attract each other more strongly than they attract oil molecules, which are 'non-polar'. Also, the water molecules end up forming a kind of cage around the oil molecules, restricting the motion of both. This is an unfavourable state, and the water and oil molecules quickly separate. The oil floats on top of the water because it is less dense.

The tablets contain citric acid and sodium bicarbonate, which are released into the water when the tablet dissolves. When particles of these two chemicals come into contact with each other, they react, producing carbon dioxide gas. The gas forms bubbles in the water. These are less dense than both the water and the oil, so float upwards, dragging along some of the coloured water. The bubbles burst once they reach the top of the oil, and the water falls back down. ***AS***

GETTY IMAGES X3 ILLUSTRATION: DAN BRIGHT

Hidden figures

JANET LANE-CLAYPON

The science of epidemiology has saved the lives of millions by helping to reveal the causes of good and bad health. Using so-called cohort studies, researchers have made some crucial discoveries, showing the deadly link between smoking and cancer, for example, and the benefits of exercise for mental health. Yet the scientist who pioneered this type of study was forced to abandon research and died in obscurity – chiefly because she was a woman.

Born in Lincolnshire in 1877, Janet Lane-Claypon was a brilliant medical student who became fascinated by epidemiology. In 1912, she published a pioneering study of two groups – 'cohorts' – of babies, fed breast milk and cow's milk respectively. Using sophisticated techniques, she not only discovered the link between breastfeeding and better growth, but also ruled out other potential explanations, such as family income.

Lane-Claypon then developed so-called case-control studies, where a group of people with a disease are compared to a broadly similar group free of the disease. This allowed her to identify risk factors for breast cancer that are still recognised as important today. But in 1929 she married a civil servant and was forced to quit under official regulations. While others took up her brilliant work, Lane-Claypon herself remains unknown even to those using her techniques. ***RM***

THEODORE BARKAS, ATHENS

WHY DO WE SWING OUR ARMS WHEN WE WALK?

Experts believe that the ancestors of modern humans began walking upright at least 3.6 million years ago. Yet the reason we move our arms out of sync with our legs has only recently been solved. For years, the answer was thought to be simply balance. Research published in 2010 by a team led by Dr Sjoerd Bruijn at the Free University, Netherlands confirmed this – but with a twist. Swinging our arms doesn't make us much more stable when walking normally – but it does help restore our balance if we suddenly lose our footing while walking over uneven ground. Earlier this year, Bruijn and colleagues also found another benefit: swinging our arms while walking is more energy efficient than keeping them still. While it takes energy to move our arms, this is more than compensated for by the reduced energy needed by the rest of the body to propel itself forward. ***RM***

JESS ROCHEFORT

WHAT WOULD HAPPEN IF ALL THE SALT IN THE OCEANS SUDDENLY DISAPPEARED?

A litre of seawater contains around 35g of dissolved salt, so desalinating the entire ocean would involve removing 45 million billion tonnes of salt. The sudden reduction in weight pressing on the seabed would probably trigger earthquakes and volcanoes around the globe. Because freshwater is less dense, the Arctic icecap would sink an extra 10cm into the water, creating the largest tidal wave the planet has ever seen along northern Europe, Russia and Canada. A few hours later, virtually all marine life would die as their cells swelled and ruptured due to osmosis (water molecules move towards areas of higher salt concentration). They would sink to the ocean floor, but their bodies wouldn't decompose, because all marine bacteria would be dead too. Marine algae are responsible for at least half of Earth's oxygen production, so there would be mass extinctions on land as well. Eventually, the oceans would resalinate because minerals are continually dissolved from the land by rivers and carried to the sea, but this would take tens of thousands of years. ***LV***

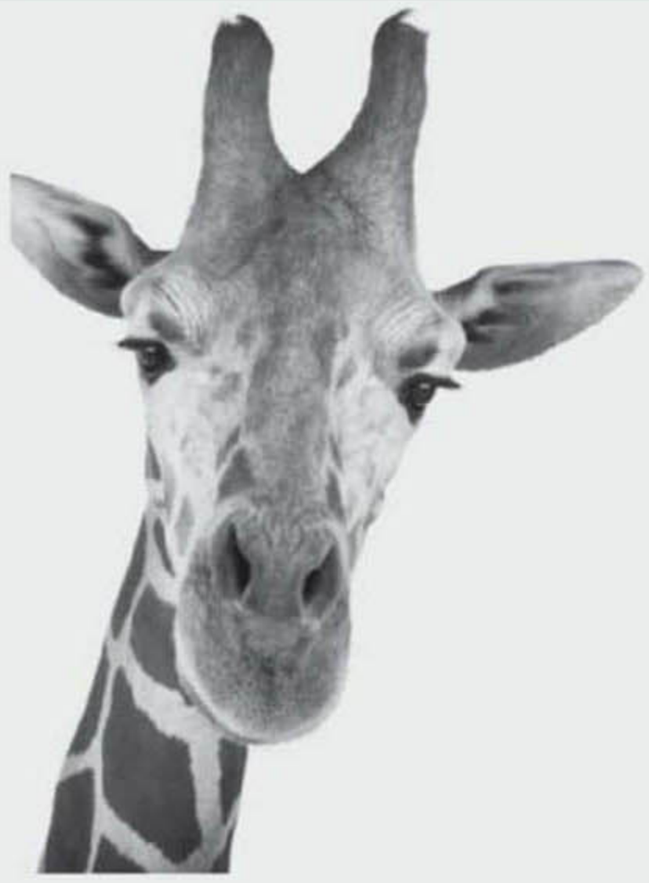
EXISTENTIAL FEAR OF THE MONTH...

I'M MORE BACTERIA THAN HUMAN

There are more bacterial cells in your body than human cells, but the ratio isn't as extreme as once thought. A 2016 study at the Weizmann Institute of Science in Israel found that our total cell count is 56 per cent bacteria (compared with earlier estimates of 90 per cent). And because bacteria are much smaller, their total mass is only about 200g. So by weight, we are more than 99.7 per cent human.

Even so, we shouldn't underestimate the contribution bacteria make to our body, nor feel threatened by it. Most of our 'human' cells contain structures called mitochondria, which we rely on to convert glucose into compounds we can use for energy. These mitochondria probably began as free-living bacteria before they embarked on a symbiotic relationship with us. The only reason that we don't include them in our tally of bacteria is that they never leave the confines of human cell membranes, though they are, in many respects, independent organisms with their own DNA.

Like all multicellular animals, we can't easily point to individual components and say "This is part of me, and this is not". Your body is like a city – it has a collective identity that goes beyond its individual inhabitants. The pigeons and squirrels that call London home are just as much a part of it as the humans who live there. ***LV***



JUNO SANDFORD (AGED 5), HACKNEY

DO GIRAFFES MAKE A NOISE?

Although not the most talkative of animals, giraffes are known to snort or hiss when threatened, and female giraffes bellow to their young. But we recently discovered that they make other noises, too. In 2015, researchers analysed recordings of giraffes from zoos in Berlin, Copenhagen and Vienna, and found that they make low-frequency humming noises at night. It's thought that these otherworldly sounds are a form of 'contact call' between individuals who have been separated from their herd, helping them to find each other in the dark. Rather charmingly, another theory suggests that the humming is actually giraffes snoring or sleep-talking! ***CC***

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The number of abnormal 'teeth' removed from the mouth of a seven-year-old boy in India. The teeth, which were found inside a growth in the lower jaw, ranged in size from 0.1mm to 3mm, and each had enamel, a crown and a small root.

GETTY IMAGES X3, SCIENCE PHOTO LIBRARY ILLUSTRATION: DAN BRIGHT

DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY SCIENCE FOCUS EXPERTS

I TOOK ONE OF MY WIFE'S CONTRACEPTIVE PILLS AS A DARE, BUT NOW I'M WORRIED. WILL ANYTHING HAPPEN?

Nothing will happen if you only took one. There's a one in four chance that the pill was a dummy anyway, as most packets include seven tablets with no drugs in them (meant to maintain the habit of taking the pill while the 'withdrawal bleed' happens). If you regularly took the 'combined pill', which contains oestrogen and progestogen hormones, it would have mild feminising effects, such as wider hips, softer skin and slight breast development. The oestrogen dose is about a tenth of that taken by transgender women, but it's a form of oestrogen associated with higher risks of deep vein thrombosis, so it wouldn't be a good idea for anyone wanting to transition. Regularly taking a progestogen-only pill would have the main impact of reducing your sperm count and libido. ***HG***

DO I REALLY NEED TO LEAVE MY FOOD TO STAND AFTER IT COMES OUT OF THE MICROWAVE?

Microwaves only penetrate to a depth of around three or four centimetres, so anything deeper is heated indirectly, by conduction from the outer layers of food. The cooking instructions on a ready meal might say to heat it on full power for five minutes and then leave to stand for another two. The first phase adds enough energy to cook your lasagne, but when it comes out of the microwave, that energy is unevenly distributed. Leaving it to stand allows the heat to make it to the centre, where it will kill off any bacteria. So always respect the instructions. ***LV***

WHY DOES NO ONE AT WORK CARE ABOUT MY LOVELY SUMMER HOLIDAY?

It may seem that way, but rest assured, it's probably not that they don't care, and it's probably not all down to jealousy, either. It's likely that they just find it difficult to fully appreciate what an awesome time you had.

Psychologists at Harvard University have been studying the social dynamics that play out when we share stories. They've found that most of us (storytellers and listeners alike) think that it will be more pleasurable for all involved to hear stories of extraordinary experiences rather than more mundane tales. Yet the converse tends to be true – it's actually more rewarding to share stories that everyone finds familiar. A key reason is that it's such a challenge to convey exciting or unusual experiences in words. Your head may be filled with memories of astonishing views or hilarious nights out, but unless you're a gifted raconteur, when you try to articulate those experiences, your audience is likely to be left cold. So, paradoxically, the more remarkable your summer escape, the more you risk alienating your audience. By contrast, if you went somewhere familiar and did what many others in your social group do, your colleagues will probably enjoy hearing about your holiday more, as they'll be able to chip in with their own anecdotes. ***CJ***

DAVID KELLY, MANCHESTER

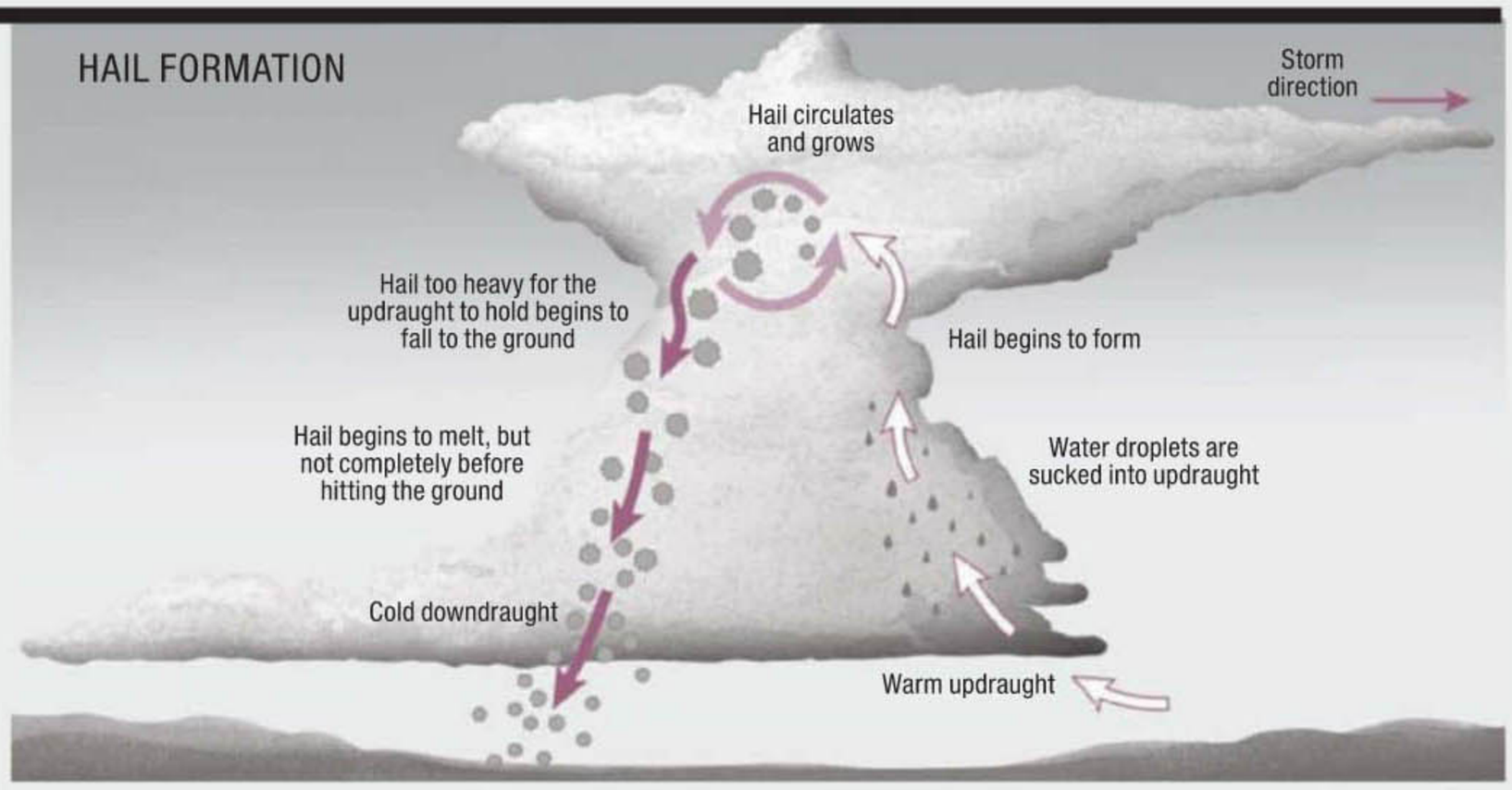
DO OBJECTS IN THE UNIVERSE MOVING TOWARDS US SHOW A BLUE SHIFT?

The wavelength of light emitted by an object is changed by its motion relative to an observer. An object moving away from us is 'redshifted' – that is, its light is shifted towards the longer wavelengths at the red end of the visible spectrum. But although the Universe is expanding, not all objects are redshifted. Some of the nearest stars, such as Barnard's Star, are moving towards us and hence show a 'blueshift' (their light is shifted towards shorter wavelengths). Even some galaxies (for example, the Andromeda Galaxy) are blueshifted. This is because, over relatively short distances, the local gravitational attraction between galaxies can overcome the general expansion of the Universe. The highest blueshift yet recorded is actually from a group of stars called a 'globular cluster' that's whizzing towards us at 1,026km/s. But fear not – it is still millions of light-years away! ***AGu***

JOYCE BURLEY, HULL

WHY DOES TOOTHPASTE CONTAIN SWEETENERS?

Toothpaste needs something to mask the soapy taste of the detergents that create the foam when you brush. Sugar is out, for obvious reasons, but sweeteners such as xylitol or sorbitol do a pretty good job. These chemicals attract water molecules, so they have the added benefit of keeping water locked in the toothpaste, preventing it from drying out. Research also suggests that xylitol can help to kill off plaque bacteria in the mouth by starving them of sugar. ***ED***



DAVE FERRIS, LONDON

WHY DON'T HAILSTORMS LAST AS LONG AS RAINSTORMS?

Hail is produced during thunderstorms, when an updraught of warm, moist air carries tiny droplets of water upwards. The droplets freeze at high altitude, and the resulting ice crystals grow until they are too heavy to stay suspended. For hail to form, a warm air mass has to meet a much colder one (this is what creates the updraught). The hail only forms in a narrow region where these two air masses meet, meaning that it falls over just a small strip of land. These high-energy storms also tend to move quickly, so someone on the ground experiences the hail as a short burst. Finally, as they need a supply of warm, moist air to fuel them, hailstorms relatively quickly run out of energy and dissipate. ***AFC***

NATURE'S WEIRDEST CREATURES...

THE PINK FROGMOUTH

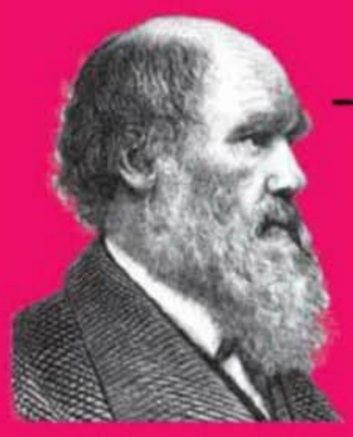
Hold onto your breath, dear readers, for this month we're diving deep. Hundreds of metres beneath the surface of the world's oceans, there lives a curious fish that waddles along the seafloor using its fins like four little legs. It has a pink complexion and a frog-like mouth. Upon its head is a unicorn-like dorsal fin which glows in the dark and entices inquisitive fish to their doom. This is the pink frogmouth, a deep-sea creature that looks to have been designed by a sugar-addled six-year-old.

Still holding your breath? Good. You and the pink frogmouth have this in common. Earlier this year, scientists discovered that this fish (and other members of its taxonomic family) has the unique ability of holding its breath underwater, for as long as four minutes.

Fish breathe by swallowing oxygen-containing water and pumping it through their gills, where the oxygen is extracted. The pink frogmouth, however, is able to hold this water in its gill chambers without exhaling. Puffed-up like this, its body volume can increase by as much as 30 per cent. There are a couple of possible reasons for this unusual behaviour: it could be a way of saving energy in an environment that's lacking in prey, and it could also help to ward off predators, similar to the pufferfish's defence mechanism. ***JH***

GETTY IMAGES X2, ALAMY ILLUSTRATIONS: DAN BRIGHT

WHAT CONNECTS CHARLES DARWIN AND CHEWBACCA?

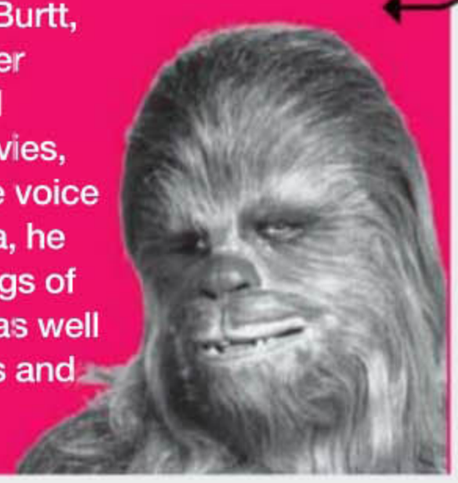


1. Although most famous for his work on evolution, Charles Darwin's final scientific book was about earthworms. It sold more quickly in its first year than *On The Origin Of Species!*

2. Earthworms are the staple food of badgers, making up to 80 per cent of their diet. Earthworms aren't very nutritious, though, so a single badger can eat several hundred of them in a night.

3. Badgers have a complex vocal repertoire of at least 16 different calls, ranging from low growls and grunts, to chitters, squeaks, yelps and even a sort of quacking sound.

4. When Ben Burtt, sound designer on the original Star Wars movies, developed the voice of Chewbacca, he used recordings of badger calls, as well as bears, lions and a walrus.



IAIN TODD, BRISTOL

WHY DO I PRODUCE SO MUCH SALIVA WHEN I GO FOR A RUN?

The various studies that have looked at this actually show conflicting results. It seems that a short jog in cold weather results in more saliva, while a marathon on a warm day actually reduces saliva production. Your body may initially be trying to offset the drying effect of the extra mouth breathing, but over longer periods dehydration sets in and your body reduces saliva production to conserve water. All exercise, regardless of the intensity, also makes you secrete more of a protein called MUC5B. This makes your saliva more sticky and viscous, which contributes to that dry mouth feeling you can get after exercising. ***LV***

ABBY SMITH, BIRMINGHAM

WHY SHOULDN'T YOU PUT TOMATOES IN THE FRIDGE?

Tomatoes from the fridge rarely fail to disappoint. Refrigeration does extend their shelf life by slowing the ripening process, but it also dramatically reduces levels of flavour and fragrance chemicals known as 'volatiles'.

A 2016 US study found that chilling tomatoes for a week reduced the activity of genes that code for enzymes needed to synthesise these volatiles, which are responsible for giving tomatoes a sweeter, more complex taste. ***ED***

STEPHEN NEWMAN, FOLEY, ALABAMA

HOW FAR DO WE TRAVEL THROUGH SPACE EVERY DAY?

This apparently simple question impinges on a fundamental axiom of physics: that there is no universal reference frame. So, when talking about the motion of the Earth, we have to declare which object the motion is with respect to. For example, at the Earth's equator you travel approximately 40,000km a day with respect to the Earth's centre. Each day, the Earth's orbit takes you about 2.5 million kilometres with respect to the Sun's centre. And each day, the Earth moves about 19 million kilometres with respect to the centre of the Milky Way. Finally, the Earth is also travelling about 47 million kilometres per day with respect to the 'cosmic microwave background' (CMB) – the leftover radiation from the birth of the Universe – which is perhaps the best surrogate we have for a universal reference frame. Since the directions of all these velocities are always changing, it would be meaningless to add them together. ***AGu***

GETTY IMAGES X8, ALAMY ILLUSTRATIONS: DAN BRIGHT

JED FITZHARRIS AND ADAM TEMPEST

DOES THE CARBON DIOXIDE RELEASED FROM FIZZY DRINKS AFFECT THE ATMOSPHERE?

Fizzy drinks do release carbon dioxide (CO_2), but this pales in comparison with overall human CO_2 emissions. A can of pop contains 2-3g of CO_2 – a tiny proportion of the six tonnes of CO_2 per year (or 17kg per day) that the average person in the UK is responsible for. What's more, the CO_2 pumped into carbonated drinks is usually a by-product from power plants – meaning it would have been released into the atmosphere anyway. ***AFC***

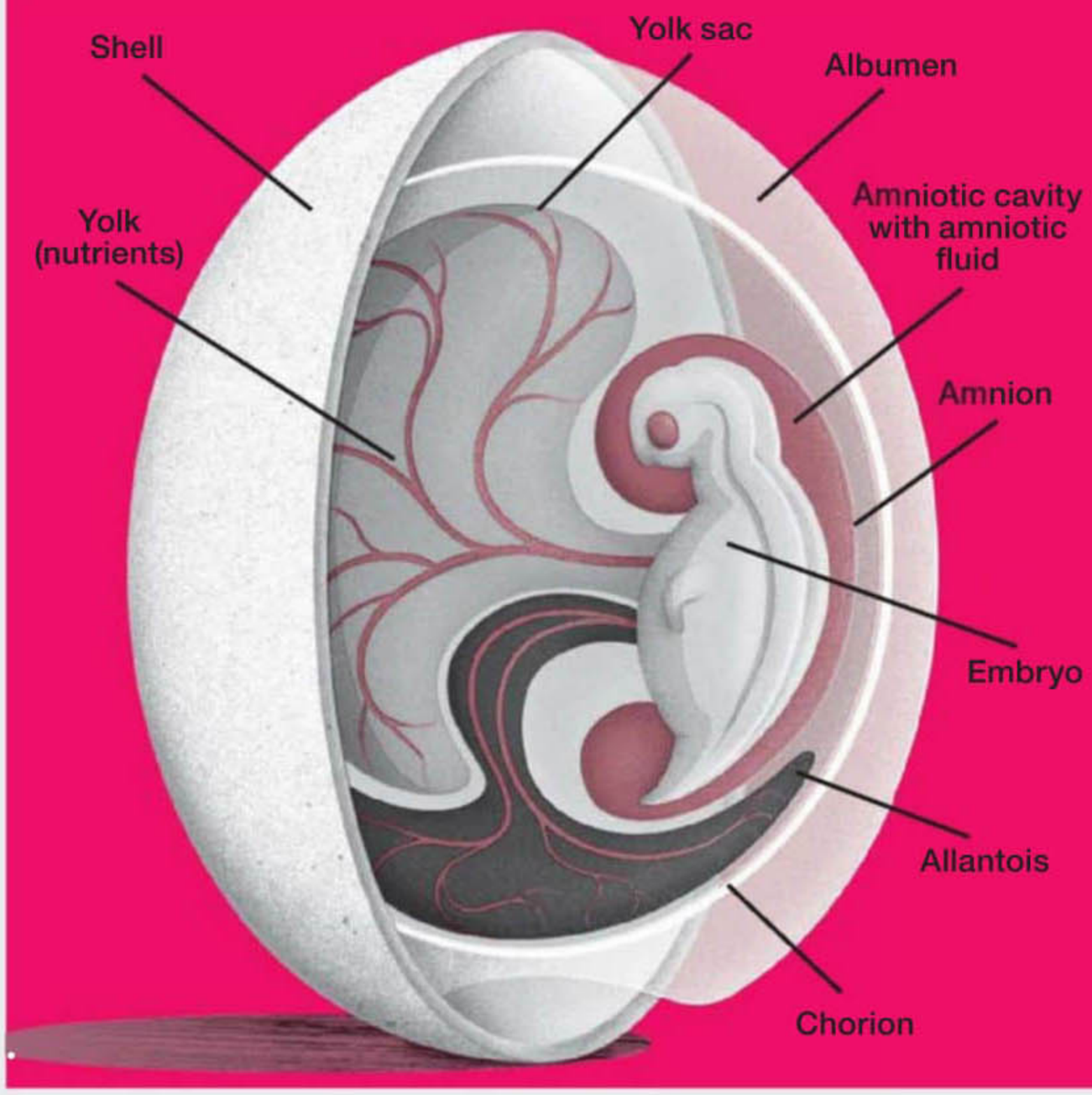
So shiny, even without an application of Pledge (other polishes are available)

REBECCA WALKER

WHY DO SOME INSECTS LOOK METALLIC?

Many insects, particularly scarab and jewel beetles, have vivid, metallic green, blue or gold colouration. This effect doesn't come from pigments, but is an example of 'structural colouration'. Microscopic ridges and transparent layers on the surface of a beetle's carapace act as an array of lenses that direct different wavelengths of light in such a way that some colours cancel out and others are amplified – the rainbow effect on a DVD is similarly caused by the microscopic pits on its surface. This metallic sheen may have evolved because it offers bright colours that can serve as a mating signal over long distances. Alternatively, some researchers have suggested that it might mimic the appearance of raindrops on leaves, helping to camouflage the beetles. The ridges and layers may also take less energy to grow than metabolically expensive pigment molecules – particularly important for insects because they regularly shed and regrow their outer skin. ***LV***

QUESTION OF THE MONTH



ELEANOR TEW, YORK

HOW DO BABY BIRDS BREATHE INSIDE THEIR EGGS?

It's all down to some nifty engineering inside the eggshell. Early on in a chick's development, it grows a hollow, sac-like structure from its gut, known as an 'allantois'. This pouch fuses with a second membrane ('chorion') surrounding the chick and its yolk, which together form the 'chorioallantoic membrane'. With one end attached to the chick, and one end close to the eggshell's inner surface, this membrane effectively acts like lung tissue, connecting the chick's circulatory system to the outside world. Oxygen diffuses through microscopic pores in the shell to the blood vessels in the chorioallantoic membrane, and then on to the chick's bloodstream. Carbon dioxide, the gaseous waste product of respiration, passes in the opposite direction. ***CC***

Profile

A TIME OF CHANGE

IN HIS NEW BOOK ABOUT REVERSE PARENTING, DEAN BURNETT HELPS TEENAGERS TO NAVIGATE THEIR RELATIONSHIP WITH THEIR PARENTS. HERE, HE CHATS TO US ABOUT THE ADOLESCENT BRAIN

WHO IS THIS BOOK IS FOR?

Ostensibly and officially, it's for 11- to 16-year-olds who are finding that they are having a bit more of a tricky time with their parents than they used to. It's common: your parents have been the bedrock of your life and suddenly you find yourself arguing with them a lot more. But, unlike pretty much every other book which addresses this subject, my book is an explanation for the child or teen.

I certainly found it quite cathartic to understand why that was happening, so unofficially, I think the book is for anyone who's been a teenager.

WHAT INSPIRED YOU TO WRITE THIS GUIDE?

Well, I could give you some spiel about the 'sign of the times' and the intergenerational disputes, the strong political divide. Take the environmental aspect: Greta Thunberg is the leading voice of climate change, she's only 16. Right now, we're at a very, very important point in history where the older and the younger generation are perhaps more distant from each other than they've ever been. Something which addresses that, or at least helps people to understand it, could be helpful, and I think it is an important thing to consider right now.

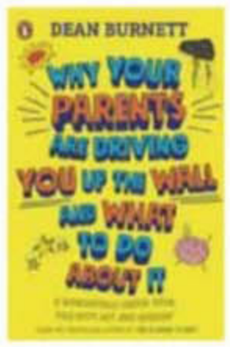
"The things that affect you as a teen will stay with you for the longest time, the rest of your life. Particularly music, apparently"

But if I'm being completely honest, it was my editor Jamie who first approached me, and said: "I've got this idea for a reverse parenting book. Would you like to write it?"

I thought, yes, yes I would, and that's pretty much what happened.

WHAT IS DIFFERENT ABOUT THE TEENAGE BRAIN, COMPARED TO THE ADULT BRAIN?

Loads of things. The adolescent phase of brain development is a distinct phase all by itself, though exactly when you start being an adult is a very



WHY YOUR PARENTS ARE DRIVING YOU UP THE WALL
BY DEAN BURNETT

GETTY IMAGES

fluctuating point, which no one seems to really agree on. When you're a child, you're absorbing everything. Some estimates say that in the first few years of your life, your brain is forming a million new connections every second, which is an incredible amount of data gathering and absorption. That carries on until we hit adolescence, though not at that phenomenal rate. Then, the brain sort of stops, takes stock, and says, right, we've got all this information. How much of this do we actually need?

It's like getting a brand-new smartphone. You're so excited, you fill it up with every single app, meme and download you can get your hands on. It's fun for a while, but eventually, that phone's going to become pretty useless. You'll try to find something basic like the calculator, and have to scroll through 50 pages of apps. With so much information in the brain, it's all about efficiency. Adolescence is when the brain starts becoming more efficient. It clears away the junk you don't need. There's a process called pruning, where lots of synapses that have never been used more than once are sort of just flushed away, and the resources for them are taken elsewhere.

WHY ARE TEENS SO EMOTIONAL?

There are some estimates that the front part of your brain, where all that higher thinking happens, doesn't finish developing until your mid-20s. The more central parts of the brain are older and more fundamental – which control things like emotions and impulses and risk-taking – they take less time to mature, so they're as efficient as possible in your early teens.

So, adolescents have this period where they can control their emotions, but it's a lot harder for them to do so, and the emotional experiences are far more intense as a result. Their emotions are harder to suppress, control or just keep under wraps. But they're constantly told to do just that. "Stop acting out. Stop being dramatic. Behave yourself; you're being stupid. You're being ridiculous."

This is the time when they're supposed to learn how to do all that stuff. If you suppress their emotions, if you make them keep quiet and sit still and never do anything, the brain never develops that ability, and it does cause serious problems down the line.

HOW MUCH OF OUR PERSONALITY IS SET DURING OUR TEENAGE YEARS?

The things you learn in your teens will stick with you for a long time, that's when you're undergoing substantial development. A lot of your baselines are established there too, like what your sexual preferences are, because you're flooded with these hormones giving you strange new feelings you've never had before, and strange longings that you can't quite get your head around.

There are some studies that show that because your teens are when your emotions are most powerful, the things that affect you as a teen will stay with you for the longest time, the rest of your life. Particularly music, apparently. That's why so many people think "music is rubbish; it was much better when I was young", that's because when you're a teen, things like music hit you at an emotional level far more profoundly than they do as an adult. Because the adult brain is more mature and more set, nothing else will really hit that same level of intoxication or emotional stimulation as it does when you're a teen. I'd say in 50 years' time there will be music journalists saying, "Oh, the 2010s, that was the year for music – we had Mambo No. 5, you don't have that."

[Actually, Mambo No. 5 was released in 1999. And we're pretty optimistic no one was emotionally stimulated by it.]

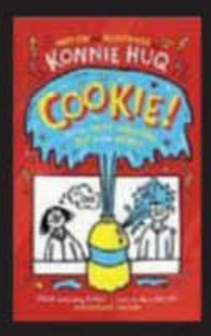
DEAN BURNETT

Dean is a neuroscientist and full-time author. His latest book, Why Your Parents Are Driving You Up The Wall And What To Do About It, is out now. ***Interviewed by BBC Science Focus editorial assistant Amy Barrett.***

AUTHOR'S BOOKSHELF

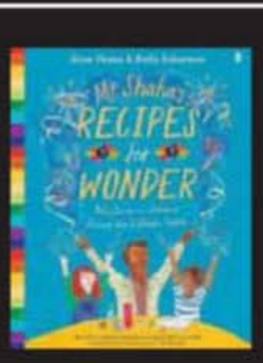
INVENTING OURSELVES
SARAH-JAYNE BLAKEMORE

An engaging and informative overview of the processes happening in the brain during teenage development, written by one of the leaders in the field.



COOKIE AND THE MOST ANNOYING BOY IN THE WORLD
KONNIE HUQ

Konnie's new book for 8- to 12-year-olds is all about a determined girl with a passion for science and her dealings with the many problems life's thrown at her.

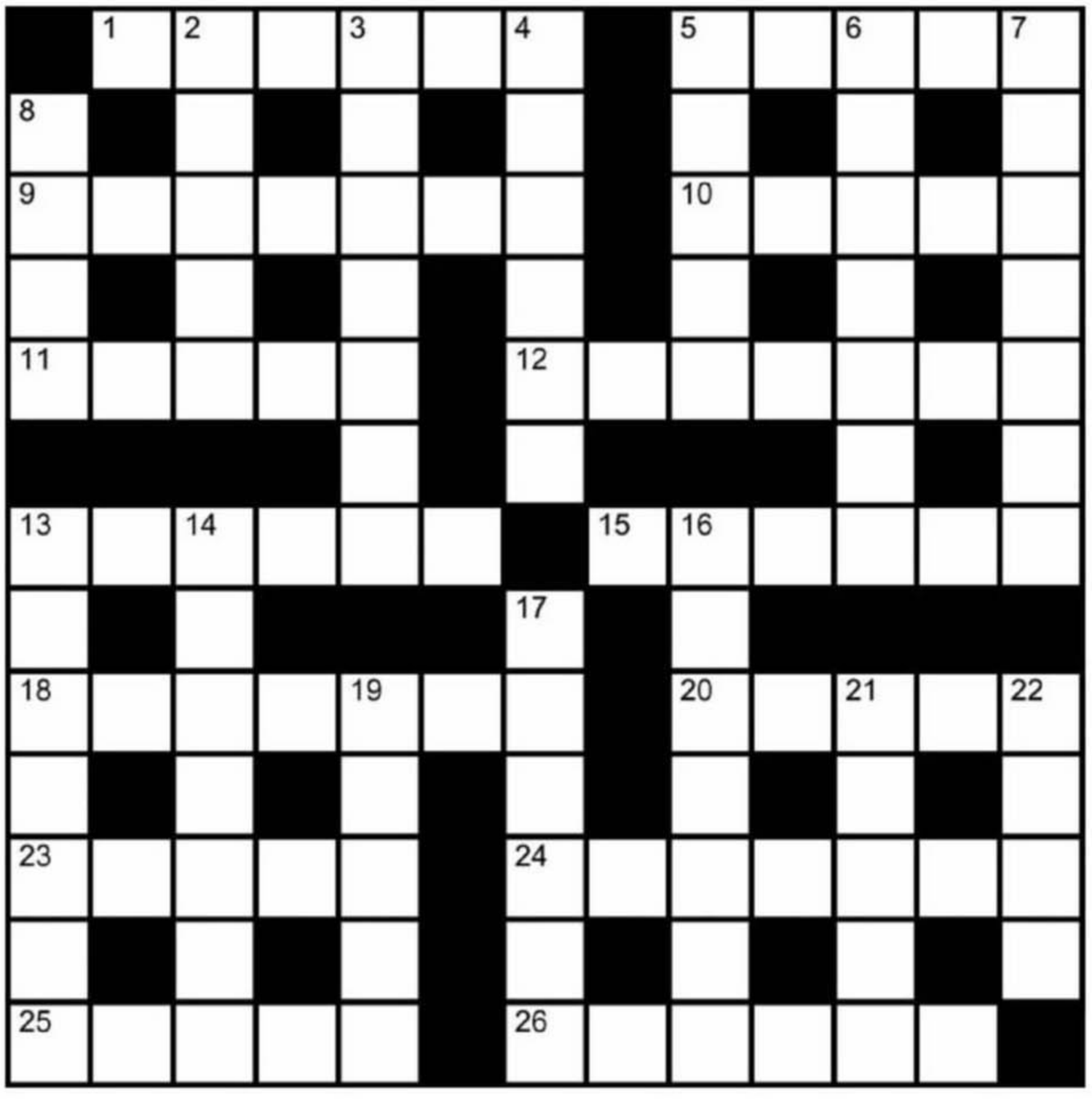


MR SHAHA'S RECIPES FOR WONDER
ALOM SHAHA AND EMILY ROBERTSON

A brilliant and beautifully illustrated book that allows parents and children to explore the fun side of science in their own home.

CROSSWORD PUZZLE

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Announced name of composer (6)
5 Difficult to follow cold vegetable (5)
9 Fair about container being Egyptian for one (7)
10 Wrong time to get right hat (5)
11 Heard note from singer (5)
12 Sea creature finds work after a month (7)
13 Continue the summary (6)
15 Chicken pursues quiet musician (6)
18 Choose unending fool over artist (7)
20 Firm, repeating a bedtime order (5)
23 Pope from the city (5)
24 Last word in bargain report (7)
25 Warden misses first appearance (5)
26 Register for a large drink (6)

DOWN

2 Borderless Italian island arranged no protection (5)
3 Style with strange propriety (7)
4 Behold new professor gets capital (6)
5 Arrive on time to see celestial object (5)
6 Car spy organised late examination (7)
7 Furniture item useful to an actor (7)
8 Loud performance, it's true (4)
13 Disturb river – put liquid on another (7)
14 Dismiss objection to early instrument (7)
16 Stole away with keys and some sugar (7)
17 Bishop should be bribed (6)
19 Bright son, amusing, having lost head (5)
21 Indifferent about British computer language (5)
22 Tree expert, orchard's second (4)

ANSWERS

Solution to crossword in the previous issue

A SCIENTIST'S GUIDE TO LIFE

PAIN-FREE SHOPPING

WORN DOWN BY THE DRUDGERY OF THE WEEKLY SHOP? RETAIL RESEARCHER **SIEMON SCAMELL-KATZ** IS HERE TO MAKE THE EXPERIENCE A LITTLE EASIER

IS THERE SCIENCE TO SHOPPING?
Absolutely. We were the first people to put cameras and eye-tracking devices in stores to monitor where people go and what they look at. When we married this with brain scans, we were able to see the effect these activities have on decision-making.

SHOULD I PRICE-CHECK?
The question is, do you want to have an easier shop or a cheaper shop? If you want an easy shop, continue on automatic pilot and accept that at some point in the past, you made a choice to say that's the sort of price you will pay for this product. Or, shop carefully and pay attention to the prices, but accept it will take two to three times longer.

HOW SHOULD I NAVIGATE AISLES?
Sideways! To properly shop a category, stop and turn to face the shelves. We have a bias to look slightly down, between waist and chest height, so scan the full height of the shelves, and work your way along. This will help you to check the prices and promotions.

SHOULD I WRITE A LIST?
People who shop without a list are more likely to buy impulsively. If you want to control your budget, write a list and stick to it. People who do this buy 15 per cent fewer items then those who don't.

BASKET OR TROLLEY?
We did an experiment in a convenience store and found that if people don't have a basket, they buy only what they can carry. If they have a basket, they buy more. We have this unconscious mentality that the size of the shop matches the size of the container. So, if we grab a trolley, we buy more.

SHOULD I BRING THE KIDS?
Do not take your children! They have the power to pester and influence what you buy. Managing them is stressful so you get distracted and end up forgetting things or buying the wrong stuff.

ONLINE VS INSTORE?
The websites for online stores tend to be poorly designed. There's the hassle of trying to build a shopping list, so people often start their shopping, then go away, come back and add to it. You end up spending more because the websites are difficult to navigate.

BIG WEEKLY SHOP, OR SMALLER TOP-UP SHOPS?
If you do small, frequent shops, you will spend more money and time than if you do a big weekly or monthly shop. But when we asked people how long they think they spend shopping, we found that people who do smaller shops underestimate the time it takes – so you feel like it takes less time than a big shop.

WHAT'S THE BEST TIME OF DAY TO SHOP?
Late morning because it's quietest, so you're less likely to get stressed or distracted. But don't go shopping hungry. You're twice as likely to impulse purchase if you're hungry.

ANY OTHER TIPS?
Our eye-tracking research shows that people are drawn to big displays. We think if it's a big display it must be a good brand, but be aware that brands pay for this level of prominence.

SIEMON SCAMELL-KATZ
Siemon is a retail researcher, self-proclaimed professor of shopping, and director of M Cloud, a shopper research and consultancy business. He is the author of The Art Of Shopping: How We Shop And Why We Buy.
Interviewed by Dr Helen Pilcher.

NEED TO KNOW...

1

Write a list and stick to it, especially if you are on a budget.

2

Do not take your kids with you, as they'll stress you out and you'll buy the wrong stuff.

3

Don't shop hungry, as you'll be more likely to buy things on impulse.

ILLUSTRATION: CARLOS ORTEGA

COMMENT

AN EGGCELLENT BREAKFAST

Eggs aren't as bad as we've been led to believe, despite what the headlines say

Recently, I saw a newspaper headline which claimed that 'Eating Just Three Eggs a Week Raises Risk of Heart Disease and Early Death'. These headlines were based on a study published in the journal JAMA where researchers followed 29,000 Americans who had filled in food questionnaires decades ago. Over that time quite a few had died. When the researchers compared the food questionnaires with what happened to those people, they concluded that eating an extra half-egg a day increased the risk of developing heart disease by 6 per cent.

As someone who eats eggs most mornings, am I worried by these findings? Not at all. Here are the reasons why.

First of all, the old idea that eggs are bad for you because they contain cholesterol is now widely recognised as a myth. The cholesterol that you eat has almost no effect on your blood cholesterol levels (most of the cholesterol in your body is produced by your liver). Second, a major weakness of this particular study was the fact that they collected data about people's egg-eating habits only once, at the start of the study. The group was followed for an average of 17 years and it is wildly unlikely that during that time they kept to the same sort of diet.

PORTRAIT: KATE COPELAND ILLUSTRATION: MAXIM USIK

> "The cholesterol that you eat has almost no effect on your blood cholesterol levels"

But perhaps, most importantly, we know that the findings of this study are flatly contradicted by the results of other, bigger studies.

First, there's the Nurses' Health and Health Professionals' Study, which involved more than 118,000 people. This research found no link between eggs and risk of heart disease or death. An even bigger study, involving more than 3,000,000 adults, published in the British Medical Journal a couple of years ago, came to exactly the same conclusion. This is why the NHS says, "There is no recommended limit on how many eggs people should eat."

A big study from China, involving over 500,000 people, was recently published in the journal Heart. Reassuringly, it found that people who eat eggs every day have an 18 per cent lower risk of dying from heart disease and a 28 per cent lower risk of dying from stroke than people who never eat eggs.

Eggs are a great source of protein (which will fill you up) and contain small amounts of almost every vitamin and mineral required by the human body. A single egg has decent amounts of vitamin B12, vitamin B2 (riboflavin), vitamin A and selenium.

Eggs are also low in calories (around 80 calories an egg). Whether you boil them, scramble them, or whisk up an omelette, they are a cracking way to start the day.

MICHAEL MOSLEY
Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *The Fast 800*

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