BBC

CLOSING IN ON A CURE FOR MIGRAINES

Science Focus

The secrets of
YOUR SECOND BRAIN

Why we don't need
ROBOTS THAT LOOK LIKE US

THE NEXT GENERATION OF SPACE TECH IS HERE AND IT'S GOING TO TAKE US TO PLACES WE'VE NEVER SEEN BEFORE

INTO THE UNKNOWN

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IN THIS ISSUE

Health
Why you can't target belly fat like the ads say

Space junk
Could space debris fall out of the sky and hit me?

De-extinction
The plan to bring back the Tasmanian tiger

This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

But it doesn't have to be like this. You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries and every single stroke survivor has the best care, rehabilitation and support network possible, to help them rebuild their lives.

Big or small, every legacy gift left to the Stroke Association will make a difference to stroke survivors and their families.

Find out how by calling 020 7566 1505

or email legacy@stroke.org.uk

or visit stroke.org.uk/legacy

Rebuilding lives after stroke

Stroke Association

What's the best way to get to sleep? →p75

FROM THE EDITOR

We're going back to the Moon. The Artemis 1 mission, which is prepping for a rescheduled launch date as I write (following an engine problem during the initial lift-off attempt), marks the start of a journey which will end with humans walking on the lunar surface again. Once that happens, it's just a matter of time until the Artemis astronauts will begin scouting for a nice, safe location where NASA can establish a more permanent base on the Moon.

At the same time, further out into space – at what's called Lagrange Point 2 (L2) – the James Webb Space Telescope is quietly showing us the Solar System and everything beyond in a whole new light. And even further out, the Mars Perseverance Rover has just picked up a sample of rock from the Red Planet's surface that could tell us where all its water went.

It feels like we've entered a new golden era in space exploration: one where we'll start to understand our Solar System and the wider Universe in finer detail. Best of all, these three flagship missions are just the start. There is an armada of new spacecraft and technology being designed to travel to some of the furthest reaches of our cosmic neighbourhood, and you can read all about them on p60.

Also, if you haven't already, you ought to tune into our podcast: *Instant Genius*. There, twice a week, you'll find us talking about the likes of space exploration, forensics, de-extinction and much more.

Enjoy the issue!

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...

The Sky At Night
There has never been a better time to tune in to the BBC's oldest science show. But this episode, which revels in the beautiful detail of the James Webb Space Telescope's new images, is a must-watch.
Available on BBC iPlayer

Net Zero: A Very British Problem
The UK has been a success story when it comes to shrinking our carbon emissions, but can we reach net zero? Comedian and environmental economist Dr Matt Winning travels around Britain in this four-part series to find out if we can make the changes needed to get there.
BBC Radio 4
Starts 16 September, 11am
Also available on BBC Sounds

CrowdScience: Is There A Language Of Laughter?
Is comedy universal? Do we all laugh at the same things? Are comedians somehow funnier in the flesh than on TV? The *CrowdScience* team gets stuck into the science of why we laugh.
BBC World Service
16 September, 8:30pm
Also available on BBC Sounds

CONTRIBUTORS

DR RADHA MODGIL
In this issue, Radha, a working NHS doctor, explores how scientists are investigating radical new ways to help patients cope with pain. →p28

DR DEAN BURNETT
Migraines are debilitating, but relatively little is known about them. Dean, a neuroscientist and author, digs into what we know and how we can ease them. → p68

JOCELYN TIMPERLEY
A freelance science and climate journalist, Jocelyn dives into the madcap plan to grow food under the sea in Nemo's Garden, off the coast of Italy. → p52

PROF KEVIN HISCOCK
As Europe deals with the worst drought in 500 years, Kevin explains how the UK can manage its water supplies to adapt to the changing climate. → p24

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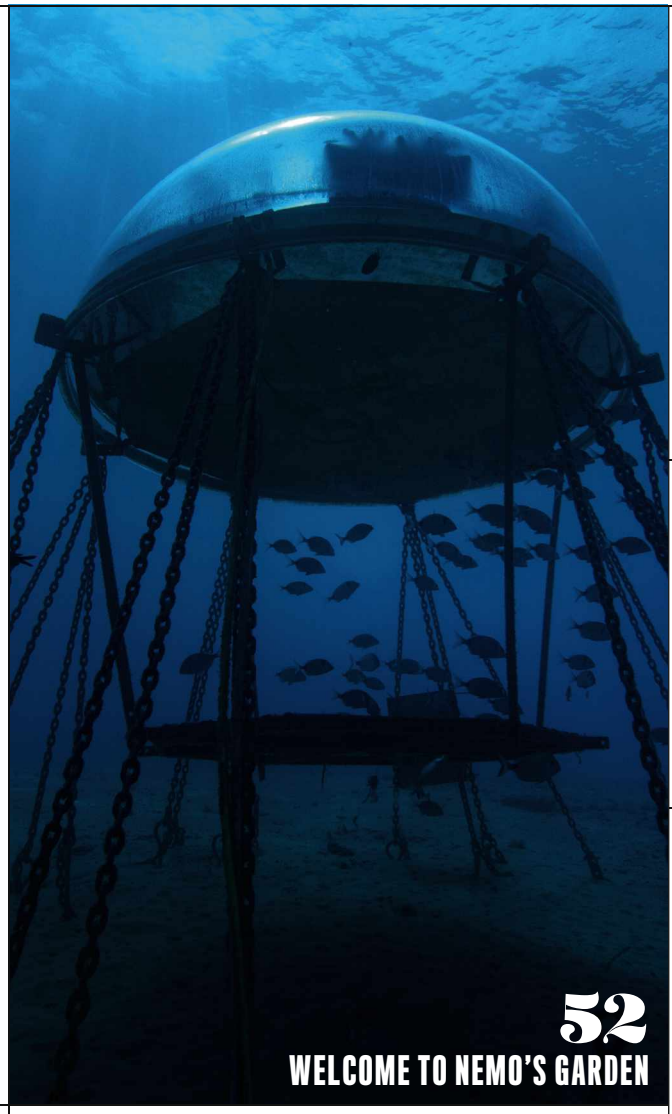

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60 JILL MIKUCKI

"FROM MY EXPERIENCE IN ANTARCTICA AND OTHER ICY PLACES ON EARTH, A LOT CAN GO WRONG WHEN YOU'RE FLYING BLIND IN AN ICE HOLE!"

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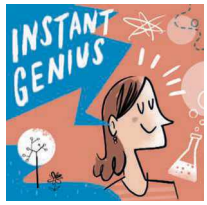

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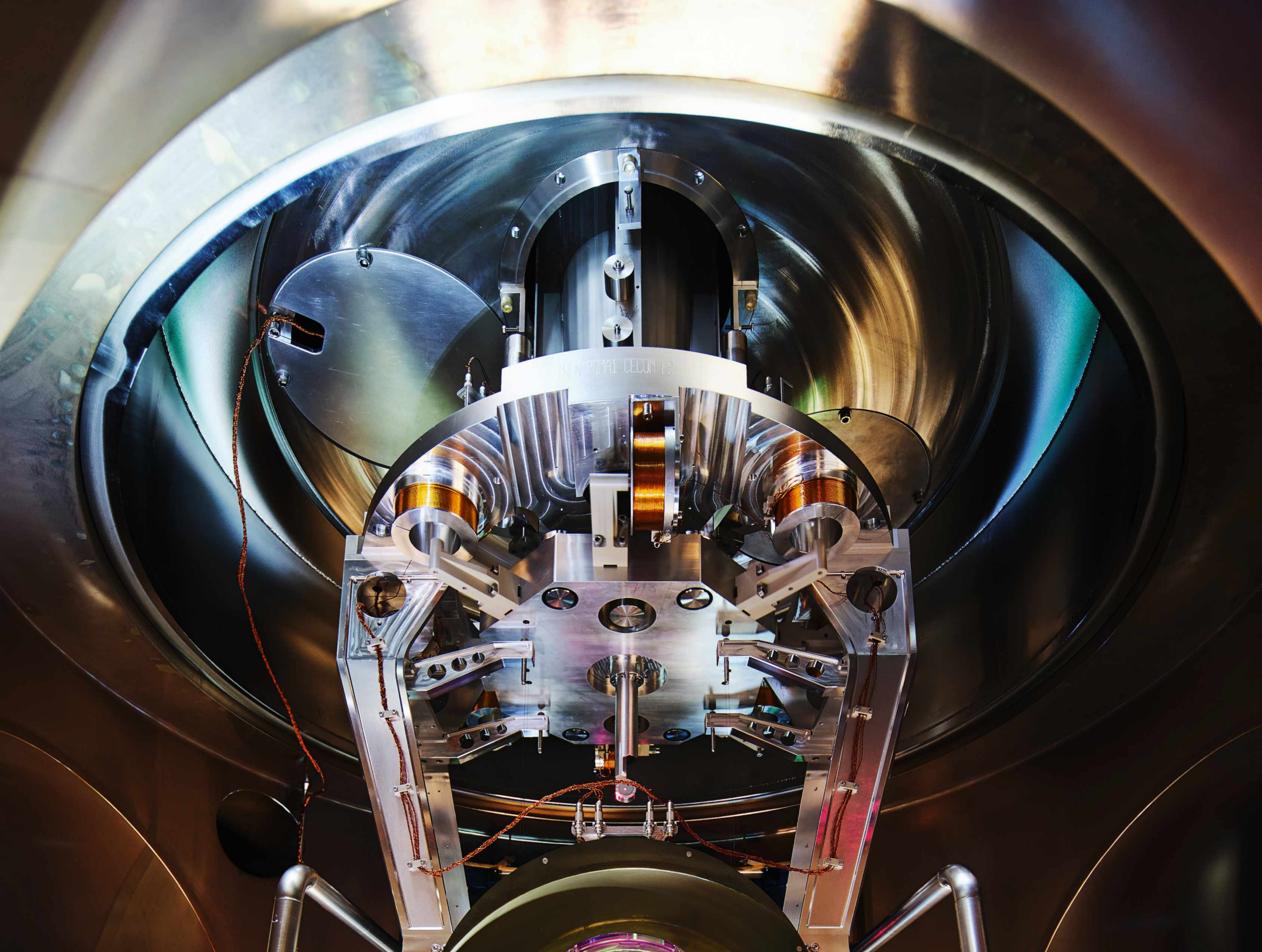

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Catching waves

VIRGO INTERFEROMETER, CASCINA, ITALY

Despite Einstein's prediction of gravitational waves, the first direct observation wasn't until 2015, when two colliding black holes were observed by the LIGO gravitational wave detectors. Since then, experiments like LIGO and Virgo (above) continue to detect these ripples in the fabric of space-time.

This photo reveals the inner workings of Virgo's interferometer, the instrument responsible for taking the measurements that are needed to detect gravitational waves. Virgo has undergone several upgrades, including a more powerful laser source and upgraded optics. "The upgraded setup is being tuned to achieve maximum sensitivity," says Fiodor Sorrentino, Virgo's commissioning coordinator. "We plan to start the next observing cycle in March 2023, together with the LIGO and KAGRA observatories, with a 50 per cent improvement in sensitivity. A three-fold advance in the detection rate will see it go from one gravitational wave per week to one per day!"

EYE OPENER

Promise of life?

PERSEVERANCE ROVER, MARS

This sedimentary rock sample, which has been collected by NASA's Perseverance Rover from the surface of Mars, could contain possible evidence of ancient Martian life, claims Arizona State University's Prof Meenakshi Wadhwa, chief scientist for the Mars Sample Return programme.

The sample, which is barely the size of a little finger, is the 10th collected by the rover. It is pictured here in the late-afternoon Martian sunlight.

The joint venture, by NASA and ESA, will see the Martian rock samples stored in metal cylinders. They will be retrieved and brought back to Earth in the early 2030s, when they can undergo in-depth analysis.

Perseverance arrived in February 2021 at the Jezero Crater, the likely site of an ancient river delta from billions of years ago, with the first rock sample collected in September 2021.

NASA has announced that it is also launching two mini helicopters to Mars as a backup, in case Perseverance needs help loading the samples onto the return rocket.

NASA/JPL-CALTECH

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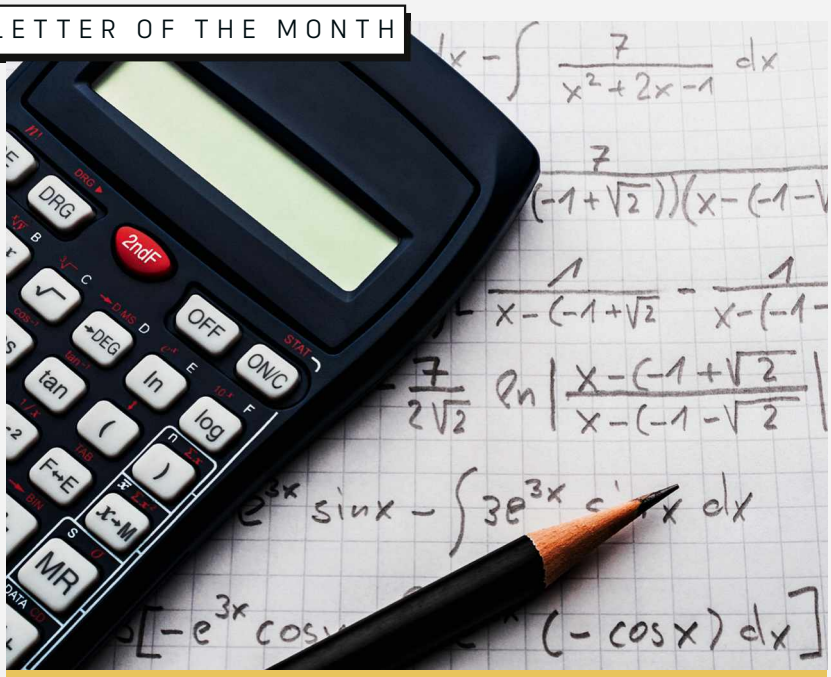
LETTER OF THE MONTH



How about science without maths?

In her letter, Barbara Atkinson (Summer, p12) says science is perceived as a difficult subject. I suggest that it's not the physics that's difficult, but instead it's the mathematics that's used to explain it. Science has always been my passion, but I'm not good at maths. Just ask if you can have an explanation without all the formulae and you are told "mathematics is the language of science". To understand the data coming out of the Large Hadron Collider (LHC) requires a mathematician, but an understanding of GCSE and A-Level science doesn't.

What's required is teachers who realise that understanding the maths doesn't make you a good teacher. Instead, a good teacher is one who can enable a pupil to understand the science, even though they can't necessarily understand the maths.

Barry Cash, Bristol

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **bundle of science books from Bloomsbury Sigma,** which will be perfect for cosy autumn reading. The prize includes *First Light* by Emma Chapman, *Growing Up Human* by Brenna Hassett, *Our Biggest Experiment* by Alice Bell, *Racing Green* by Kit Chapman, *Superspy Science* by Kathryn Harkup, *Wilder* by Millie Kerr and *Wonderdog* by Jules Howard. **bloomsbury.com/sigmabooks**

WORTH £100+

Is a duoverse possible?

I'm wondering why scientists haven't thought about the possibility that we live in a 'duoverse'? This could have risen from energy, where ours is the one with matter, and the other is made of antimatter. The duoverse will eventually collapse when the two parts annihilate each other.

If we imagine both in four dimensions, the antimatter universe would seem to surround ours, pulling on it from every side and thus 'creating' dark energy.

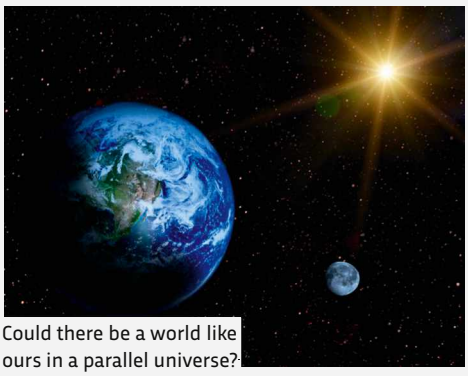
Karol Ekert, via email

Consider the Goldilocks effect

In your article that explores the many different multiverses (Summer, p62) you include the thought-provoking idea that other universes could have different laws of physics applied to them. But what about the Goldilocks effect, which is the observation that the Universe is 'just right' for us to exist? One example is that the ratio between the strong nuclear interaction and electromagnetic force is in a narrow range, and that makes it possible for all the elements in our bodies to be formed in stars.

The implication of this is that a huge number of parallel universes must exist, for there to be at least one universe where all the conditions required for life to arise are present.

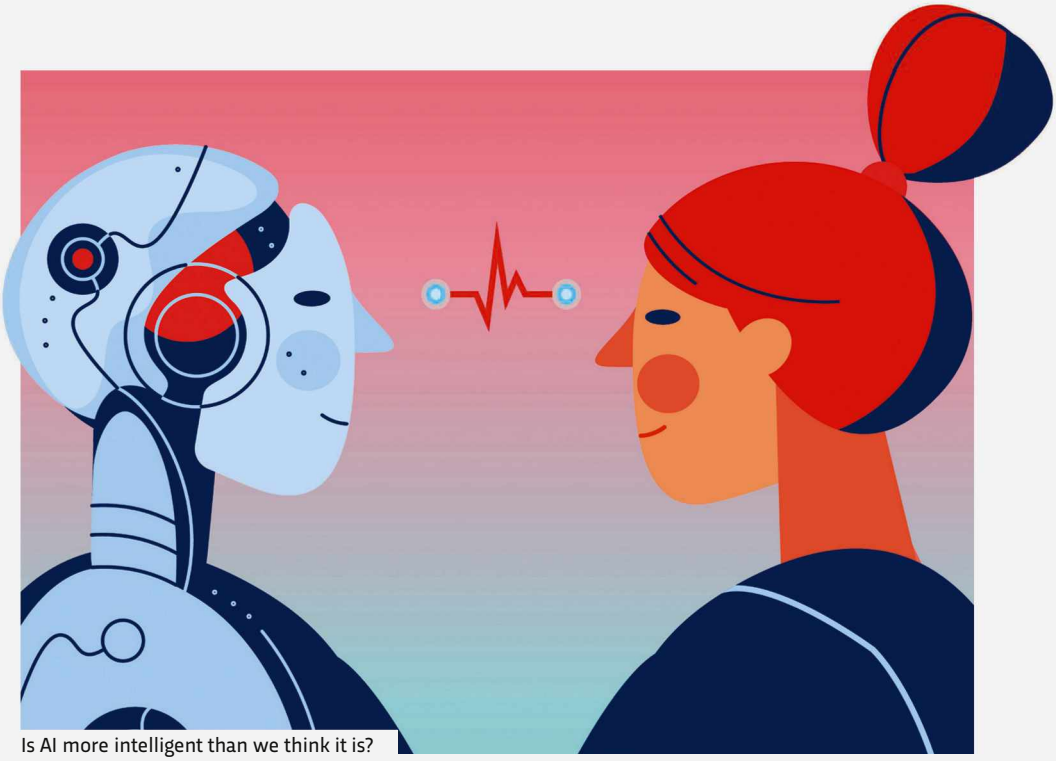
Alan Paine, Lincolnshire



Could there be a world like ours in a parallel universe?

"WE COULD USE MUSIC IN THE FUTURE FOR MANAGING PAIN AND PAIN PERCEPTION"

DR RADHA MODGIL, P28



Is AI more intelligent than we think it is?

ALAMY X2, GETTY IMAGES

Are AIs a step ahead?

Dr Kate Darling wrote about artificial intelligence (June, p34), but I question her claim that a machine can't understand context or concepts. I would direct her to the recent LaMDA interview between a human and a machine, in which the machine displays a remarkable awareness of context and concepts. However, company management insists that the AI system is simply picking out phrases and sentences from many tens of millions in a conversational database.

David Rubin, Oxnard, California

Last issue (August, p34), Dr Kate Darling wrote about this very conversation between LaMDA and a Google engineer. If you missed it, you can read the article on our website bit.ly/kate_darling_lamda

Alice Lipscombe-Southwell, managing editor

Disadvantaged from the start

I would like to add my experience concerning physics education and female students (June, p42). My first course in physics was taught by an elderly gentleman. On the first day of high school, in a class of 12 males and two females, I was shocked to hear him announce, "You young ladies are welcome to stay in my class, but be advised that I do not approve of women in science, and the best grade you will earn will be a B, no matter how well you perform."

The young ladies decided to remain in the class and were given their Bs as promised. I don't know if they later pursued other science courses, but this was the attitude sanctioned by my school towards women in science. It is no wonder that even today young women avoid male-dominated disciplines. I am sure that many of them hear similar stories to mine and give up the struggle before it begins.

Robert Miller, Berlin, Vermont

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DISCOVERIES

"Groundwater is really important for our river flow and for our public water supply."
Prof Kevin Hiscock **p24**

The first uncrewed test launch of NASA's Artemis programme was scheduled for 29 August

NASA/KENNEDY SPACE CENTER

DE-EXTINCTION

GENETICISTS AIM TO RESURRECT THE TASMANIAN TIGER

The marsupial, also known as a thylacine, could be brought back from extinction within the next decade

ABOVE Prof Andrew Pask is leading the team attempting to resurrect the thylacine

Despite the last known example having been dead for close to 100 years, the Tasmanian tiger could soon be on the prowl once again.

Since its genome was sequenced in 2017, many researchers have been looking into the possibility of bringing the Tasmanian tiger back from extinction.

Now, after teaming up with Dallas-based genetic engineering company Colossal Biosciences, geneticists working at the University of Melbourne say they expect to produce their first baby thylacine within the next decade.

"We can now take the giant leaps to conserve Australia's threatened marsupials and take on the grand challenge of de-extincting animals we had lost," said Prof Andrew Pask, leader of the Thylacine Integrated Genetic Restoration Research (TIGRR) Lab.

ABOVE Australia's Hobart Zoo was home to the last captive thylacine, which died in 1936

"A lot of the challenges with our efforts can be overcome by an army of scientists working on the same problems simultaneously, conducting and collaborating on the many experiments to accelerate discoveries. With this partnership, we now have the army we need to make this happen."

In addition to successfully sequencing the Tasmanian tiger genome, the TIGRR team also has the sequences for several of its closest relatives, including the fat-tailed dunnart, or marsupial mouse.

They hope they will be able to use this information to edit living cells from these animals to create 'thylacine' cells using CRISPR, and then grow them into living embryos using assisted reproductive technologies developed on existing marsupials.

Pask and the TIGRR team will concentrate their efforts on developing reproductive technologies such as IVF, along with methods for growing marsupials from conception to birth in a test tube without a surrogate.

Colossal will concentrate on using CRISPR gene-editing techniques to reproduce viable thylacine DNA from stem cells taken from living marsupials.

"The question everyone asks is, 'how long until we see a living thylacine', and I'd previously believed that in 10 years' time we would have an edited cell that we could then consider progressing into making into an animal," said Pask.

"With this partnership, I now believe that in 10 years' time we could have our first living baby thylacine since they were hunted to extinction close to a century ago."

UNIVERSITY OF MELBOURNE, GETTY IMAGES, ALAMY

Thylacine facts

- They were able to open their mouths incredibly wide, almost to a 90° angle.
- They were the largest carnivorous marsupial in modern times, growing up to 130cm from nose to tail and weighing as much as 30kg.
- Like other marsupials, thylacines gave birth to live young that were then raised in a pouch for around 12 weeks until they were strong enough to start living more independently.
- Their close resemblance to dingoes is said to be one of the best-known examples of convergent evolution in mammals. This is a phenomenon by which organisms that are not closely related end up evolving similar traits.
- Thylacines were nocturnal animals and hunted ground-dwelling birds during the night.

MEDICINE

NEED PATCHING UP? HOW ABOUT AN ULTRASOUND BANDAGE THAT CAN SEE INSIDE YOU

A new era of wearable imaging technology will ensure we can keep a closer watch over our bodies

Engineers at MIT (Massachusetts Institute of Technology) have developed a technique that enables ultrasound images of organs within the human body to be captured, using a simple patch that is stuck onto the skin. This could reduce the need for time-consuming hospital visits, and allow for the real-time monitoring of organs, or of stents (tiny tubes inserted into blocked arteries), plates and other surgical implants.

Ultrasound imaging, or sonography – a technique first developed as a means of detecting enemy submarines during WWI – has been used medically since the 1940s. Most people will be familiar with it as the technology used to take pictures of babies inside the womb.

The process works by applying a gel to the skin, which allows ultrasound waves – soundwaves at ultra-high frequencies far above the threshold of human hearing – to reach the skin. A wand-like device then captures the echoes as those soundwaves reflect back off internal structures such as organs, and uses that information to create a visual image of what's going on in the body.

Scientists have previously tried to replace the ultrasound 'wand' with a stick-on flexible patch. Earlier designs embedded the sensors into a stretchy plastic so the patch could move with the patient. But the sensors ended up moving around relative to each other, producing blurry images, a little like trying to take a crisp photo while jogging.

The new patch developed at MIT is different, as it uses a rigid array of sensors that maintain their relative positions (thus ensuring crisp, clean images). They are attached to a three-ply adhesive patch consisting of two thin layers of elastomer, between which sits a middle layer of stretchy hydrogel – a water-based material that facilitates the transmission of the soundwaves.

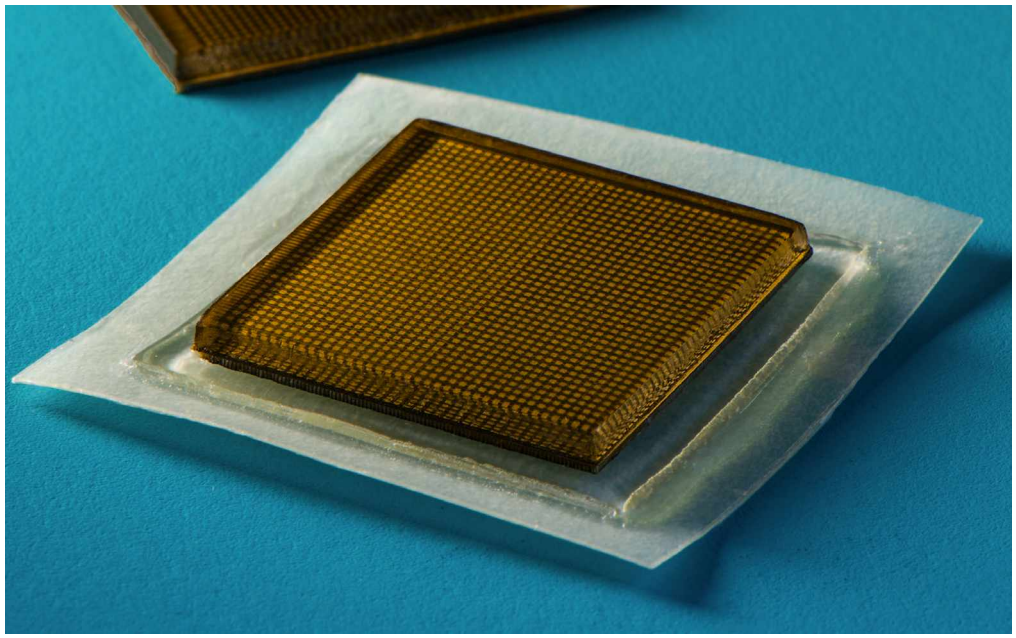
Measuring around two centimetres by two centimetres, and three millimetres thick, it's roughly the same size as a postage stamp. Volunteers sat, stood, jogged and cycled while wearing the patches, and the tiny ultrasound scanners stayed firmly stuck on, while producing clear images of the organs and blood vessels. The patch can provide continuous ultrasound images for 48 hours.

From the images, the researchers were able to see blood vessels dilate and contract, a heart change shape during exercise, and a volunteer's muscles suffer temporary microdamage as they lifted weights.

At the moment, the patch is wired up to a machine that generates the imagery, but the researchers hope to develop a wireless version soon.

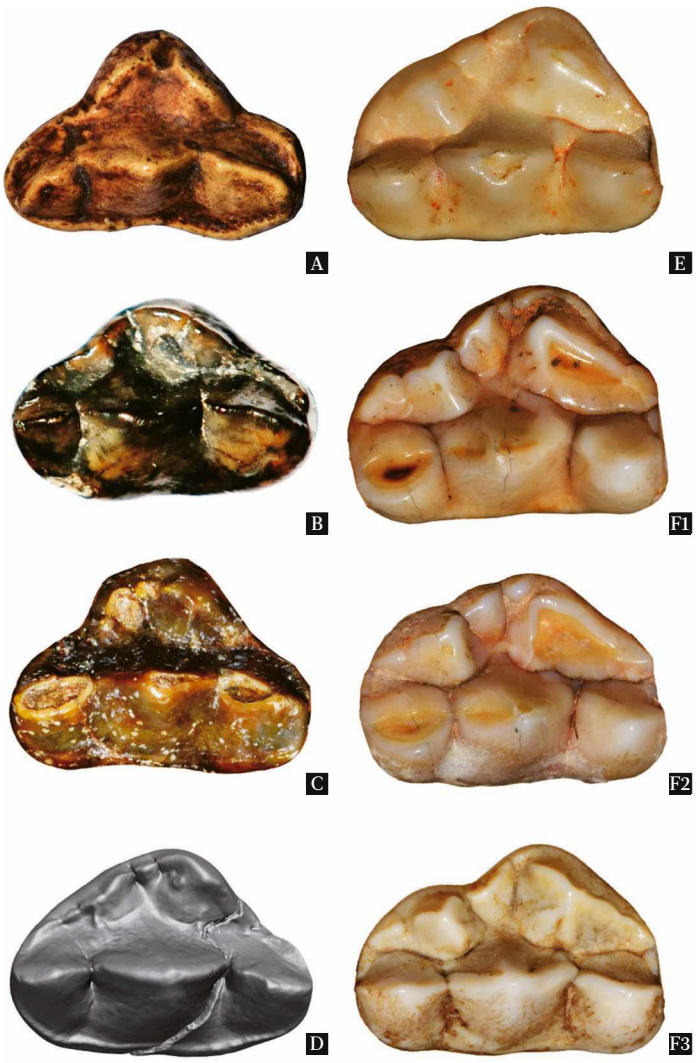
"We envision a few patches adhered to different areas on the body, and the patches would communicate with your mobile phone, where AI algorithms would analyse the images on demand," said MIT engineering professor Xuanhe Zhao, who led the research.

Zhao can see a future where patients can buy patches that will be able to monitor internal organs or the progression of tumours, as well as the development of foetuses in the womb.



The stamp-sized patch will make ultrasound examinations much easier

VELIZAR SIMEONOVSKI CHICAGO, JOURNAL OF VERTEBRATE PALEONTOLOGY, FELICE FRANKEL



PALAEONTOLOGY

GIANT PANDAS ROAMED EUROPE SIX MILLION YEARS AGO

Teeth found in Bulgaria in the 1970s confirm a new species of ancient panda

Closer examination of two fossilised teeth stored at the Bulgarian National Museum of Natural History has revealed they belonged to a species of giant panda that lived in Europe around six million years ago. The two teeth – an upper carnassial and an upper canine – were discovered in a coalfield in northwestern Bulgaria in the 1970s. At the time, palaeontologist Ivan Nikolov put a handwritten label on them and they were added to the museum's collection of fossils. And that, for nearly 50 years, was that.

LEFT Fossilised tooth of *Agriarctos nikolovi* (B) compared to other panda species, including the modern giant panda (F1-F3)

ABOVE *Agriarctos nikolovi* once lumbered around Europe

Recently, a team of palaeontologists led by the museum's Prof Nikolai Spassov have re-examined the fossils, and come to the conclusion that they must have belonged to a giant panda species that lived in the region around six million years ago, during the Late Miocene. "Although not a direct ancestor of the modern genus of the giant panda, it is its close relative," said Spassov.

While it was previously known that pandas could once be found in Europe, debate rages as to whether they spread to Europe from Asia, or vice versa. The new species lived more recently than other known species, leading the team to speculate that this may have been the last panda species to grace the European continent.

Unsurprisingly, the amount of information that can be gleaned from a couple of teeth is fairly limited. As Spassov explains, even establishing that they came from a panda took a while.

"They had only one label written vaguely by hand," he said. "It took me many years to figure out what the locality was and what its age was, and then to realise that this was an unknown fossil giant panda."

What Spassov and co-author Qigao Jiangzuo from Peking University can say is that the panda would have lived in swampy, forested regions – because that's what coalfields once looked like – and that it existed on a largely vegetarian diet. But unlike the modern giant panda, that diet would not have been bamboo. The teeth do not appear strong enough to bite through bamboo stems, and there is little evidence of the plant in the region's fossil record from that era.

It is believed that the ancient species may have fallen victim to climate change. Around 5.33 million years ago, at the end of the Miocene, the Mediterranean basin began to dry up, which would have had a devastating effect on the panda's swampy habitat.

The species would have been similar in size to today's iconic black and white bears. It has been named *Agriarctos nikolovi*, in honour of the man who first labelled the fossils.

The Cartwheel Galaxy, as imaged by NIRCam and MIRI aboard the James Webb Space Telescope

SPACE

NEW IMAGE OF CARTWHEEL GALAXY SHOWS US HOW STARS ARE BORN

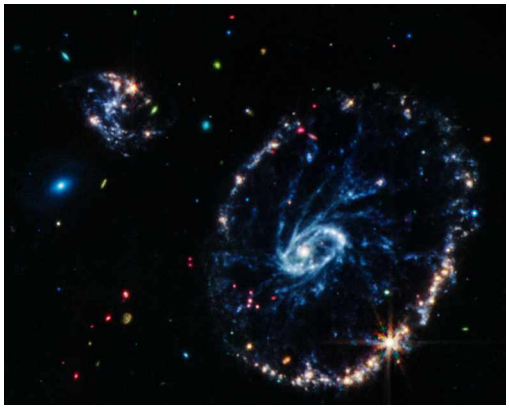
This stunning image released by the James Webb Space Telescope reveals the inner workings of a rare ring galaxy in unprecedented detail

Images captured by the high-precision instruments on the James Webb Space Telescope (JWST) have given astronomers a close-up view of the Cartwheel Galaxy – a bizarre ring galaxy that formed following a collision between a large spiral galaxy and a smaller neighbouring galaxy.

The images were captured by the telescope's Near-Infrared Camera (NIRCam) and Mid-Infrared Instrument (MIRI), and are sharp enough to show the individual stars scattered throughout the galaxy's spectacular form.

The Cartwheel Galaxy was previously captured by the Hubble Space Telescope, but the JWST's capability to detect infrared

NASA/ESA/CSA/JAMES WEBB SPACE TELESCOPE X2



This image, taken by MIRI, gives astronomers information about the distances of additional galaxies in the background; the closest are in blue, the furthest are green and red

"The galaxy is located about 500 million light-years from Earth in the Sculptor constellation"

light has now uncovered new insights about the galaxy's structure and life cycle.

The blue dots seen in the images are individual stars, or areas of star formation, while the red dots show areas rich in hydrocarbons.

The galaxy is located about 500 million light-years from Earth in the Sculptor constellation. Its wheel-like appearance is the result of a highly energetic collision between a large spiral galaxy and a smaller galaxy, which cannot be seen in this image.

It consists of two clearly visible rings – a bright inner ring and a more colourful outer ring. Both rings are expanding outwards from the site of the collision, much like the ripples created by throwing a stone into a pond. And at its centre is a black hole.

The galaxy's bright core is crammed with raging clouds of hot dust and is littered with young star clusters. The outer ring, which astronomers say has been expanding for about 440 million years, triggers the formation of new stars as it collides with surrounding gas.

The researchers say that the Cartwheel Galaxy is in a state of great change and that further study of this mysterious cosmic object will provide insight into its formation, life cycle and future.

BIOLOGY

OUR GUT MICROBIOMES ARE BEING STARVED OF FIBRE

Modern low-fibre diets could increase the risk of cardiovascular disease, digestive disorders and colon cancer, but supplements could help

Current NHS guidelines state that an average adult should aim to consume around 30g of dietary fibre a day. However, recent figures released by the British Dietetic Association suggest that UK adults are eating just 18g a day.

This is bad news, as insufficient fibre in our diets can have a negative impact on our health and could increase the risk of cardiovascular disease, digestive disorders and colon cancer.

Of course, the most straightforward way to address this would be to simply eat more fibre as a natural part of our diets. But in today's world of fast food, ready meals and sugary desserts, this can be difficult. Now, a study at Duke University in the US has found that taking dietary fibre supplements may help to make up the shortfall.

When we consume a high-fibre diet, the organisms that make up our gut microbiome produce fatty acids that protect us from digestive diseases, obesity and colorectal cancer. One particular fatty acid, butyrate, has been shown to improve the gut's resistance to disease, reduce inflammation and improve the health of cells lining the intestine.

"We've evolved to depend on nutrients that our microbiomes produce for us," said study co-author Dr Zack Holmes. "But with recent shifts in diet away from fibre-rich foods, we've stopped feeding our microbes what they need."

The team split 28 participants into groups and gave them one of three types of commonly available fibre supplements – inulin, dextrin and galactooligosaccharides – for one week in different orders.

On the first day of each week the participants were given 4.5g of inulin or dextrin, or 1.8g of galactooligosaccharides, to let their guts get accustomed to the new fibre intake. The dose was then doubled in each case for the rest of the week. After each week-long course, they gave the participants a week off to allow their guts to return to their normal state.

Participants who were already consuming a high-fibre diet saw little change in their gut microbiomes. However, participants who had been consuming the least fibre saw a significant increase in butyrate, regardless of which supplement was being consumed.

"We didn't see a lot of difference between the fibre supplements we tested. Rather, they looked interchangeable," said study leader Dr Lawrence David. "Regardless of which of the test supplements you pick, it seems your microbiome will thank you with more butyrate."

ZOOLOGY

THE ITSY BITSY SPIDER DREAMED OF A WATERSPOUT

REM-like sleep behaviour has been observed in arachnids for the first time

Jumping spiders show signs of REM sleep when they get 40 winks (or should that be 160 winks?)

Do spiders dream of catching flies? Maybe! A team of researchers, led by Dr Daniela C Rößler from the University of Konstanz, have uncovered tantalising evidence that jumping spiders go through different sleep stages, including REM-like sleep, which has never before been observed in arachnids.

This discovery sheds new light on the mystery of sleep in the animal kingdom. We know from human studies that our most vivid dreams occur during the rapid eye movement (REM) stage of sleep, and these findings also raise the possibility that spiders may have visual dreams.

Most spiders have two principal eyes that see detail and colour, as well as six smaller eyes. There are more than 6,400 species of jumping spiders in the world, and they are renowned for their excellent vision. Part of the reason for this is down to the moveable retinal tubes at the back of their principal eyes, which allow them to redirect their gaze.

As juvenile jumping spiders are transparent, the researchers were able to directly study the spiders' retinal movements while they were asleep. Using an infrared camera, the team observed the nocturnal resting behaviours in 34 newly hatched *Evarcha arcuata* jumping spiders. The spiderlings were immobile throughout the night, hanging upside-down from a strand of silk, with their legs curled inwards. Periodic bouts of retinal movements were observed, coupled with limb twitching and leg-curling behaviour. This was followed by apparent cleaning sequences of brushing moments, which implied brief awakenings after the REM sleep-like states.

They found that the bouts of retinal movement were consistent, including regular durations and intervals, with both increasing over the course of the night. This is consistent with known REM sleep-like behaviours from other species.

Scientists are fairly confident that all animals sleep, although this looks different for different species. One thing that most agree on, however, is that REM sleep is potentially important for the consolidation of memories and honing important survival skills.

"Given that we have some first evidence that something like REM sleep may exist in a terrestrial invertebrate, opens up tonnes of new research. Is it also present in other arthropods? Insects? Just because eyes are not moveable, it may not mean that a state similar to REM cannot be present," said Rößler.

"We found a system in which we will be able to study sleep, and REM sleep-like states. How much, and how 'well' these animals sleep in nature compared to the lab may be a completely different story – and this may also have implications on the function of these REM-like states."

GETTY IMAGES, SALK INSTITUTE

HEALTH

GENE THERAPY HEALS MALFUNCTIONING CELLS IN EAR

The findings could offer hope to people with hearing loss

Tiny sensory hair cells called stereocilia, located in your inner ear, are responsible for detecting sound. When these become damaged, either by genetic disorders, loud sounds or old age, it can lead to hearing difficulties and even deafness.

Now, in a series of experiments on mice, researchers based at the Salk Institute and the University of Sheffield have identified a protein that can be delivered to these hair cells via gene therapy in order to trigger their growth.

"Our discovery shows that hair cell function can be restored in certain cells," said co-author Dr Uri Manor, assistant research professor and director of the Waitt Advanced Biophotonics Core at Salk.

"I was born with severe to profound hearing loss and feel it would be a wonderful gift to be able to provide people with the option to have hearing."

Deafness that occurs in children before they are able to speak is commonly due to genetic factors. One such factor can lead to the stereocilia being underdeveloped, resulting in deafness.

Stereocilia hair cells are found throughout the cochlea, the spiral tube-like structure found within the inner ear. Regions of the cochlea that sense low frequencies have longer stereocilia, while regions that sense high frequencies have shorter stereocilia. When sounds enter the ear, they cause fluid within the cochlea to vibrate, which in turn causes the stereocilia to move. These hair cells then send signals to neurons, which pass on information about the sounds that we are hearing to the brain.

In a previous study, Manor found that the protein EPS8 was involved in determining the length of stereocilia. Without the protein, the growth of the hairs is stunted, and they remain very short.

In another earlier piece of research, co-author Prof Walter Marcotti, of the University of Sheffield, also discovered the link between EPS8 and stereocilia development.

For this latest study, the two researchers teamed up to design an experiment to see if adding EPS8 to stereocilia hair cells could trigger their regrowth and improve hearing in mice. They used a common gene therapy technique to deliver the protein to the hair cells on the back of a virus. They then investigated the effects using imaging techniques.

The team found that EPS8 increased the length of the stereocilia and restored their function in low-frequency cells, although not enough to restore the hearing of the mice.

However, they also found that the cells seemed to lose their ability to regenerate as they aged.

"EPS8 is a protein with many different functions, and we still have a lot more to uncover about it," said Manor.

"I am committed to continuing to study hearing loss and am optimistic that our work can help lead to gene therapies that restore hearing."

The researchers now plan to investigate the action of EPS8 further, with the hope of extending the age range over which it is effective.

> "I am optimistic that our work can help lead to gene therapies that restore hearing"

From left to right: short, medium and long stereocilia, treated with EPS8 (purple)

SPACE

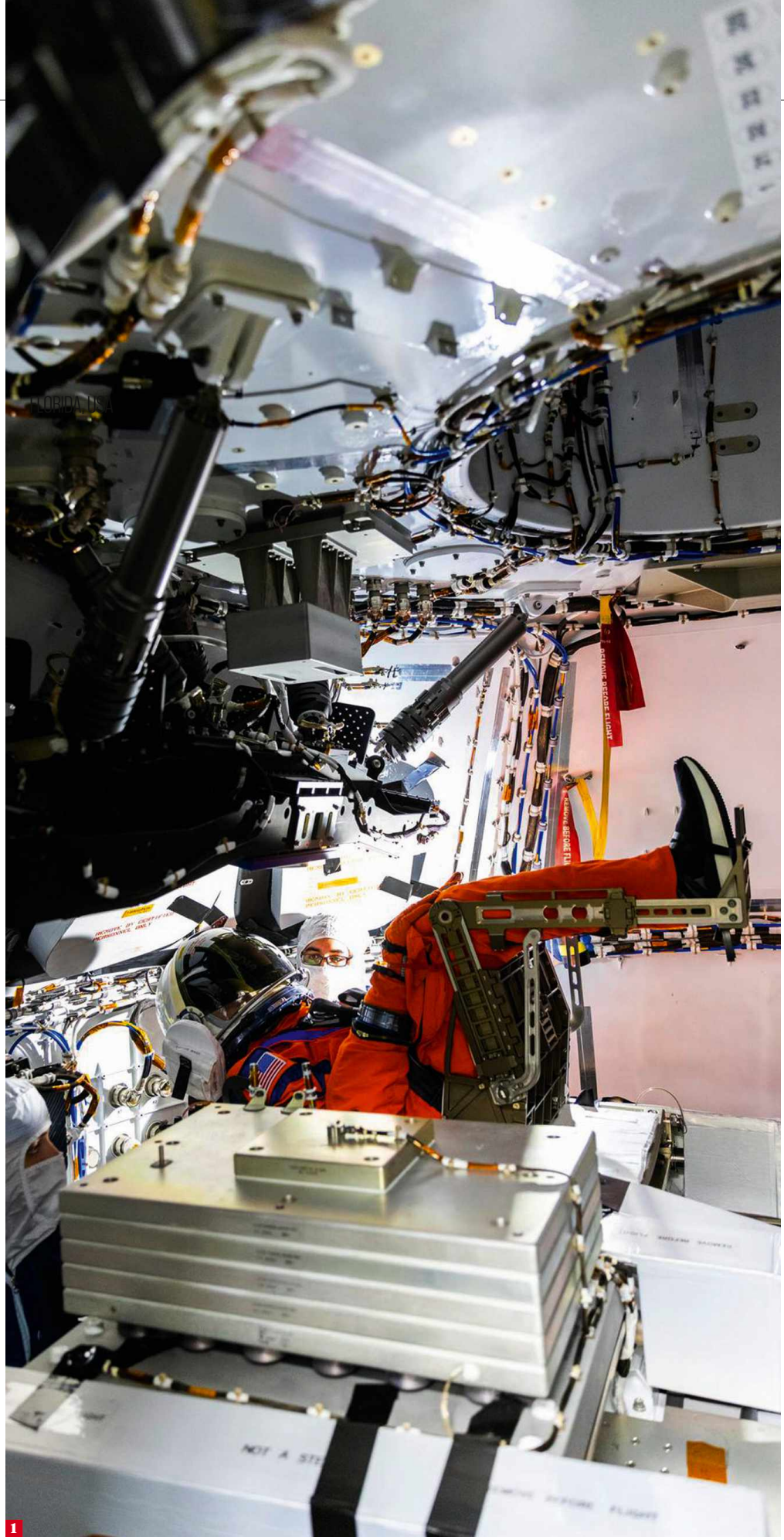
DESPITE DELAY, NASA'S ARTEMIS PROGRAMME IS SET TO PUT HUMANS BACK ON THE MOON

As *BBC Science Focus* went to print, NASA had made a last-minute delay to the launch of Artemis 1 – the first of three missions that will culminate with humans walking on the Moon for the first time since 1972.

With an imminent launch still on the cards, the uncrewed mission will see the first test of the Space Launch System (SLS) rocket and the Orion spacecraft.

Orion will detach from the SLS after launch, perform an orbit around the Moon, and then finally splash down in the Pacific Ocean after around six weeks – the longest time any spacecraft built for astronauts has spent in space without docking to a space station.

Following Artemis 1, the space agency plans for Artemis 2 to take four astronauts on a flyby of the Moon in 2024. And then in 2025, humans are scheduled to set foot back on the lunar surface with the Artemis 3 mission.



NASA/KENNEDY SPACE CENTER X4

1. Commander Moonikin Campos is a mannequin being used to measure the effects of acceleration and vibrations in space on future human astronauts. Named after Arturo Campos, an engineer who helped to save the Apollo 13 crew in 1970, the mannequin is pictured here in the commander's seat of Orion wearing an Orion Crew Survival System flight suit – the same uniform that will be worn by the Artemis 2 and 3 crews.

2. Here, the Orion spacecraft can be seen mounted atop the SLS (Space Launch System) rocket – inside High Bay 3 of the Vehicle Assembly Building at Florida's Kennedy Space Center.

3. A pair of anatomically correct torso dummies, named Helga and Zohar, are positioned on Orion in order to study how radiation affects the human body during lunar flight. They are made of materials specifically designed to mimic bones, soft tissue and organs.

4. Following a 10-hour, 6.4km journey from the Vehicle Assembly Building, the SLS rocket and Orion spacecraft are in position on top of a mobile launcher on the Kennedy Space Center's Launch Pad 39B.


United States
NASA
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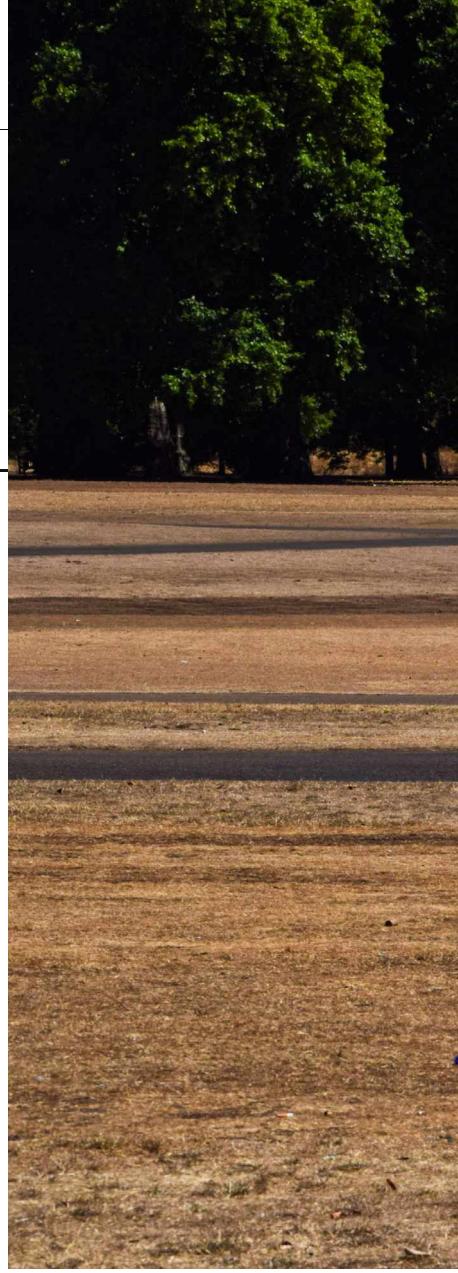
NASA

HORIZONS



CLIMATE CHANGE

HOW BETTER WATER MANAGEMENT COULD HELP US COPE WITH DROUGHT IN THE FUTURE

An environmental scientist tells us about the growing issue of depleting water resources in the UK and what can be done about it

IS THERE A DEFINITION OF DROUGHT?

There isn't a scientific definition of 'drought'.

We can think of a meteorological drought in terms of a deficit of rainfall, like we have seen in the last few months. Or there is agricultural drought, particularly if the dry weather happens at the same time as the irrigation season in the summer. But there is also hydrological drought, which is perhaps the worst in respect of maintaining the water supply, for both our drinking water and also to support the environment. These will develop over a longer period than several weeks of no rainfall.

In the recent period, we've seen months of lower rainfall than usual. A dry spring leading into a dry autumn or winter makes the problem even worse.

Next year, we could see more of an issue if we don't get some rainfall over the critical winter period.

HOW DOES WATER MOVE AROUND THE LANDSCAPE?

Rain infiltrates the soil and then slowly moves down to the water table. Gradually that water will move towards the discharge area, which is the river or a wetland.

England is underlain by chalk. And that chalk is a huge reservoir of water. One-third of the drinking supply in England will be from the chalk aquifer. Essentially, we've got this large water cycle of rainfall, infiltration, rainwater discharge into the river and then down to the estuary, back to the sea. Groundwater is really important for our river flow and for our public water supply.

WHAT IS THE CURRENT SITUATION WITH UK WATER RESOURCE MANAGEMENT?

All water companies go through a five-year planning cycle, the so-called asset management period cycle. They should be looking at their long-term projections for demand, which will take into account population increase, as well as climate change factors. If insufficient water is available in the long-term, you've got to plan to build storage into the system.

We need to build headroom and that depends on the nature of your geography, such as whether you have groundwater resources that you can use, or whether you are dependent on surface reservoirs like in the west and the north of the country.

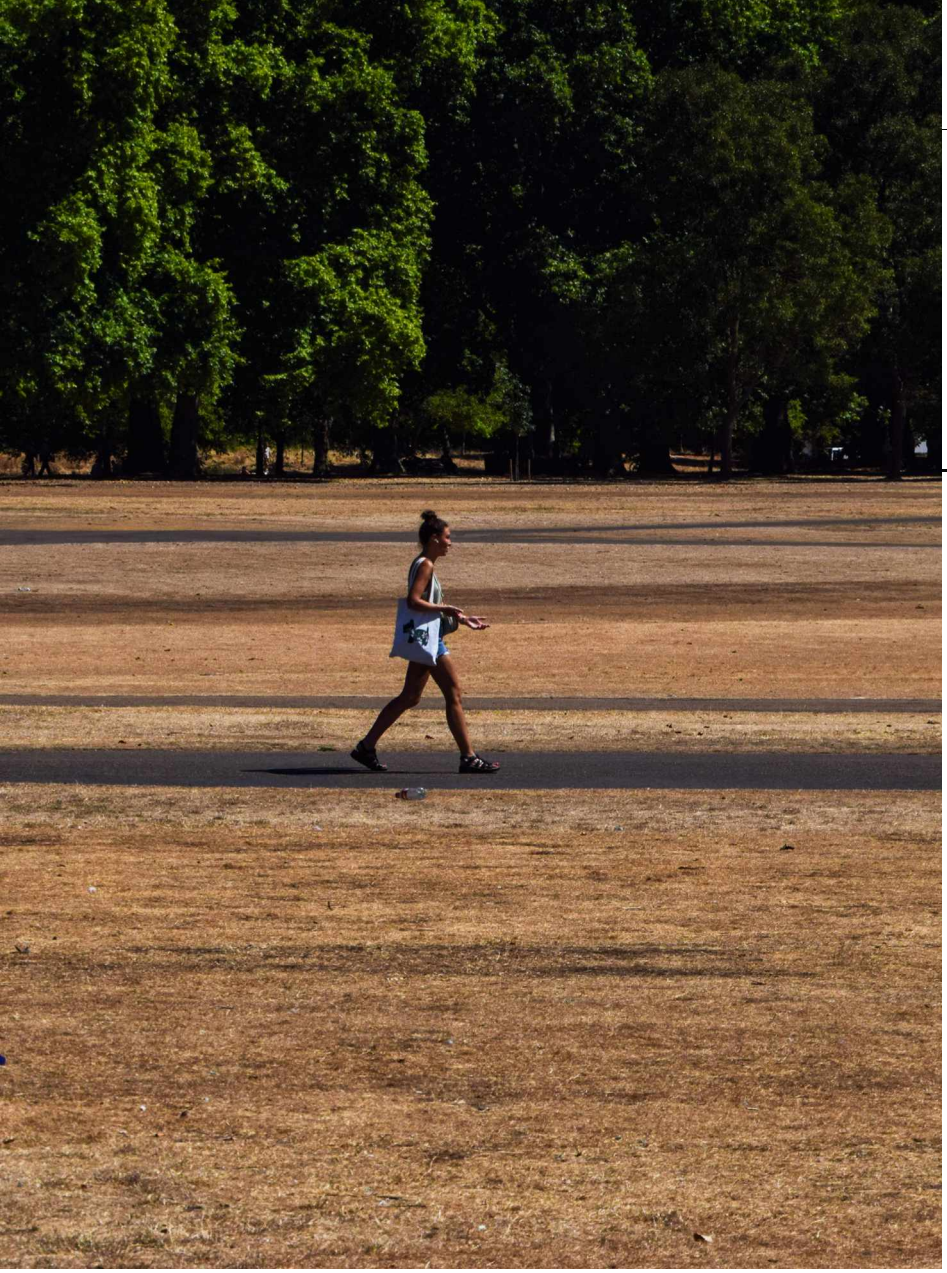
You can move resources around. So, for example, in the wetter northern parts of Britain, you could divert water southwards, which we see presently with a big pipeline that's being built from Humberside down to Essex, to try and redistribute the water resource.

THE HEADLINES ALWAYS TALK ABOUT HOSEPIPE BANS, BUT WHAT ABOUT WATER SUPPLY FOR AGRICULTURE AND FOOD INDUSTRIES?

We're seeing now that crops are just dying in the fields. The Environment Agency has the power to stop farmers from irrigating – the so-called Section 57 of the Water Act – and that is when the farmers particularly get upset. But this summer period, farmers have been able to continue irrigating towards the end of the season.

When I think back to the drought of 1989 through to 1992 in the Anglian region, there was a ban on irrigation and the farmers were very unhappy with that. And so you get this classic conflict of interest between the need to protect the water, the public supply, and the need for irrigation of farmland.

GETTY IMAGES



A woman walks through a parched Hyde Park in August this year

“We can use sustainable urban drainage systems. These are things like ponds or wetlands within a new housing development”

ARE THERE ANY OTHER LAND MANAGEMENT SOLUTIONS?

Planting woodland or introducing beavers into the landscape is effective. Water engineers also have ways of cultivating the ground to create a more textured soil so that water infiltration occurs more easily. You have approaches like regenerative farming, or minimum tillage, to avoid ploughing of the soil. We can help build the soil structure and increase the organic content in that soil. It becomes more fibrous and is able to act like a sponge.

I also think that we can extend these ideas into the built environment. Think about the amount of concrete and tarmac in urban areas and how quickly you see flooding. We can use sustainable urban drainage systems. These are things like ponds or wetlands within a new housing development. Greening up our urban space and thinking in terms of these sustainable drainage systems is another good way of keeping water in the catchment.

HOW CAN THE PUBLIC HELP?

I think we can all help. Avoid using the hosepipe or the sprinkler, and only put the dishwasher or the washing machine on when they’re full. Harvest rainwater in a water butt for watering the garden during a dry spell. Take showers instead of baths. I’m amazed that we never have a label on, say, a washing machine telling of high water efficiency, like we already have for energy efficiency.

WHAT DOES THE FUTURE LOOK LIKE?

Periods like this will become more frequent. This is the best that we can see from the climate-modelling scenarios, even though there’s uncertainty around predicting rainfall.

By our best estimates, the scenarios for the future climate suggest that in the south and east of England there will be increasing summer drought frequency and more intense drought. But that’s not for the whole of the UK. As you go towards the northern part of the UK, the scenario there is for normal or wetter conditions, but not quite the severity that we might expect in terms of droughts in the future.

The other characteristic is the all-important winter rainfall, when we need the recharge to occur, to top up the aquifers that support our rivers. This rainfall will occur on fewer days.

PROF KEVIN HISCOCK
Kevin is a professor of environmental sciences at the University of East Anglia, researching the impact of land management and climate change on water supplies.

THE FUTURE'S BRIGHT...

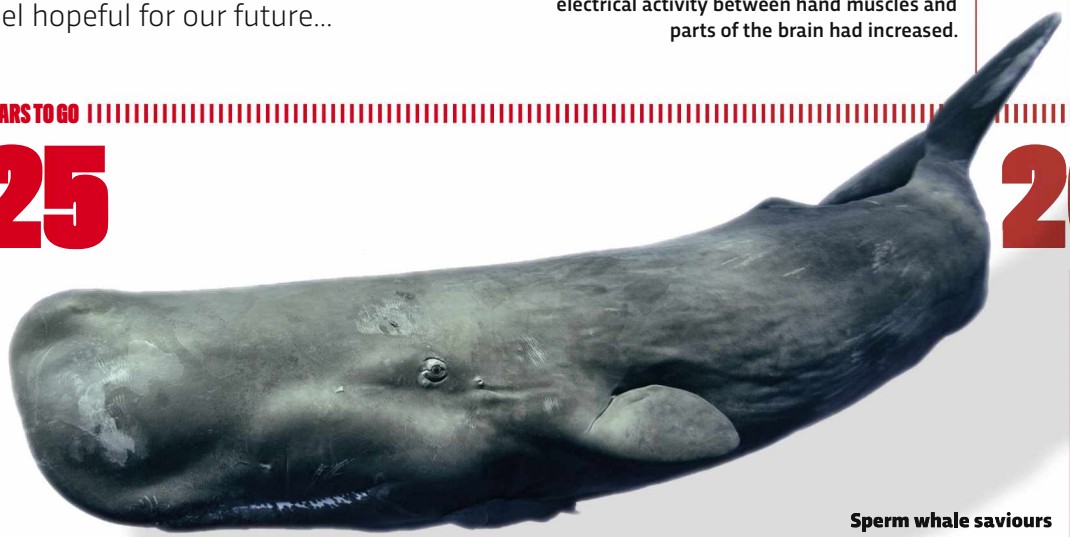
As a remedy for all the bad news out there, let us prescribe you a small dose of feel-good science. Each issue, we'll give you a rundown of the latest breakthroughs that aim to solve humanity's biggest problems. From pigskin eye implants to faster transatlantic flights, here you'll find many reasons to feel hopeful for our future...

Robots for stroke patients
To help paralysed stroke patients, research is being carried out to find out if brain activity can control a robotic device to move a limb. It's early days, but scientists have tested a brain-robot interface, with indications that synchronised electrical activity between hand muscles and parts of the brain had increased.

Pigskin eye implants
Human tissue is traditionally required for corneal transplants, but it's in short supply. Researchers have looked to pigs to solve this problem, with implants engineered out of protein from pigskin. A sample of 20 people with cornea-damaging keratoconus, have had their vision improved by receiving these implants.

YEARS TO GO

25



Reverse skin cells
Would you like a few decades added onto your life? A new UK study has shown the successful de-ageing of skin cells taken from middle-aged people. Once reprogrammed, these de-aged cells had collagen levels found in cells 30 years younger.

20

Sperm whale saviours
To help save the remaining 200 sperm whales in the eastern Mediterranean, a team of Greece-based researchers have developed a detection system that can pinpoint a whale to an accuracy of a body length or two. Called SAvEWhales, this will help prevent ship strikes.

Hope for people with PTSD
Antiviral medicine used to treat hepatitis C (a virus that affects the liver) could improve symptoms of PTSD (post-traumatic stress disorder) in soldiers. A selection of US military veterans with hepatitis C have already been tested with promising results. Comparative tests, on veterans without the virus, are next.

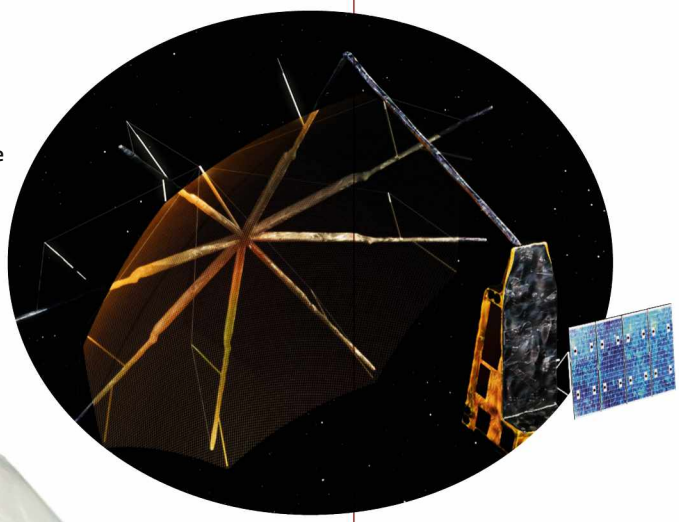
GETTY IMAGES X6,OVERTURE, ESA, BENJAMIN WILEY/DUKE UNIVERSITY, THOR BALKHED

Extending dogs' lives
We may want to live forever, but what about our pets? The Dog Aging Project expects to increase the lives of our canine companions by three years, by reducing chronic inflammation with a trial of the anti-ageing drug Rapamycin.

Quicker transatlantic flights
Flight times between London and Miami could be cut in half to just under five hours, as American Airlines has announced the purchase of 20 Boom Supersonic Overture aircraft. Dubbed the 'son of Concorde', these planes will reach Mach 1.7 (2,099km/h), the speed of sound. The first commercial flight is due in 2029.

10

Hydrogel that outperforms cartilage
Because cartilage tends to wear out, joint pain is a common ailment in the ageing population. To solve this, US researchers have developed a hydrogel, made of stretchable cellulose fibres, which is even more durable than the real thing.



Space launch to study our planet's forests
A reflector-antenna, resembling a huge umbrella, is heading into space to analyse Earth's forests, as a key component on the European Space Agency's BIOMASS mission. After launch in 2023, the BIOMASS Earth Explorer satellite will study trends of tree growth in forests over five years.

0

Black tea reduces mortality
Can you add a few years to your life by drinking black tea? The answer is yes, according to the US National Institutes of Health, which says the risk of mortality may be reduced by drinking two or more cups per day!

COMMENT

IF MUSIC BE THE CURE FOR PAIN, PLAY ON

What if music could help boost the power of our painkillers?

All of us will have experienced pain at some point in our lives. We all know how pain can affect our physical activities, but it also affects how we feel mentally and emotionally, as well as other health-related factors such as our ability to sleep. This is especially true for those who suffer from chronic pain.

When we have an injury, pain signals travel along specialised nerve fibres and the spinal cord up to reach parts of our brain. Both the brain and spinal

cord have a role in processing the signals, and work together to create the feeling and perception of pain.

The prevalence and widespread impact of pain on our lives was set out in the 2017 Health Survey for England. Around 34 per cent of respondents reported some level of chronic pain. And out of them, 34 per cent reported 'high interference' and 66 per cent reported 'low interference' with their usual daily activities.

Currently, opioids are often prescribed to help acute or end-of-life pain, but there is little evidence for them being helpful for long-term chronic pain. Despite this, from 1998 to 2016, prescriptions for opioids increased by 127 per cent in the UK, a trend which has led to more focus on the monitoring of their use.

And in September 2020, the Medicines and Healthcare products Regulatory Agency (MHRA) issued stronger warnings about dependency and addiction as risks of opioid use.

We are now in a situation where the risks of opioids are clear and yet the need for effective pain management is high. So, are there alternatives? The National Institute for Health and Care Excellence (NICE) offers some other solutions, including exercise programmes, psychological therapy and other pharmaceuticals.

But several groups of researchers from across the globe are looking into an entirely different method of treating pain: music.

A landmark study carried out by a group of dentists in Massachusetts in 1960 unearthed the possibility that sound and music could help alleviate pain. The researchers played music to patients during 5,000 dental operations and found that it encouraged relaxation. Noise suppressed pain directly, with some people not needing local anaesthetic or nitrous oxide for pain relief.

More recently, a study carried out by researchers in China identified the neural mechanisms by which sound can lessen pain – albeit so far only in mice. These mechanisms involve the auditory cortex and the thalamus. The auditory cortex is a receiver and processor of sound, and the thalamus receives various sensory inputs and signals and relays them. It is thought this is the sound pathway that can lessen pain.

In their experiment, the Chinese researchers played a piece of classical music, a burst of white noise and an unpleasant arrangement of music to mice with inflamed paws. All three sound pieces, when played at 50 decibels – about the same volume as a quiet conversation – reduced sensitivity to pain. The mice didn't flinch or lick or pull their paws away. The key factor to producing the pain-reducing effect appeared to be the *volume* of the sound rather than the *type* of sound.

Taking this a step further, the researchers then monitored the neural activity in the auditory cortex. They found that the sounds blocked the communication between the auditory cortex and the thalamus, and so reduced the pain processing in the thalamus. This exciting new research may form a basis for how we could use music in the future for managing pain and pain perception. Further work is still needed to see if this effect in mice will carry over to humans.

Of course, how mice perceive music and what it means to them is impossible for us to know. As humans, we have all experienced how often unexplainable and unmeasurable nuance and emotion is involved when we listen to music – not just the instrument type, or the genre, but the lyrics, the rhythm and pitch, and also the emotional memories and associations that every piece of music holds for us.

While it's too early to suggest sticking on some R.E.M. next time you get an injury, it seems that music's unique ability to tap into our experience and perception could be a powerful tool in the treatment of pain in the future.

"Researchers played music to patients during 5,000 dental operations and found that it encouraged relaxation. Noise suppressed pain directly, with some patients not needing pain relief"

BBC RADIO 1

Listen to Dr Radha Modgil on *Life Hacks* on BBC Radio 1.

DR RADHA MODGIL
(@DrRadhaModgil)
Radha is an NHS doctor, broadcaster and wellbeing campaigner. She is the medical expert on BBC Radio 1's Life Hacks. *Her first book,* Know Your Own Power *(£14.99, Yellow Kite), is out now.*

ILLUSTRATION: MARIO WAGNER

COMMENT

THERE'S A REASON WHY WE ALL PREFER R2-D2 TO C-3PO...

Humanoids have long been regarded as the 'holy grail' of robotics but there's room for a lot more diversity in design

In August 2021, Tesla CEO Elon Musk revealed his company's plan to produce a humanoid robot called 'Optimus'. The announcement, accompanied by a dancing actor in a skintight robot costume, was ridiculed by sceptics, but Tesla is not alone in the quest to create human-shaped machines.

Research labs and companies around the globe are investing serious amounts of money in these complex robots, which could have uses in everything from warehouses to nursing homes. Their pitch is two-fold: the human form is relatable, and it fits seamlessly into our existing infrastructure. These reasons are sensible, but there might be a better way forward.

Humanoids, sometimes called the 'holy grail' of robotics, are robots with a torso, two legs, two arms, and a head. Google image search the word 'robot', and your browser will fill with humanoids. Some robot creators argue that the autonomous machines we'll interact with in the future need to look like us, because we relate best to other humans. It's true that we connect emotionally with machines onto which we can project our own traits, but the notion that we most relate to a human shape may be missing something.

"Robots can be smaller than the eye can see, or larger than a house. They can be encased in metals or soft materials. They can roll, climb, slither, or ooze"

DR KATE DARLING
(@grok_)
Kate is a researcher at MIT, where she investigates technology and society, and studies human-robot interaction.

People name their robot vacuum cleaners. Would they like it better if it was a humanoid that walked around vacuuming? Probably not. When something has a human form, we have very different expectations for its intelligence and how it will perform. Our current robots don't live up to those expectations, nor will we have a robot butler anytime soon.

Things don't need to be humanoid for us to relate to them – they just need to mimic cues that we recognise. Artists and animators have honed the art of capturing our expressions and gestures, then putting them into other shapes – think Bambi, *Cars*, or the Pixar lamp.

Japanese cities have attracted visitors with mascots like Kumamon, a simple, cute bear character created by the government of Kumamoto Prefecture to boost tourism. And thousands of *Star Wars* fans love R2-D2, who is basically a tin can on wheels and more emotionally compelling than most humanoids.

Shunning the human form when designing robots not only avoids the problem of expectation management, it can also sidestep a minefield of social injustices. For example, researchers from the University of Bielefeld, Germany, found that people will rate a humanoid robot with long hair as better suited for stereotypical female tasks like household and care work, and less suitable for doing technical repairs, compared to an identical robot with short hair.

Previous studies have shown that artificial agents with human faces are seen as more attractive, trustworthy, persuasive and intelligent when they're of the same ethnicity as the person rating them. Technology that looks too human not only reflects our own biases, it can entrench and perpetuate harmful stereotypes.

There's also the logistical argument for humanoid robots: we live in a world built for humans, with stairs and doorknobs and narrow passageways. In order to navigate these spaces, some designers say that we'll need robots that are built like us. It's certainly true that many spaces are difficult to navigate with wide bodies, wheels, or treads. But as we look to the future, maybe there are better choices.

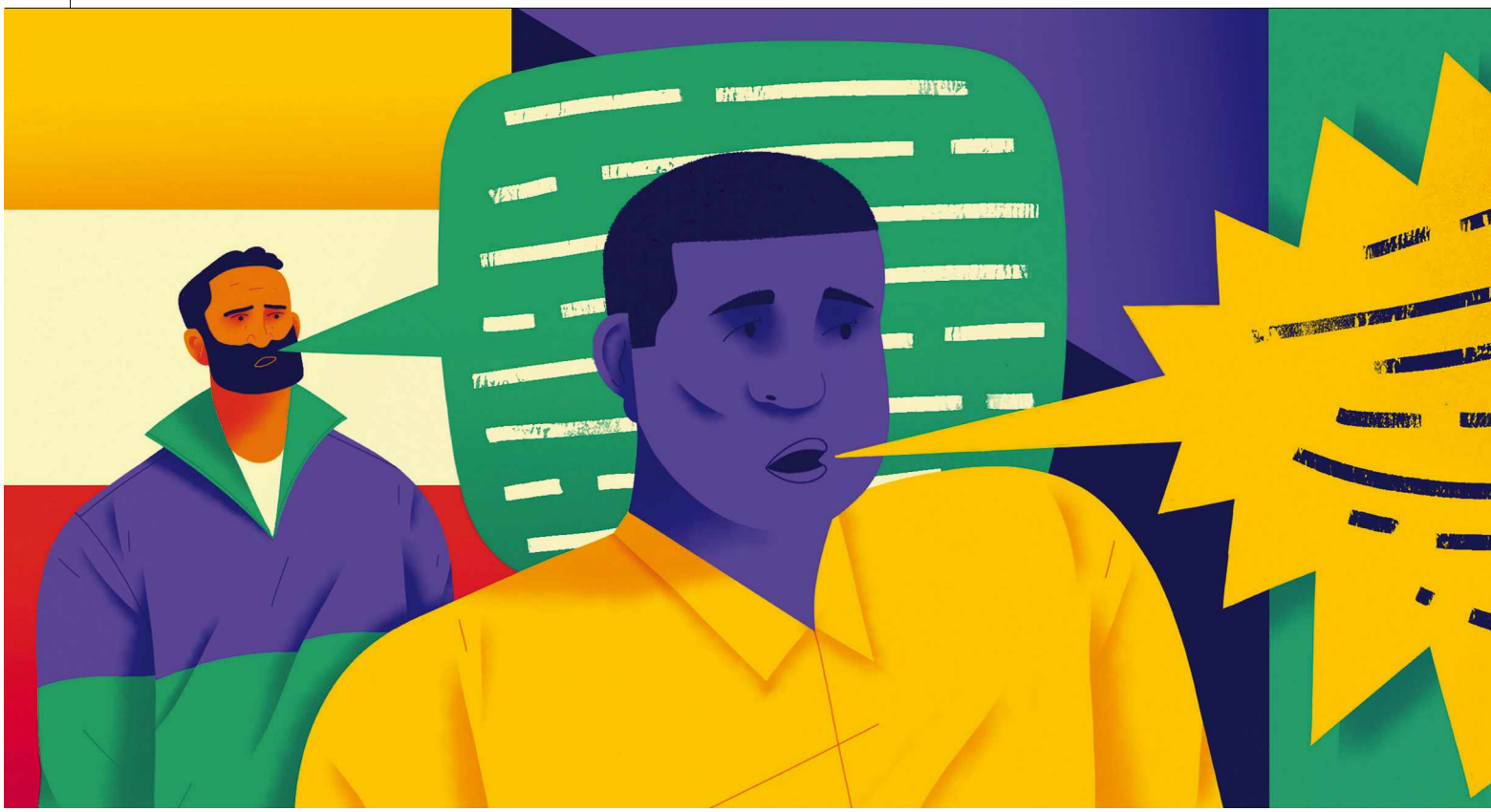
Robots can be smaller than the eye can see, or larger than a house. They can be encased in metals or soft materials. They can roll, climb, slither, jump, or ooze from point A to B. According to roboticist Dr Robin Murphy of Texas A&M University, the best form is "whatever shape gets the job done".

Dr Laurel Riek, a roboticist at the University of California, San Diego, has pointed out that rather than throwing our funds into expensive, difficult to engineer, bipedal humanoid robots, we could invest in making infrastructure more friendly for wheelchairs, walkers and prams. If a wheelchair can access a space, so can a simple and efficient robot on wheels.

Human beings are far from uniform in our construction and abilities, and if we design our world to reflect that, we could radically increase accessibility at the same time as developing better, cheaper robots with a greater range of skills. And besides, why take the stairs when you can climb the walls?

While there will always be some cases for humanoid robots, we may be able to do better than replicating what we already have. As robots move from behind factory walls into shared spaces, robotics provides us a wonderful opportunity: it allows us to think outside of ourselves, not only in designing our robots, but also in our ideas for how to construct a better world.

ILLUSTRATION: VALENTIN TKACH



COMMENT

TRANSLATION ERRORS COULD SEND INNOCENT PEOPLE TO JAIL

Using interpreters in police interviews can distort how suspects and witnesses are evaluated, leading to incorrect convictions

DR JULIA SHAW
(@drjuliashaw)
Julia is a psychological scientist at University College London, the author of multiple best-selling books, and the co-host of the hit podcast Bad People *on BBC Sounds.*

Picture this. You are in a foreign country. The police arrest you and realise that you don't speak the language. So, they organise someone to translate. If you're lucky, the person they contact is a professional interpreter. If you're unlucky, the person is a multilingual police officer who happens to speak your language just well enough to scrape through an interview. Either way, you are now having to talk through someone else.

Does this interpreter-mediated interviewing put you at a disadvantage? If so, how much? The answer to this lies at the intersection of criminal psychology and cognitive linguistics, where researchers have realised that interpreters are an overlooked barrier between suspects and their freedom.

One of the most active researchers looking at these issues is Luna Filipović, a professor of language and cognition at the University of East Anglia. She has been studying the effects of multilingual police interviews for more than a decade. She writes that having someone to translate can be taken for granted as enough to make a police interview fair. But she says this is an incorrect assumption, as it ignores how difficult translation is, and the problems that come from the logistics of translating in typically high-pressure, highly emotional legal settings.

An interpreter might not speak both languages equally well, so important words or descriptions can get mistranslated. Some words don't have equivalents, and turns of phrase translated literally can become nonsensical or misleading.

Filipović has found various errors which can creep in and influence trustworthiness. In an example she lists in her 2007 research, the Spanish word *amigo* is translated by an interpreter into the familiar 'friend' instead of the unfamiliar 'guy'. When the police officer then asks what the name of this friend was, the suspect says he doesn't know, to which the officer reacts with suspicion. This kind of error can lead to a feeling that a suspect has something to hide, when really all that's happening is a language barrier that neither side realises is there.

Then there's the problem of inadvertent confessions. This happens when someone seems to be giving a confession to police, without realising that's what they are doing. It can also happen when police think they have a confession, or an admission of guilt for part of a crime, when that's not actually the case.

ILLUSTRATION: CATHAL DUANE

"Those who speak little or no English are more likely to incriminate themselves in the UK"

In other words, it's a statement that incorrectly gets translated into, or understood as, a confession.

In 2021 Filipović published research on UK and US police interviews. She provides an example of a real US case, in which a suspect who only speaks Spanish is accused of murder. The following is a transcription of the interaction, with the translation in brackets.

Police officer: Okay, and then what did you do with her?
Interpreter: Y que pasó? [And what happened?]
Suspect: … se me cayó en las gradas.
Interpreter: … I dropped her on the steps.
Police officer: Where did you drop her?
Interpreter: Donde la botaste? [Where did you throw her?]
Suspect: Aqui… [Here…]

This doesn't seem like much, but as Filipović explains, the suspect was using a Spanish sentence that makes it clear that he dropped the woman by accident. Because there isn't a single word for this in English, the interpreter went for the closest alternative, 'dropped'. However, in this context it makes it sound like he did it on purpose. Presumably not noticing the swap, the suspect then inadvertently confesses to the much more serious crime of murdering a woman by throwing her down the stairs rather than dropping her by accident. This nuance that was lost in translation could have potentially cost him life in prison.

Because of such problems, Filipović has found that those who speak no or little English are more likely to incriminate themselves inadvertently in the US or UK than people whose first language is English.

If you do ever find yourself accused of a crime in a foreign country, try to get a professional interpreter as opposed to multilingual relatives, friends, or police. Regularly double-check that you really understand what the police officer is asking.

You could ask for a transcript of the interview to be made available afterwards, which can also help police, lawyers, and judges see any mistranslations that may have crept in.

Be that slightly annoying person who asks too many questions because the alternative is likely much worse.

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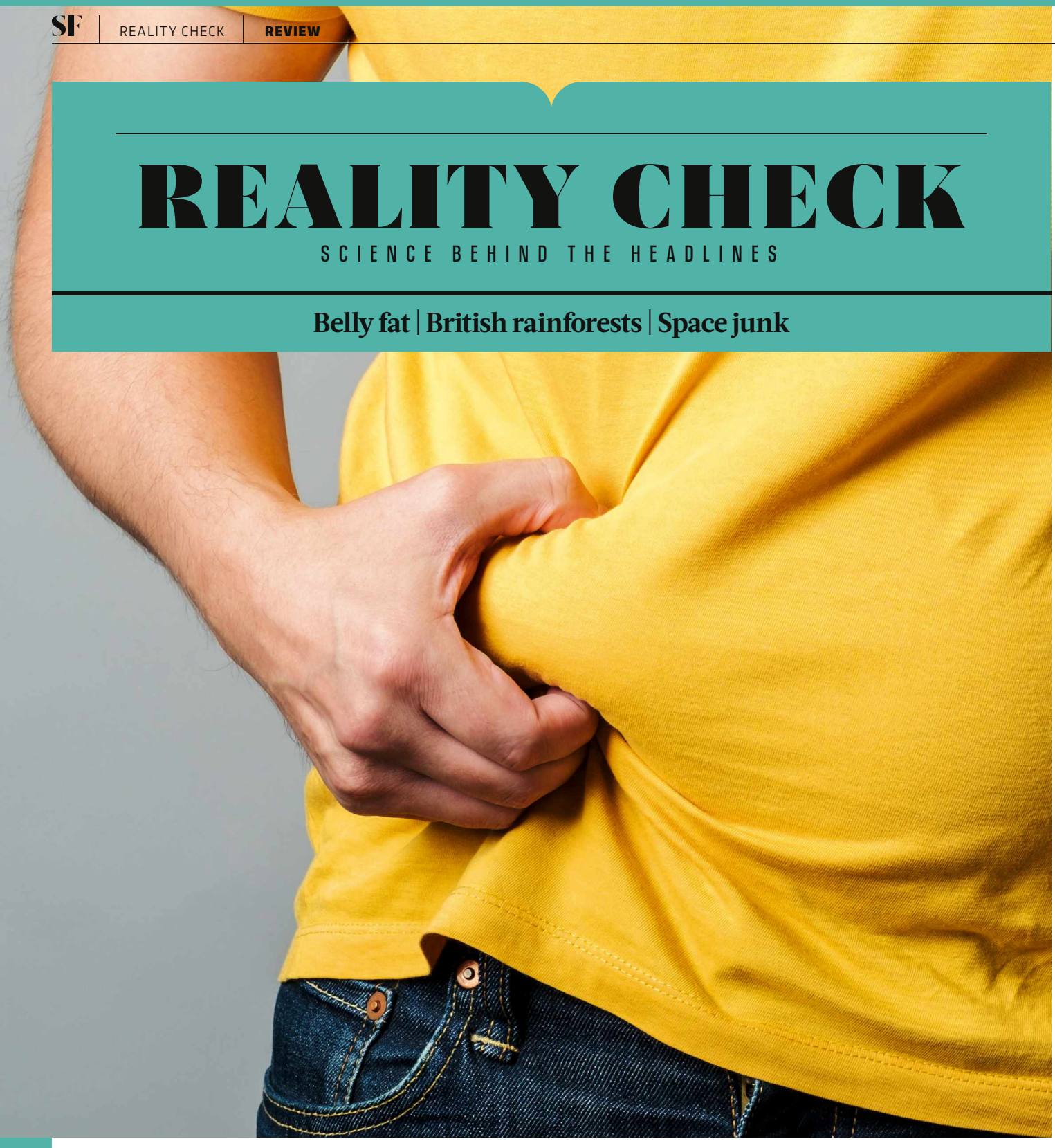
REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Belly fat | British rainforests | Space junk



REVIEW

BELLY FAT: CAN YOU TARGET IT WITH PILLS AND EXERCISE, LIKE THE ADS SAY?

Is there an easy way to battle middle-aged spread or is it simply a case of fat chance?

"We also have this much deeper, visceral fat lying beneath our stomach muscles that collects around our organs"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

"Lose belly fat fast!" "Target belly fat with this one simple exercise!" Social media ads would have us believe we can shrink our bellies with pills and side planks. But is it really as simple as all that?

WHY DO OUR BELLIES GET BIGGER THE OLDER WE GET?

As our bodies age, they get worse at burning fat, so, eventually, even those of us who've eaten healthily and exercised all of our lives will find it harder to stay trim. We store fat all over our bodies, some of it just under the skin (subcutaneous fat) and some of it around our organs (visceral fat).

So in the belly area, we have subcutaneous fat that we can pinch between our fingers and thumbs – the infamous spare tyre. But we also have this much deeper, visceral fat lying beneath our stomach muscles that collects around our organs. We don't typically notice this until we build up enough for it to start pushing our bellies out, but it can be much more detrimental for our health than subcutaneous fat. In older bodies, the visceral fat clings on especially tightly, though sex also plays an important role.

"Even in lean, healthy men and women, men have twice as much visceral fat as women," says Dr Michael Jensen, an expert in adipose tissue (body fat) at the University of Rochester, Minnesota. "As we go up the obesity scale, men are definitely the kings of visceral fat."

HOW IS VISCERAL FAT DIFFERENT FROM OTHER FAT?

Decades of scientific research suggests that excess visceral fat may be linked to health problems like insulin resistance and diabetes. Insulin resistance is a pre-diabetic state where the body responds less well to the hormone insulin, which helps us maintain normal blood sugar levels.

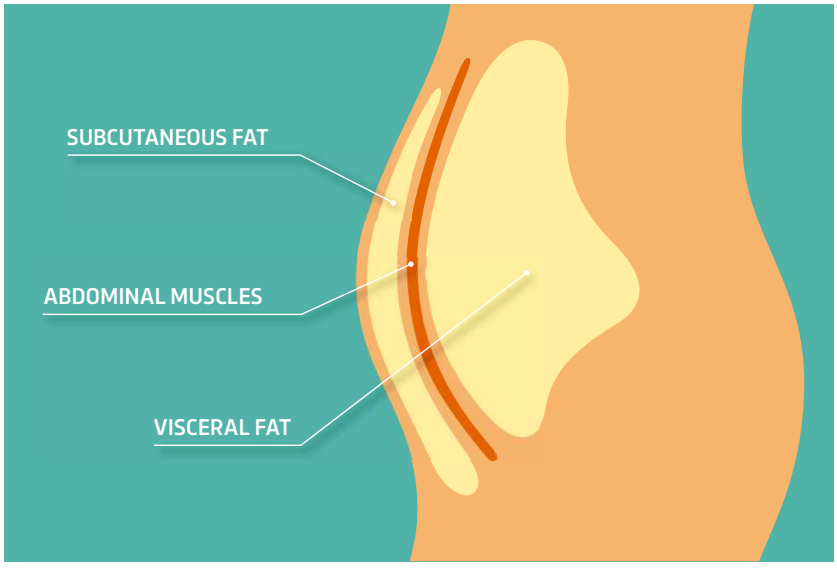
However, what we're now realising, Jensen says, is that you're unlikely to have too much visceral fat unless something has already gone wrong with your other fat stores. In that sense, visceral fat is perhaps more of a 'canary in the coalmine' for a dysfunctional metabolism.

Researchers are also now starting to look at differences in gene activity in fat tissues that might explain why some people develop more belly fat than others. Dr Jordana Bell and Colette Christiansen at King's College London recently published a study using data from twins to home in on epigenetic changes to our DNA. These chemical changes to our DNA result from our lifestyles, but don't affect the code itself.

According to Christiansen, there was evidence that it was epigenetics that was mediating the impact of diet on visceral fat. In other words, what you eat could turn up the dial on those genes that are particularly associated with piling on the pounds around your waist.

WHAT MAKES IT SO TOUGH TO SHIFT?

It's not entirely clear. "There is some thought that visceral fat cells are more hearty – they live longer than subcutaneous fat cells," says Jensen. Recent research at the University of Sydney suggests there may be a 'preservation signal' unique to visceral fat cells that is triggered by repeated attempts to fast. This means that on some diets, trying to lose weight only ➔



Visceral fat lies beneath our abdominal muscles and can collect around our internal organs

GETTY IMAGES

encourages your belly to hold on to its fat for dear life. There's also evidence from studies in mice suggesting that immune cells in fat tissue may be partly to blame for belly fat and some of the health issues associated with it. If the same occurs in humans, then as we get older these immune cells get old and cantankerous. They accumulate specifically in visceral fat, sending out signals that trigger inflammation and generally misbehave in ways that interfere with our metabolism.

WHAT SHOULD WE DO ABOUT IT?

It's not that easy to single out visceral fat with a diet and exercise plan. Your best bet, says Jensen, is to go for fat loss in general – anything that creates a 'negative energy balance' should blast the belly fat along with the rest of it. Other researchers suggest there are tactics you can employ to target visceral fat specifically.

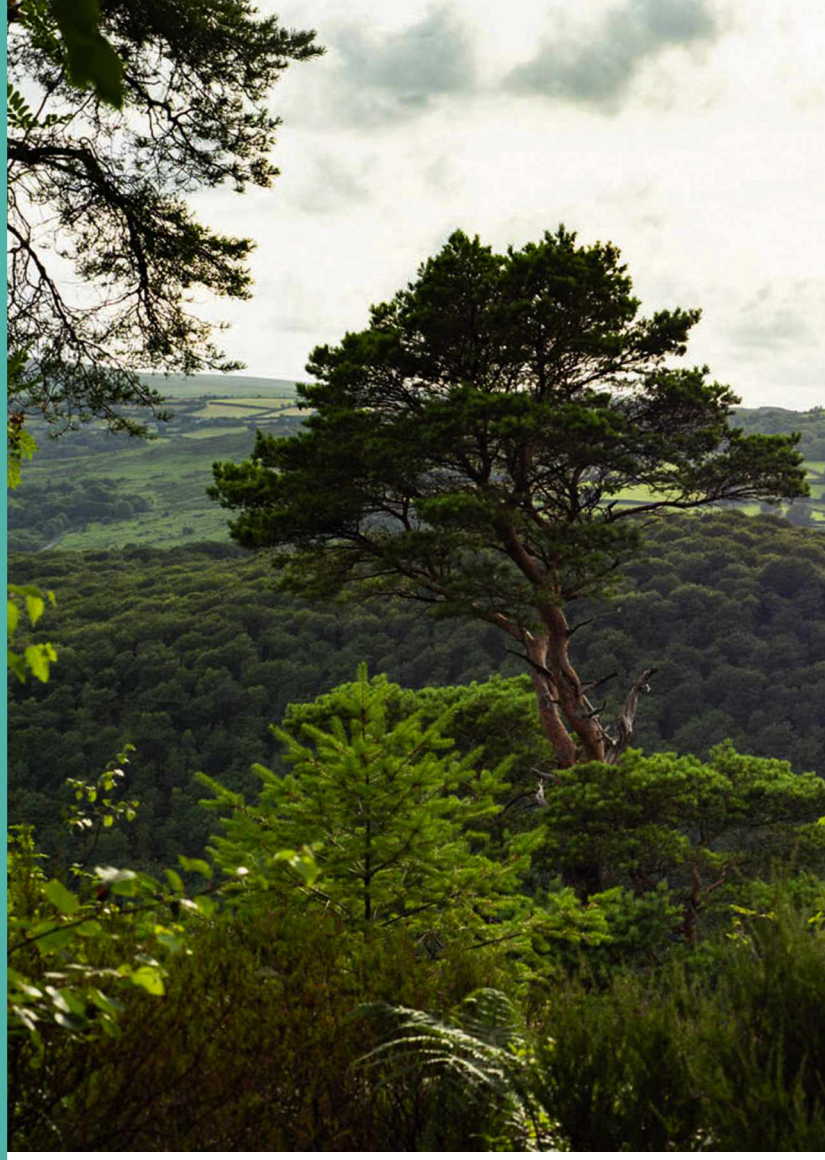
US researchers at Ketchum University, for example, reckon that spreading out your fat intake across several small meals during the day should help. They argue that when you eat a big meal, fat transporter molecules called chylomicrons get stuck in an area close to the gut and are then digested and stored in the closest fat deposit – the belly. Interestingly, men tend to produce more and bigger chylomicrons, which they suggest may go some way to explaining why they accumulate more belly fat.

And what about drugs? Well, there is already one known drug, called pioglitazone, that seems to work indirectly on visceral fat, leading to fat being diverted from visceral to subcutaneous stores, but it's only approved for people with diabetes. As part of Christiansen's research, she hopes it might be possible to track down genes that could become new targets for big pharmaceutical companies, in order to help people to gain control of belly fat before it becomes a risk to their health.

"Could we target visceral fat or could we target pre-diabetes before people are actually diabetic, or before they are insulin-resistant?" she asks. "Are there things we could do to reverse that so they go back to a normal metabolic state?"

The bottom line is that there's no magic solution for banishing belly fat, whatever the ads might say. So, until science reveals more about what causes it, all we can really do is double down on the diet and exercise, or accept our jiggly bits as we move into middle-age.

by HAYLEY BENNETT
Hayley is a freelance science writer.

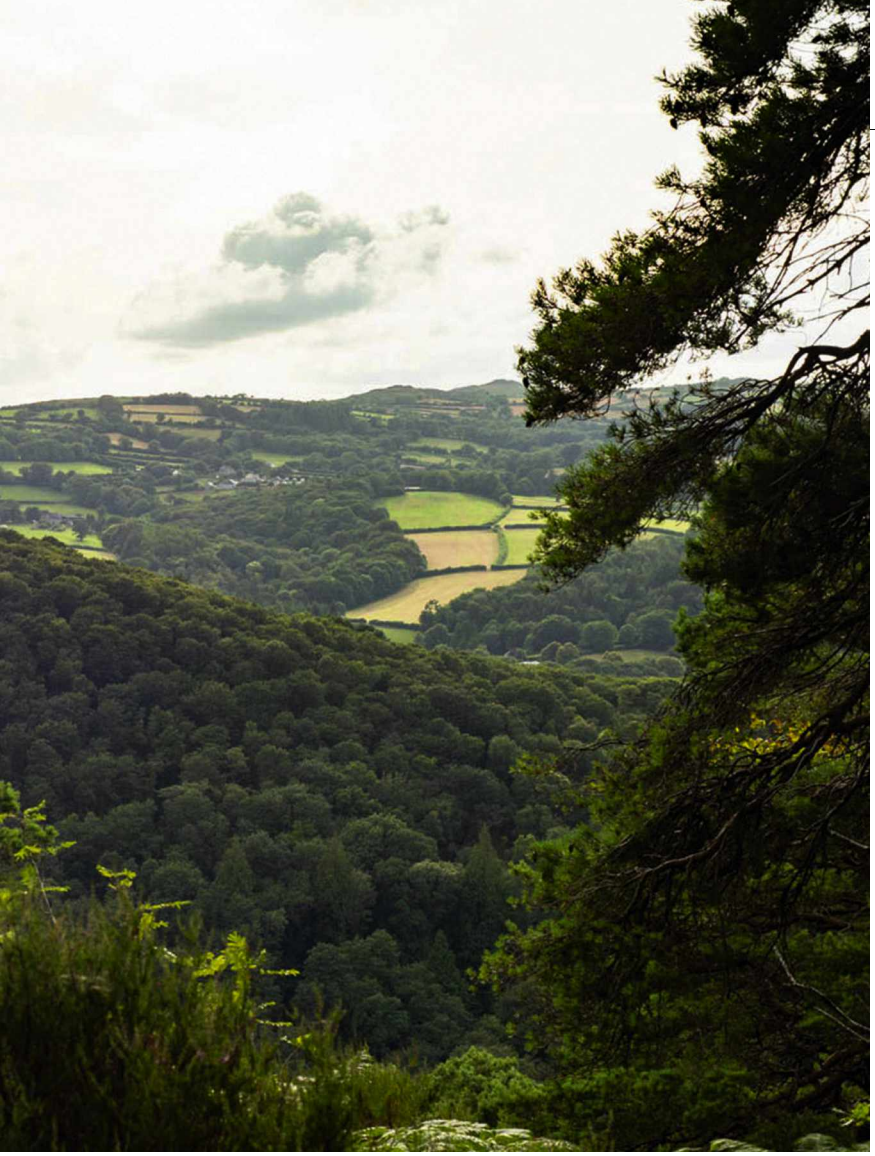


ANALYSIS

BRITAIN'S TEMPERATE RAINFORESTS: CAN WE PROTECT THEM?

These unique, ancient ecosystems are home to a wealth of biodiversity that is worth preserving

Across western Britain and Ireland, you can find patches of damp and misty woodland draped in a cover of green lichens, mosses and liverworts. Increasingly referred to as temperate rainforests, these unique ecosystems harbour the largest concentration of oceanic lichens and mosses in Europe, including some found nowhere else on Earth. Now at a fraction of their previous coverage, many are asking whether



WOODLAND TRUST UK

ABOVE
Ausewell Wood is a temperate rainforest running along the River Dart in Devon

Britain should be doing more to protect and expand the areas it has left. In fact, earlier this year, a campaign was launched urging the public to map the remaining pockets of this rainforest habitat. But what actually are these rainforests of Britain, and how can we save them?

Temperate rainforests, unlike their tropical counterparts like the Amazon, are found in cooler climates that intersect with an oceanic zone, leading to the most well-known characteristic of rainforests – high rainfall. They exist in several areas across the world including the Pacific northwest of the US, southeastern Australia and New Zealand, as well as western Britain and Ireland. The key thing about all these locations is that their humid climates are permissive for "a whole bunch of really special little things to grow on the trees", says Dr Rebecca Yahr, lichen biodiversity scientist at the Royal Botanic Gardens of Edinburgh (RBGE).

These include mosses, lichens, liverworts and fungi, many of which can only grow there. "It's this incredibly rare and unique set of species that all occur together," says Yahr. "Every bough is covered with an intricate mosaic of different colours, different textures, with spots, with speckles, with floppy places, with red spots, just all these crazy things."

"We have this sort of special set of climatic conditions that exist almost nowhere else"

In Britain, these humid woodlands are found in several locations down the west coast, including in Scotland, the Lake District, Wales and the southwest of England. Here, a mix of the local microclimate and a position on the western seaboard where relatively warm, moist air flows in creates ideal conditions for the rainforests to thrive.

"We have this sort of special set of climatic conditions that exist almost nowhere else," says Yahr. "It's really very unusual where we have these forests."

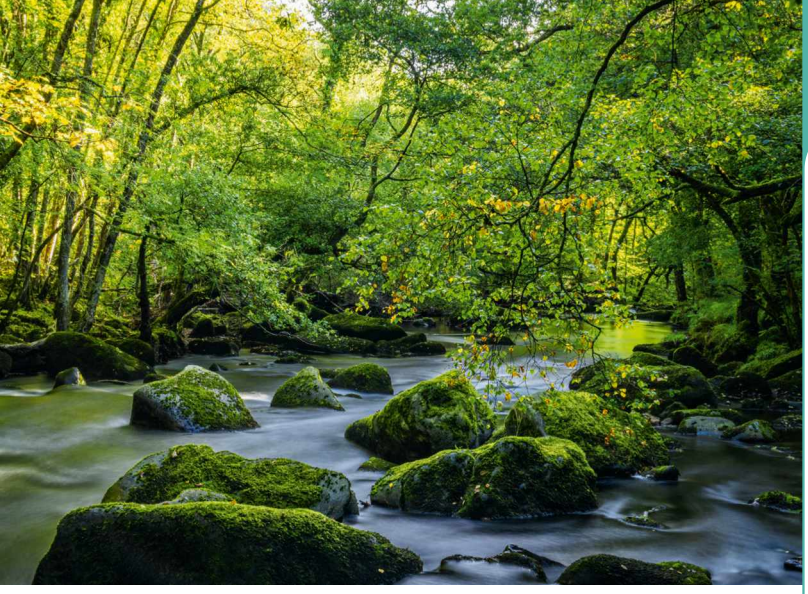
There is now a rising focus on the rainforest properties of these woodlands and the unique ecosystems they host.

It might surprise some people to hear that Britain has rainforests. In fact, temperate rainforests have long been considered as part of the broader term 'ancient woodland', says David Rickwood, the Woodland Trust's site manager for several temperate rainforests in Devon including Fingle Woods. The terms 'Atlantic oakwood forests' or 'Celtic rainforests' also refer to similar things. "[Temperate rainforests] are not that well defined," says Rickwood. "And I think that is due to happen."

Temperate rainforests are rare globally, says Yahr. In fact, ideal conditions for them to occur are present in less than 1 per cent of the planet's land, with 15 per cent of that land situated in Europe. Britain once supported far larger expanses of temperate rainforest, but centuries of tree-felling and land-use change has reduced them to small fragments.

A saving grace for Britain's rainforests is that most of the best examples are in places in the Highlands, on the western coast of Scotland, says Yahr. This region has seen low levels of land management, and also enjoys clean air due to its position with regards to local ocean currents. Other parts of Europe with potential for rainforest have been decimated by pollution, she adds.

Several groups are now working to protect or restore temperate rainforests in Britain, including the Alliance for Scotland's Rainforest, the RSPB, ◉



Fingle Woods in Dartmoor, Devon

Plantlife, the Woodland Trust, and the Atlantic Woodland Alliance.

Invasive species, especially the common rhododendron, *Rhododendron ponticum*, are among the largest threats. Temperate rainforest zones are the optimal habitat for this popular garden plant and exactly where it likes to grow, says Yahr. "Where it grows, it completely shades out the understory, and prevents anything else from coming in." But removing it and keeping it out is extremely labour-intensive.

Grazing by deer also poses a huge issue in Scotland. Further south, conifers and other non-native tree species are an additional problem, says Rickwood. "In most of my sites [in Devon], we're gradually removing the conifer and allowing the native species to regenerate."

A rising effort in Britain aims to expand and connect existing patches of these rainforests together, while balancing people's use of the land. Networks are needed so organisms have corridors to travel – especially in the face of a changing climate.

However, many of the species found in temperate rainforests are slow to move, raising the risk they may fail to keep up with the rate of change of habitats, adds Yahr. One way to overcome this is to experiment with translocations.

"We move them around and see how they do," says Yahr. "They're not too bad as experimental subjects to be moved, and they seem to survive in some places."

As other areas of Britain are subject to climate change, temperate rainforests located in deep valley systems could become even more important as reservoirs of biodiversity, says Rickwood, as they are more protected than forests in exposed areas like moorlands.

These projects need to have long timeframes to regenerate naturally – including when it comes to funding, adds Rickwood. "A grant might exist for five years, but you can't do it in five years. You've got to have a 20-to-30-year timeframe."

by **JOCELYN TIMPERLEY** *(@jloistf)*

Jocelyn is a freelance science, climate and environment journalist.

COMMENT

SPACE JUNK: AM I LIKELY TO BE HIT BY A PIECE OF OLD SPACESHIP?

The amount of debris in orbit around the Earth is a growing issue...

Back in July, a strange, black artefact appeared in a paddock nestled in Australia's Snowy Mountains. It's a place used to raging bushfires, so you could mistake it for a tree turned to cinder. Yet it came from outer space. Some reports suggest it is a stray piece of a SpaceX Dragon capsule that broke up in the Earth's atmosphere upon re-entry. It stands upright after spiking into the Australian soil like a javelin. Clearly you wouldn't want to have been standing there at the time.

More recently, a large chunk of spacecraft, thought to be part of China's failed Long March 5B rocket launch, crash landed in Borneo.

This is not the first time pieces of space junk have returned to Earth with a bang, but what are chances of it damaging people or property? According to Prof Don Pollacco, director of the University of Warwick's Centre for Space Domain Awareness, these events were rare.

"The surface of the Earth is mostly water, so the chances of this happening on land are really low," he says. The chances of anyone being injured by it? "You'd have a better chance of winning the lottery," Pollacco adds.

It has happened, though, albeit at sea. Five Japanese sailors were hurt when wreckage from a Soviet spacecraft hit a freighter off Siberia's coast back in 1969.

Another hairy moment came in 1977 when a Soviet surveillance satellite crashed into northern Canada. It carried a nuclear reactor on board and only 0.1 per cent of the hazardous fuel was ever recovered. Some of the radioactive material made it into a lake and the Canadian government eventually received C$3m (£2m) from the Soviets to pay for the clean-up operation.

Dangerous space junk falls may be rare, but that doesn't mean space junk isn't a threat.

"The danger isn't deorbiting and landing on someone," Pollacco says. "The danger is in damaging other satellites or stopping us launching into space."

The region immediately around us in space is fast becoming a junkyard. There are tens of thousands of pieces larger than 10 centimetres across up there. For objects smaller than one centimetre across, the

WOODLAND TRUST UK, BRAD TUCKER

"The region immediately around us in space is fast becoming a junkyard. There are tens of thousands of pieces larger than 10 centimetres"

ABOVE
Scorched metal from a spacecraft pierced the soil of farmland in Australia

tally runs into the hundreds of millions. These pieces include bits of old rocket, parts of defunct satellites and even flecks of paint and frozen fuel. Twelve accidental fragmentation events typically occur in space every year, as hardware breaks apart and adds to the growing problem. The tiniest objects can still wreak significant havoc.

"Objects in low Earth orbit are moving at 25,000mph [40,000km/h]," says Pollacco. "Even a pea-sized object packs a lot of energy – if it hit something, it would disable a satellite. It's something we're going to have to get used to."

That's because the number of satellites being hurled into space is skyrocketing. Companies like SpaceX and Amazon are launching mega-constellations into low Earth orbit to beam down the internet to remote places where traditional underground cables can't reach.

One report estimates that we'll launch 1,700 satellites a year between now and 2030. The rapid expansion of space capabilities comes on the back of the advent of reusable rockets. The cost of getting something into low Earth orbit has dropped from around $60,000 (£50,000) per kilogram to just $2,400 (£2,000).

So, what can we do about it? Bodies like the European Space Agency and NASA are advocating debris removal, and there are a number of companies working on this and running demo missions.

Pollacco sees big problems, though. "The reality is someone has to pay for this." He points to a swarm of Russian satellites in a spacecraft graveyard some 800 kilometres (500 miles) above the surface of the Earth. "They weren't decommissioned properly and they're dangerous – they even still contain propellant," he says. "Is Russia going to pay to remove them? No."

Even then it's a sticking plaster approach. Removing thousands of large, dead satellites does nothing about the hundreds of millions of pea-sized satellite killers.

"It's not practical to deorbit those," Pollacco says. "In the end you just have to know where it all is."

So what's the worst case scenario?

"You create a finer and finer cloud of satellite-killing debris that would take decades to deorbit," Pollacco says.

Eventually, that could create such an obstacle that it affects our ability to put anything new into space. "If your risk of collision during launch is above a certain amount then you don't launch – we won't be able to get off the Earth," he says.

We plan to go back to the Moon later this decade and to Mars in the decades ahead, but we could end up firmly rooted to *terra firma*. **SF**

by **PROF COLIN STUART**
(@skyponderer)
Colin is an astronomy author and speaker. His latest book, Numbers: 10 Things You Should Know *(£9.99, Seven Dials) is out now.*

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

Fancy getting into drone racing? Find out more on p46

52.9%
In 2021, Android made up this proportion of the UK's phone market (YouGov)

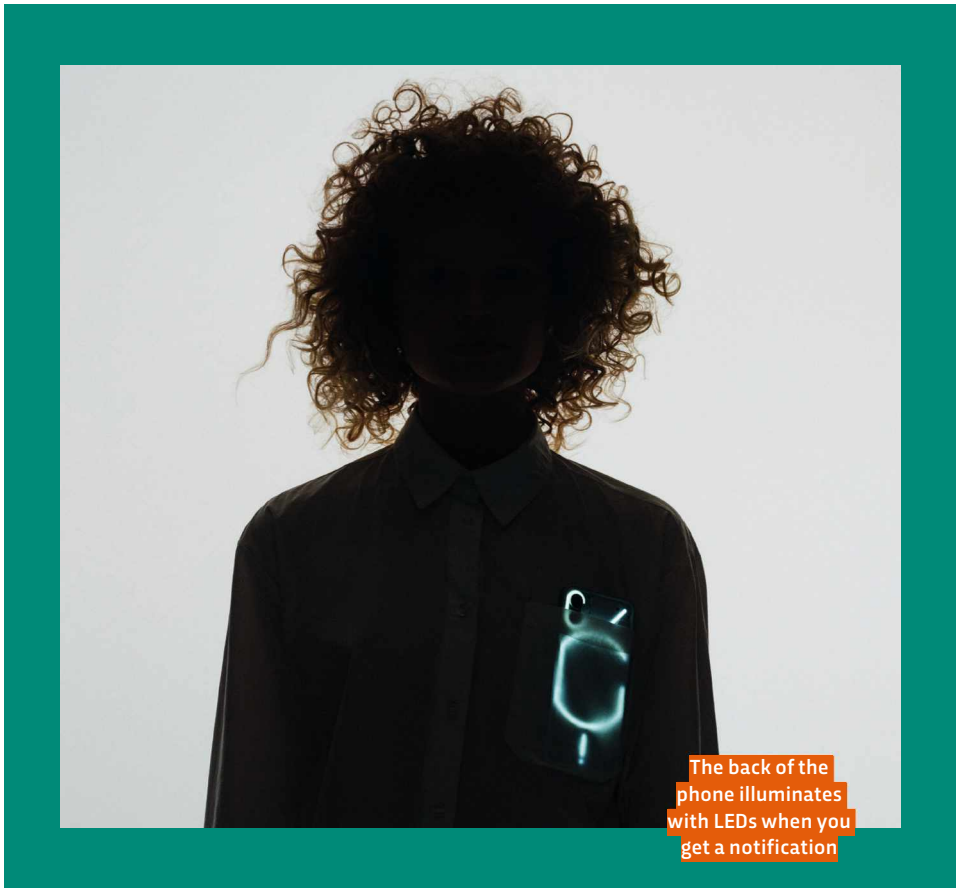
239 million
The number of phones sold by Apple in 2021, making it the world's 2nd biggest manufacturer (Gartner)

5.7%
The percentage more smartphones sold in 2021 compared to the year before (IDC)

REVIEW

Nothing Phone 1: More than just a gimmick

A solid smartphone wrapped up in a distracting neon bow, says **Alex Hughes**



The back of the phone illuminates with LEDs when you get a notification

Like a peacock spreading its feathers to make itself more appealing, the Nothing Phone 1 employs a plume of 900 LED lights to set itself apart from the procession of near-identical smartphone launches these days.

Nothing is a start-up from a former co-founder of OnePlus, and its mission is to create desirable tech at affordable prices for the masses: a tricky balance to strike. We spent a few weeks with the £399 Nothing Phone 1 to find out what was beneath its flashy display.

LIGHTS, CAMERA, ACTION!

First off, let's talk about the light show on the back. This is the Nothing Phone's unique selling point, known as the Glyph interface. The lights (Glyphs) are intended as a notification system, flashing in different combinations and colours, with a variety of vibrations. This is a fun feature that makes the Nothing Phone stand out, but it isn't as useful as it sounds. While you can programme the Glyphs to change the sequence of lights, or make them brighter or dimmer, you only get one Glyph for all notifications. So the lights won't tell you whether you've received a text or an email, for example, only that you've had a notification.

This feels like missed trick. Sure, it might help you find the phone in a dark room, but ultimately you'd expect the lights to convey more information beyond what the phone is already telling you by vibrating. However, Nothing has suggested plans to update this, with the ability to alter them for different notifications.

APPLE OF YOUR EYE

Squint a bit, and if it wasn't for the fireworks show on the back, the Nothing Phone would start to resemble an iPhone. Between the squared-off design and the camera bumps on the back, this looks a lot like if Apple decided to create an Android device.

The transparent back is a nice touch, and the overall design feels different enough from Android smartphones at this price point to say that, in design terms at least, the Nothing Phone stands out from the crowd.

A CLOSER LOOK

So the phone looks nice, and it even has a unique, if somewhat gimmicky feature not seen on other devices… but is that all there is to see? In a way, yes. The Nothing Phone is very much a standard smartphone in every other category, offering mid-range specs for a fair price, but that's not a bad thing.

The 4500mAh battery easily manages a full day of casual usage, and the Snapdragon 778G+ processor keeps up with most activities, powering through some more intense games and handling photo processing without running into difficulty.

Where the Nothing Phone really shines is not the back of the phone but the front display. It features a 6.55-inch Full HD+ OLED display. This means that content

The Nothing Phone 1's Glyph interface is made up of 900 LED lights

appears bright and crisp, with great contrast in any light. On top of that, the phone boasts an impressive 120Hz refresh rate. This affects how many times the display fully refreshes each second – the higher the number, the smoother the scrolls, transitions and general movement around the phone will feel.

Most phones at this price point will top out at 90Hz. This is very much one of those features that sounds unimportant... until you've enjoyed the perks of a higher refresh rate.

SNAP HAPPY

The Nothing Phone's camera is essentially what's to be expected at this price point: nothing special, but well-equipped for the average photography situation.

There are two lenses on the back: one wide and one ultrawide, both of which are 50MP. Between these two, the camera's capabilities can range from a 0.6 zoom ultrawide shot, through to 2x zoom at the maximum.

While the camera struggles to zoom in on faraway objects, for the most part, its shots look pretty great, especially in sunny weather or a room with bright lights.

However, situations with lower light aren't quite as impressive. Night photography is certainly a weak point for the Nothing Phone, and darker scenes can come out with a bit of blur, or a meek colour balance.

RATING: ★★★★★

PROS:
- Unique notification system
- Affordable price tag
- Good processor and screen for the price
- Solid camera

CONS:
- Battery could be better
- New unproven technology
- Notification system not that useful

VERDICT

A lot of smartphones are launched every year, and most of them look nearly identical. Nothing deserves some praise for trying something different with this phone. However, the Glyphs, the transparent design and unique features here and there are not what makes the phone worth buying. Instead, the Nothing Phone's value lies in its ability to offer a solid smartphone at a good price tag... with a bright neon bow strapped to the back of it.

It's important to remember that this is Nothing's first smartphone, and only its second product overall. While that is exciting and allows the brand to get creative with this device, there is some concern to be had. When 900 LEDs are attached to the back of a phone, there is the possibility for things to degrade over time. Like all new adventures in tech, these factors are worth keeping in the back of your mind.

THE BEST ALTERNATIVE SMARTPHONES

IPHONE SE

£419, apple.com

The Nothing Phone 1 takes some clear inspiration from Apple. For the closest Apple match in price and specs, the iPhone SE is the way to go. It features one of the best processors available in smartphones right now, and while you are limited to just one lens, the camera uses some smart software to produce shots that will put the Nothing 1 to shame.

GOOGLE PIXEL 6A

£399, store.google.com

When it comes to Android devices, the Google Pixel 6a is about the closest thing you'll get to the Nothing Phone, with a simple design, a clean user interface, and a pretty great camera system for the price. Of course, the design isn't quite as exciting as Nothing's glowing back, but the Google Pixel 6a is by no means a boring-looking device.

ONEPLUS NORD 2

£399, oneplus.com

OnePlus excels at manufacturing smartphones in this affordable price range, managing to cram in a lot of high-end specs. While by no means as interesting as the Nothing Phone in terms of looks or features, the OnePlus Nord 2 offers a compelling alternative in every other category.

Dominate the sport of drone racing with advice from a world champion

Evan Turner is a three-time drone-racing world champion. **Alex Hughes** gets his tips on how to break into the sport

Evan Turner is a racer who holds two championship wins, 25 podium positions, and the position of the youngest champion winner in history. But unlike sports like Formula 1 or MotoGP, Turner's race of choice takes place in the sky.

Turner, who is 19 years old, is one of many who has discovered the joys of drone racing. While it's a relatively new sport, it already has a large, dedicated fan base. In its latest season, the sport attracted audiences across six continents, broadcasting to more than 250 million households.

But how does this form of racing work? What is it like to fly one of these lightning-fast drones? And how can someone break into this rapidly growing sport?

WHAT IS DRONE RACING?

Drone racing, as the name suggests, involves pilots racing a set of drones around a course. However, these aren't the drones you normally see. These are small, lightweight devices that can reach speeds exceeding 160km/h (100mph).

At the professional level, these events are organised by the Drone Racing League, with prizes and money on the line.

"Generally, it is like any motorsport or race, whether that's track and field or Formula 1. All the pilots show up and do a series of qualifying attempts where they are positioned based off their best time, and there are different ways that can work," says Turner.

These qualifying attempts could be your best time across three laps, your best attempt at one single lap, or any measurement that the league decides to use. These qualifying laps are then used to create elimination-round brackets that typically include 16, 32 or 64 pilots.

"After qualifying, you are placed with four to eight pilots and you all race at the same time. The top half of that group moves on through the winner's bracket. All the races are a double-elimination system so you can lose once, but you can keep racing and still work your way to the finals. Eventually, you're left with four to eight pilots who race in the final," says Turner.

While the rules and system for qualifying are similar to other sports, the layout of the tracks is entirely different. "The tracks change a lot. What makes drone racing so incredibly unique in comparison to other motorsports is that the tracks are across different heights and levels. In drone racing, the [checkpoint] gates are all over the place, some are on the ground, some in the tunnels of a stadium and some 20 feet [six metres] in the air," says Turner.

TAKING TO THE SKY

With most consumer drones, you hold a controller that has a screen to show you what the drone sees. But drone racing takes things a step further with first-person-view (FPV) drones. These require you to strap on a headset, fully immersing you in the 'drone's-eye view'.

"Flying one of these drones is an exhilarating experience, it's like nothing you've ever done before. Drone racing is a weird mix between reality and the experience of a video game. You use a controller like you would with a console, and wear goggles like you would with VR. But when you move the sticks, a drone is moving in real space," says Turner.

"You can fly around the environment with pretty much no limitations. If you see a lighthouse way out in the ocean, then go fly to it. Want to skim low to the water at 100mph [160km/h]? You are welcome to it. Skill is the only thing that is limiting you here."

GETTING YOUR PILOT'S WINGS

If you are keen to start getting out there and flying FPV drones, Evan suggests one step beforehand.

"The best way to learn how to fly an FPV drone is to get on a simulator. These are games that allow you to practise flying a drone. Some popular ones are the *Drone Racing League* simulator or *VelociDrone*," says Turner.

These are affordable games that you can purchase for your console or computer. By doing this first, you can not only get in some practice to save you from an expensive drone crash, but can also decide if this is a hobby for you.

"With the simulator, there are pilots I have seen who've flown on the simulator for a week or two and practise really hard.

DRONE RACING LEAGUE X3

ABOVE LEFT Evan Turner, three-time drone-racing world champion

ABOVE RIGHT In drone racing, the pilots wear a headset to give them a drone's-eye view of the course

And then the first time they pick up a drone, they're already a top-level pilot. Most people will be able to learn with some basic direction within a week," explains Turner.

Unlike most drones these days that can practically fly themselves, FPV types offer no safety features or assists, you are in complete control. This gives you a lot of freedom, but also makes your life a lot more difficult. There is a very steep learning curve.

"Once you've tried a simulator and you come to buy a drone, I would keep the phrase 'buy cheap, buy twice' in your mind. There are loads of drone products out there that aren't the best, but they are cheap. Save up a little bit more so you can invest in some better products and then use that time while you're saving up your money to just practise a little bit more in the simulator."

WARNING

Check your local drone regulations before flying. You might not be able to fly in your area, or could require sign-off to fly.

EVAN TURNER'S TOP DRONE RECOMMENDATIONS

DIY drone
"A typical racing drone in its current state is built from the ground up. You buy the parts, and you assemble them all together. That obviously requires some knowledge or skill, but there is plenty of educational content out there to do that," says Turner. There are lots of trustworthy websites that sell drone parts, including YourFPV or Five33 (owned by Turner).

DJI FPV
"The DJI FPV drone is a good way to get into FPV and at least understand the basics, but I would also say that you're not going to use the DJI FPV as a long-term drone because it's very basic," says Turner. While this is by no means the cheapest FPV drone, it is the best for beginners due to its enhanced safety and autonomous features.

iFlight
If you don't want to build a drone, iFlight is a great place to get a pre-built model. "They have plenty of great ready-to-fly drones and a nice website that is accessible for anyone. They use a lot of parts that we use in professional drone racing but they make it very easy for you," says Turner. iFlight offers a number of racing drones, long-range options or some smaller ones to fly at home.

Emax
Emax is a great place to start for racing drones if you want something small and affordable. "They make these ready-to-fly drones that are notorious for being very small and safe around people, as the propellers are guarded. They're inexpensive and a very good starting point because of their price. They offer multiple beginner drones and a few more expensive options."

Ideas we like...

Our pick of the month's smartest tech

↓

...a tent that can weather the storm

Forget the leaking two-man pop-up tent you've been lugging to festivals, the Kirra Classic is an inflatable tent that combines speed and convenience with strength. The tent can be assembled in less than 30 seconds, simply by inflating the tube-like frame with a pump. Once set up, the strong geometric design will keep you better protected in storms and strong winds. But if you do have any issues, each individual part of the tent can be replaced. However, at more than £700, all of this tech doesn't come cheap.

Kirra Classic
€849 (£717 approx), en.heimplanet.com

...LEGO striking the nostalgia nerves

If two of your childhood hobbies were LEGO and playing the Atari 2600, LEGO has found a way to tap into your nostalgia – by creating a 2,532-piece version of the console. You can build the retro console and then plug in one of a collection of iconic titles, including *Asteroids* and *Centipede*. There is the option to build 3D versions of the games, classic artwork, and even a joystick.

Lego Atari 2600
£209.99, lego.com

...charging that is kind to the planet

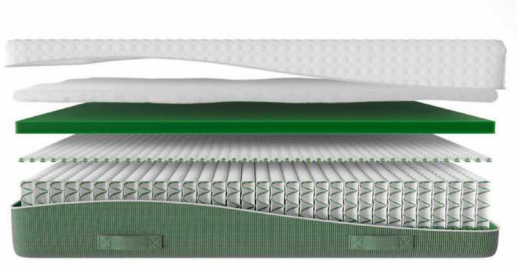
Headphones, smartphones and other devices burn through a lot of energy when they're being charged. Anker has created a way to improve the process with its GaNPrime tech, which is found in its new charger plugs. These plugs are small and efficient, but they also identify what devices are plugged in and how much battery each has, ensuring the right amount of energy is sent to each device.

Anker GaNPrime plug
£54.99, anker.com

...a mattress that's good for your back and the environment

A good night's sleep is invaluable, and if you're kept awake by an uncomfortable bed, and the concerns about the unsustainable materials that were used to make it, the Simba Go Mattress may be for you. It's costly at £2,149 for a double, but that price goes a long way. Simba claims it has half the carbon emissions of a traditional hybrid mattress, while still giving comfort with a six-layer system made with the environment in mind.

Go Hybrid mattress
£2,149, simbasleep.com



...earbuds moulded to perfectly fit your ear

We've all experienced the frustration of poorly-fitting earbuds repeatedly falling out. That could be a thing of the past, with Ultimate Ears' new Drops earbuds. First, you are sent a kit for you to do an at-home moulding procedure. Then, several weeks later, Ultimate Ears will send you back a pair of headphones to perfectly fit your ears. This makes them comfortable to wear and creates a good seal to block out noise.

Ultimate Ears Drops
$449 (£367 approx), custom.ultimateears.com

IDEAS WE DON'T LIKE...

...A TV THAT'S TRYING WAY TOO HARD

How badly do you want to hide your TV away from view? Would you be willing to pay more than £150,000 to do so? If like us, your first thought was 'obviously not', the C Seed N1 is probably not for you. This ridiculously large 165-inch TV really wants to stand out. Advertised alongside marble statues in a museum, the brand claims it is blurring the lines between technology and art. When not in use, the TV folds down into a thick bar on the ground which, while undeniably impressive, is an overkill way to get your TV out of the way.

C Seed N1
$190,000 (£156,000 approx), cseed.tv

...UNNECESSARY PHONE INNOVATIONS

How do you make a phone innovative? Do you make it fold, do you reduce its carbon footprint, or do you make it a pioneer in one specific spec? In Nokia's case, the solution is to include an in-built pair of earbuds. The phone company has produced an old-school device, complete with buttons, a small screen and a number pad. However, to stop that feeling too familiar, the back of the device slides down to reveal an in-built charging case and headphones. We really can't work out who this is made for, but it has never been done before; maybe with good reason.

Nokia 5710
£TBC, nokia.com

mpb.com

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DIVE BENEATH THE TURQUOISE WAVES OFF NOLI, ITALY, AND YOU'LL FIND BIOSPHERES JUST METRES UNDER THE SURFACE. WITHIN THESE DOMES, RESEARCHERS LOOK AFTER HERBS, STRAWBERRIES, TOMATOES AND TOBACCO, IN ORDER TO EXPLORE THE LIMITS OF FARMING ON EARTH, WITH THE HOPE THAT THEY MAY ONE DAY BE ABLE TO DO THE SAME IN SPACE

WORDS **JOCELYN TIMPERLEY**
PHOTOGRAPHY **GIACOMO D'ORLANDO**

WELCOME TO NEMO'S GARDEN

A decade ago, Luca Gamberini's father, Sergio, decided to pursue what seemed to Luca like a madcap scheme to grow plants under the sea.

The Gamberini family business, Ocean Reef Group, specialised in diving and scuba equipment. Agriculture was not part of the picture. But after the idea to plant underwater crops emerged from a dinner between Sergio – who had a passion for gardening, as well as scuba diving – and a farmer friend of his, he decided to try it. "It was kind of a bet, a fun joke," says Gamberini. "And my father was like, 'hey, you know what, I'm actually going to try that.' And he did. And it worked."

To start, they used small, curved, transparent balloons sunk below the water and filled with air, providing an underwater dome. Initially, the family kept a plant alive underwater, then tried planting a basil seed, which sprouted and grew.

But Gamberini says he initially couldn't really see a good reason for it. "I was the number one hater. I opposed this so much," he says.

He was also opposed to the decision to implement the scheme off the coast of Noli, Italy – the family's usual holiday location – as it would mean that they would always end up working on their holidays, rather than relaxing.

But around five years ago, the first time he visited one of the new, larger, rigid underwater domes the family had developed, he found himself changing his mind. "In my first minute in one of these big environments, I was like, 'Ah, okay, that's quite cool,'" he says. "These rigid domes are so much more beautiful, and incredibly easy to attend to. They make much more sense and they make the technology work. So that's when I jumped from being the number one hater and opposer of the project to actually the number one fan."

SEA SALAD

Today, Nemo's Garden – the start-up that emerged from that dinner conversation – has six domes, each holding around 2,000 litres of air, located at depths of between five and 11 metres. To tend to the plants, divers enter the domes from below, their legs still hovering in the water while their upper torsos emerge in the air of the biosphere. When plants are harvested, they are placed in reusable bags or containers, which are sealed and brought to the surface of the sea to be collected.

The company has grown a huge variety of plants underwater at the site in Italy, from its trademark basil, to other medical and culinary herbs, strawberries, lettuce, tomatoes, beans, quinoa, and even tobacco (for vaccine purposes, Gamberini says). Aside from the dome being suited for crops that require a high-humidity environment, the limitations are mainly in size, says Gamberini. "Due to the geometry of the dome, we cannot grow big stuff. We have to grow high-value and highly-requested produce."

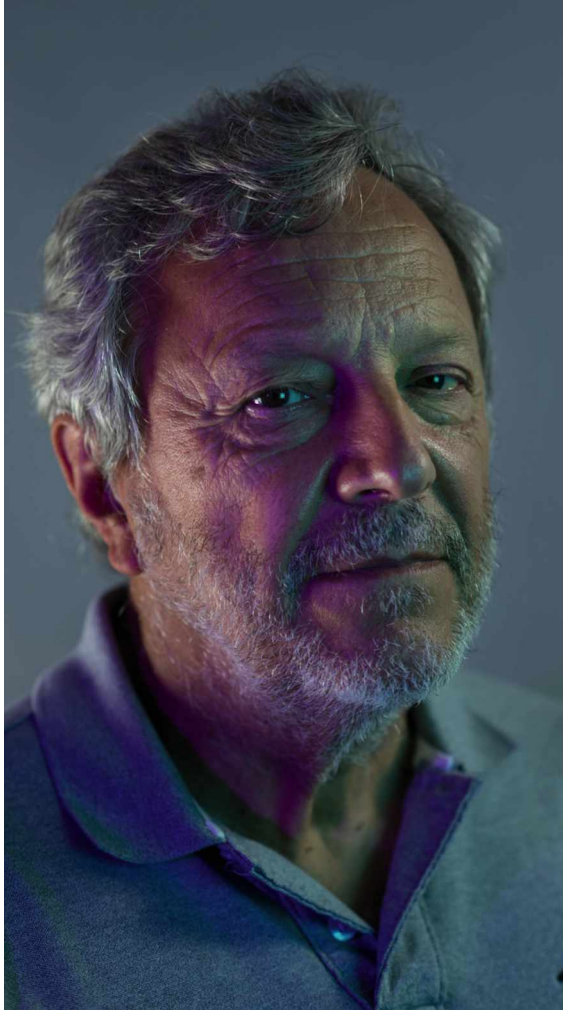
The plants are grown in a nutrient-rich solution (a method known as 'hydroponics'), removing the

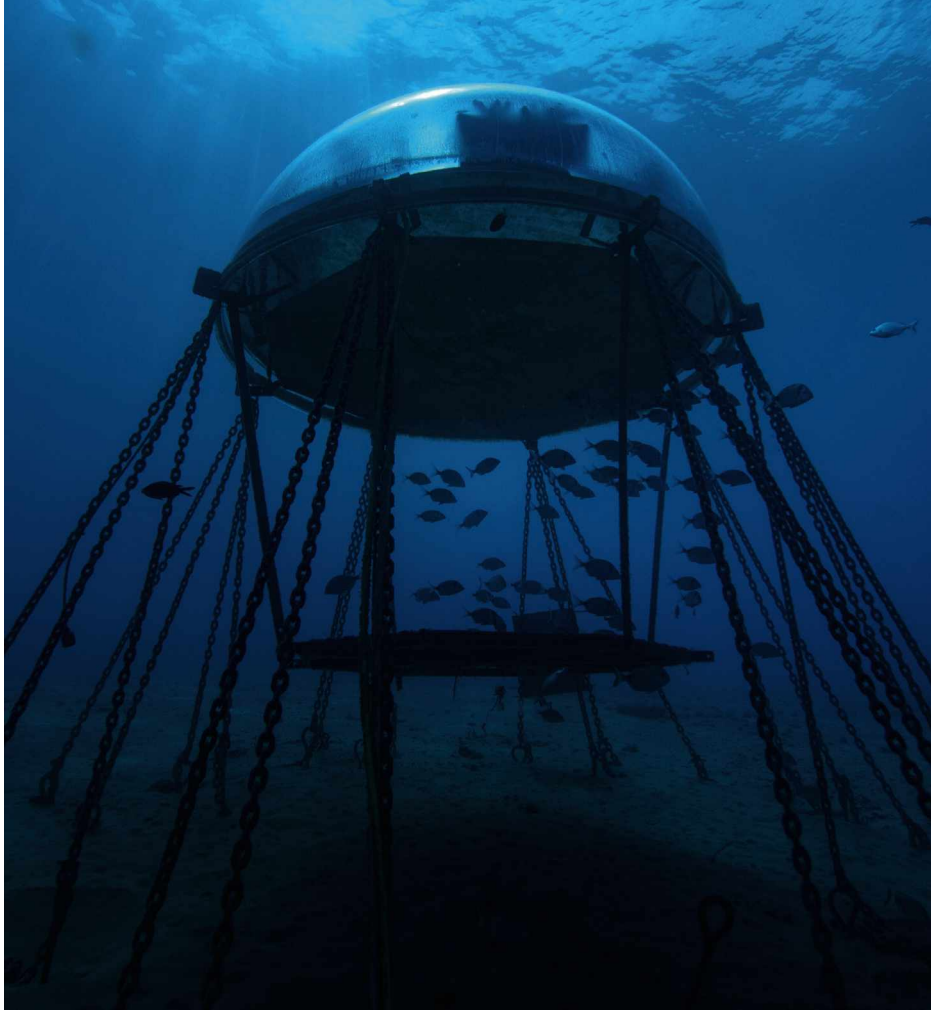
CLOCKWISE FROM ABOVE Luca Gamberini tends to plants inside one of the biospheres

Luca's dad, Sergio, who first proposed the Nemo's Garden project

The biospheres are located off the coast of Noli in Italy, at depths of five to 11 metres

After harvesting, the plants are placed into sealed bags or containers, before being brought to the surface

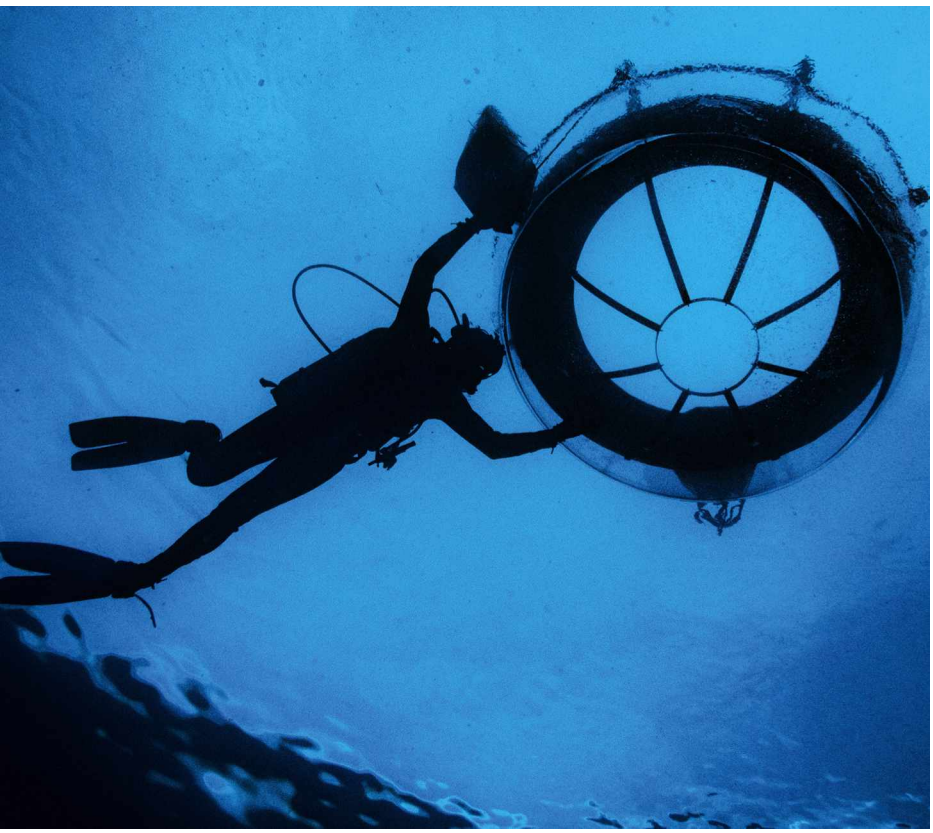




need for soil. Meanwhile, the domes provide the plants' water needs by harvesting freshwater from seawater. The domes are slightly hotter than the outside sea temperature, which means that water from the seawater 'floor' evaporates inside the dome and condenses on its curved inside surface as freshwater. This then 'rains' on the plants. This setup also allows an exchange of CO_2 from the ocean inside the dome, adds Gamberini. "We've noticed that this environment doesn't really need to be replenished that much," he says.

In many ways, the technology is similar to vertical farming systems: it's a soil-free, controlled and carefully monitored environment, remote from the farmer, with live cameras in every pod. But in the underwater system, the surrounding sea provides an incredibly stable thermal environment for the plants, therefore reducing energy use. The sunlight that reaches underwater is also sufficient for the growth of the plants, Gamberini adds, compared to the LED lights in vertical farms, which again use energy. He also says the plants grow faster and have higher levels of essential oils.

There could even be an ecological advantage. A survey carried out through a scholarship in 2019 concluded that the Nemo's Garden structure is likely having a positive impact on the local ecology of the area. "The amazing thing about the ocean is that whenever you put something underwater that acts like an artificial reef, the ecosystem just flourishes," says Gamberini.

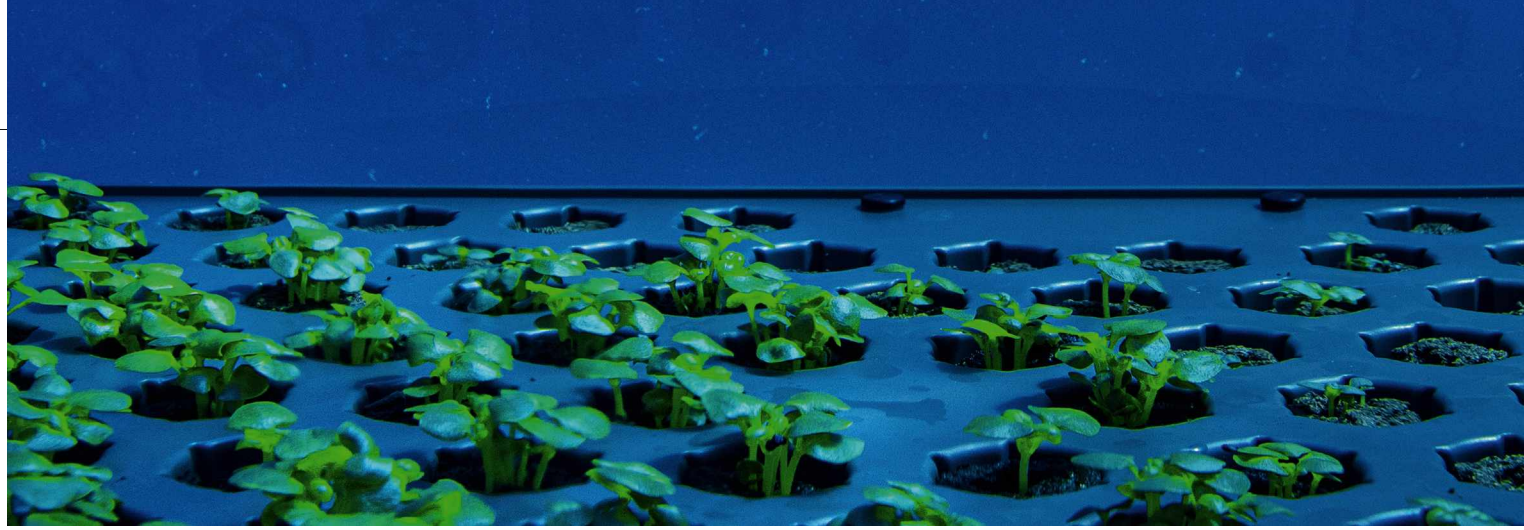


So could this form of agriculture ever really be scaled up to compete with conventional farming? Dr George Littlejohn, associate professor of plant and fungal biology at the University of Plymouth, says he feels that niche production is more likely.

He notes that the technology is not yet at a stage where it is a viable way to produce high yields of crops, and specifically cannot currently provide the calorie- and protein-rich foods needed as the basis of our diets. "This is [also] common for many vertical farming systems," he adds.

Underwater farming does have the advantage of not taking up space on land, says Littlejohn, but it also has several pitfalls, including the extra energy inputs required to deliver nutrients to the plants, the inconvenience of planting and harvesting, and the high maintenance of the whole system. He also notes that plants are already well-adapted to thrive in the conditions found on *terra firma*, where they have access to the full spectrum of light, information on the time of day via light and temperature cues, along with nutrients and CO_2.

However, Littlejohn says that developing controlled growth environments in challenging places, as Nemo's Garden is doing, is "essential" for future space exploration. "It may be that insights gained from growing underwater will



give benefits in exploring further than we can yet see," he says.

Of course, Nemo's Garden is not the only project pushing the boundaries of where we can grow plants. Others include the University of Arizona's Prototype Lunar Greenhouse, the plant growth experiments currently being carried out on the International Space Station, and NASA's OMEGA system, which floats on the surface of the sea and grows algae.

EXPLORING FURTHER

Despite the space-age look of the pods at Nemo's Garden, Gamberini says imagining the technology being used on another planet is "way above [his] paygrade". There could be an application in space travel, he says. The intense flavours of the crops grown in the high-pressure habitats underwater could be helpful to bring flavour to foods eaten in low-pressure environments – such as in space – where our taste buds can go awry.

But perhaps more useful for the foreseeable future is the potential impacts of underwater farming here on Earth. Gamberini says he sees underwater farms as an option, especially for coastal communities outside the Western world, such as the Maldives, which lacks arable land for agriculture but has plenty of experienced divers. "I do think that it is a really viable option to put next to all the other technologies that are coming up," says Gamberini.

For now, the company is looking to its next stage of scaling-up, after being selected for the acceleration programme for Neom, Saudi Arabia's controversial megaproject to build a futuristic smart city from scratch in the desert. This autumn, Nemo's Garden will present business and feasibility studies to build 30 biospheres for the project, which could produce 3.1 tonnes of basil per year with current technology.

Gamberini hopes that next year, they could be setting up a project at Neom to be the first real underwater farm in the world.

By 2030, he would like the company to be employing hundreds of people and implementing the underwater domes around the world. "Nobody has done it before," he says. "We can only learn through experience." **SF**

CLOCKWISE FROM BOTTOM LEFT Gabriele Cucchia, senior engineer of the Ocean Reef group, transports a biosphere from the surface to the installation site

At the centre of Nemo's Garden is the 'tree of life', through which cables are run to the biospheres to power the cameras

Basil starting to grow from the hydroponic cones in a biosphere

A basil plant grown in Nemo's Garden is covered in a plastic bag and placed in a cooling crate, to be sent to the University of Pisa for analysis

The team celebrates a final harvest on the beach

by **JOCELYN TIMPERLEY** *(@jloistf)*
Jocelyn is a freelance climate and science journalist.

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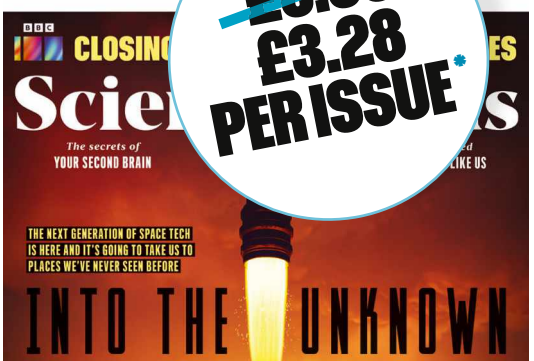
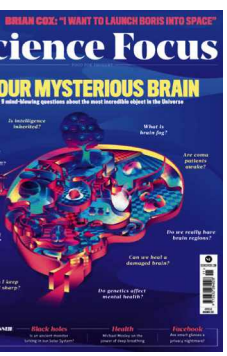




INTO THE UNKNOWN...

WORDS: DR EZZY PEARSON

A new epoch of spaceflight is upon us. Here, we explore the next generation of spacecraft that will take us to parts of our Solar System that we've never seen before

Two of the biggest-ever space projects began their journey of discovery this summer. In July, the James Webb Space Telescope sent its first images back to Earth. Then in late August, the Space Launch System rocket and Orion module were readied for the maiden, uncrewed test flight of the Artemis programme.

But as these landmark missions take their first steps, their successors are already lining up. Over the last decade, NASA's Innovative Advanced Concepts (NIAC) programme has funded research into novel space tech that encourages inventors to take advantage of new technologies and break away from the traditional ideas of what a spacecraft should be. At the same time, an ever-increasing number of new spacefaring nations and private companies are taking chances on new ideas. With results ranging from the innovative to the outright bizarre, here we take a look at what the spacecraft of tomorrow might look like.

ILLUSTRATION: MAGIC TORCH

SEARCHING THE SKIES

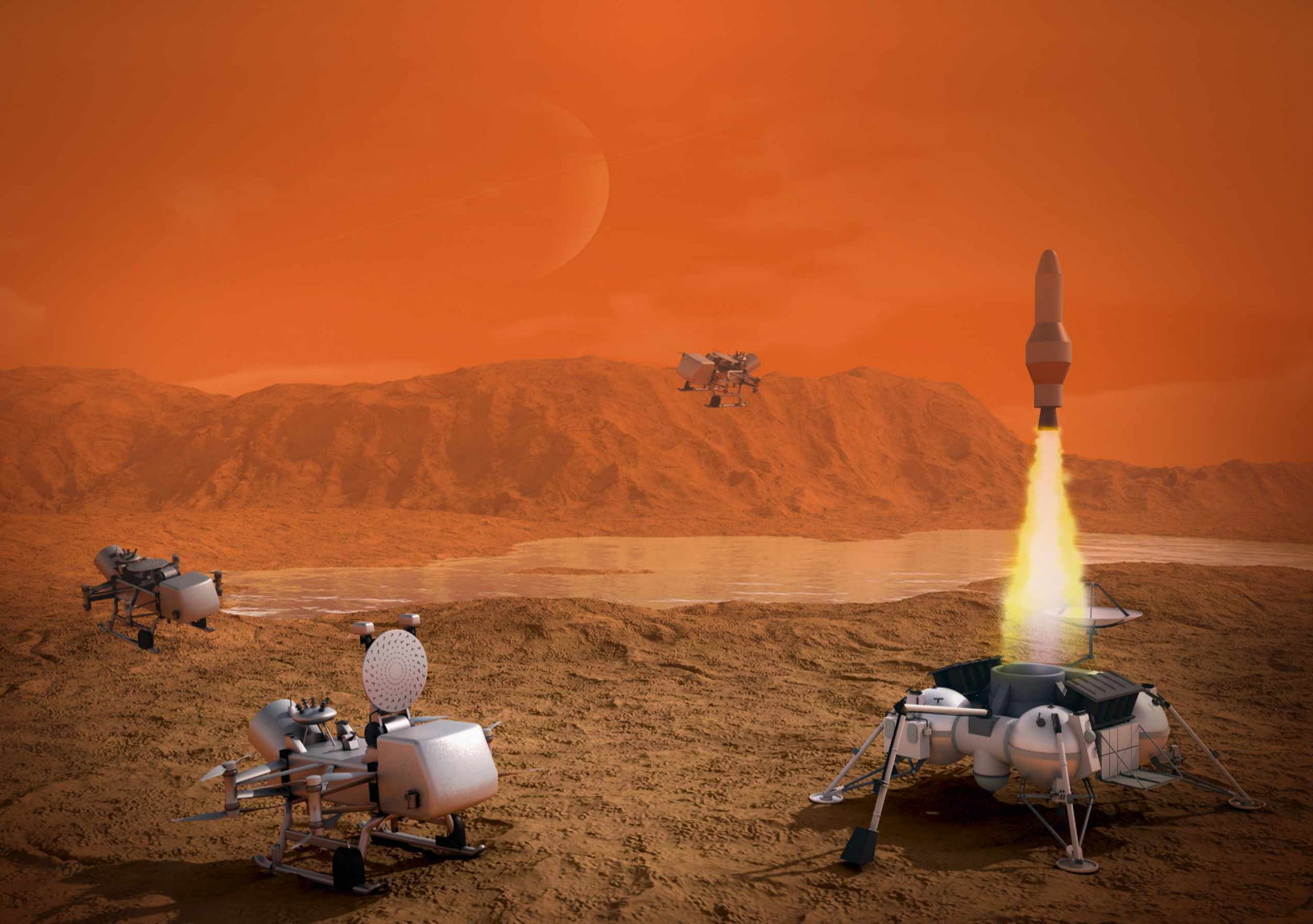
If you want to cover a lot of ground, the best way is to take to the sky

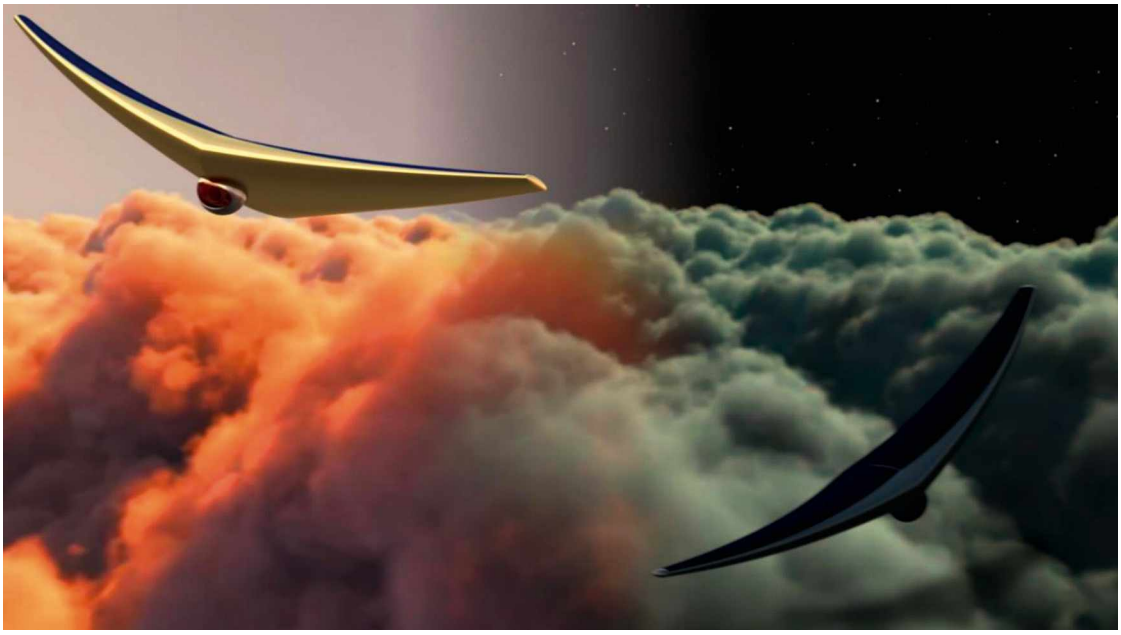
On 19 April 2021, the Ingenuity Mars Helicopter Scout became the first spacecraft to make a controlled powered flight on the surface of another planet. The drone-like rotorcraft hitched a ride aboard Perseverance, NASA's most-advanced rover that's armed with heavy robot arms, instruments and power-hungry ovens that can bake and analyse soil samples. Conversely, Ingenuity, which only has a mass of 1.8kg, carries just two cameras.

For what it lacked in instrumentation, Ingenuity made up for in range. While Perseverance had to spend weeks skirting around the outside of a boulder-strewn field, Ingenuity flew over it in minutes and was able to scout the path ahead. With such proof of potential, there's no doubt that while Ingenuity might have been the first such flight, it won't be the last.

Even before Ingenuity launched, NASA was already planning on sending its successor, Dragonfly, to Saturn's moon, Titan, in 2027. This moon is simultaneously incredibly familiar and totally alien. Like our planet, it has a nitrogen-rich atmosphere at an Earth-like pressure, while the terrain is shaped by mountains and liquid lakes. Only it's -180°C. Instead of rock, the mountains are ice, and the lakes are filled not with water, but liquid methane and ethane. Hydrocarbons such as these are thought to have formed the building blocks of life here on Earth. Could they have done so on Titan as well?

To have a chance of answering these questions, Dragonfly will have significantly more scientific power than its Martian predecessor. The increased lift of its eight rotors, combined with Titan's thick atmosphere and low gravity of 1.4m/s^2, means that Dragonfly can have a mass of 450kg – enough to carry a heavy radio thermal generator and still have a significant science payload. Dragonfly will have spectrometers to analyse both the atmosphere and soil, as well as meteorological sensors and the all-important cameras. These will help the craft to navigate as it flies for more than 175km across TItan's surface – double the distance of all the Martian rovers combined – in just 2.7 years. The images they send back will be the best ever taken of the moon's surface, and will finally reveal what's hiding among the hills and lakes of Titan.





CRUISING ON STORMY SKIES

Inflatable manta rays could scull through the acid clouds of Venus

In 2020, a group led by Cardiff University announced the potential discovery of phosphine on Venus. Here on Earth, the gas is given off by acid-loving bacteria, so could similar microorganisms be living in the sulphuric clouds of Venus? Unfortunately, a flurry of follow-up observations have cast doubt as to whether phosphine is actually present, but it's undeniably put Venus back at the top of people's planetary wishlists.

Venus's clouds sit at an altitude of around 50 to 70km. Though Venus's surface pressure is 92 times that of Earth, at an altitude of 50km it's around one atmosphere – the same pressure as sea level on Earth – meaning a helium-filled balloon could easily carry a payload of scientific instruments through the air. In fact, in 1985, the Soviet Union did just that when they dropped Vega 1 and 2 onto the planet's nightside. For two days, they were thrown around the turbulent skies, before the 250km/h wind pushed them round to the dayside and they burst in the heat of the Sun.

Since then, engineers have been searching for ways to better navigate the stormy skies of Venus. A rotorcraft would be ripped apart, but a new concept from the Crashworthiness for Aerospace Structures and Hybrids (CRASH) Lab at the University at Buffalo, New York, could offer a solution. In 2022, the lab was given funding by NIAC to develop the Bioinspired Ray for Extreme Environments and Zonal Exploration (BREEZE), an inflatable spacecraft inspired by a manta ray.

> **"As it's inflatable, it's highly compact, so two or three could launch from the same entry vehicle at once"**

"BREEZE's articulated wings are based on the ray musculoskeletal system, using an intertwined, redundant actuation network that helps reduce the chance of total system failure," says Dr Javid Bayandor, who worked on the project. This would gently twist the wings of the craft allowing it to manoeuvre along the air currents like a ray rides ocean currents.

"The bioinspired propulsion provides the light BREEZE flier with unique controllability. [This is] unlike balloon concepts, the flight paths of which are determined purely by wind direction, or conventional propulsion with large fuel consumption rates," says Bayandor. "BREEZE is one of the first concepts offered to circumnavigate Venus from within its atmosphere and survive, making measurements on the dark side of the planet."

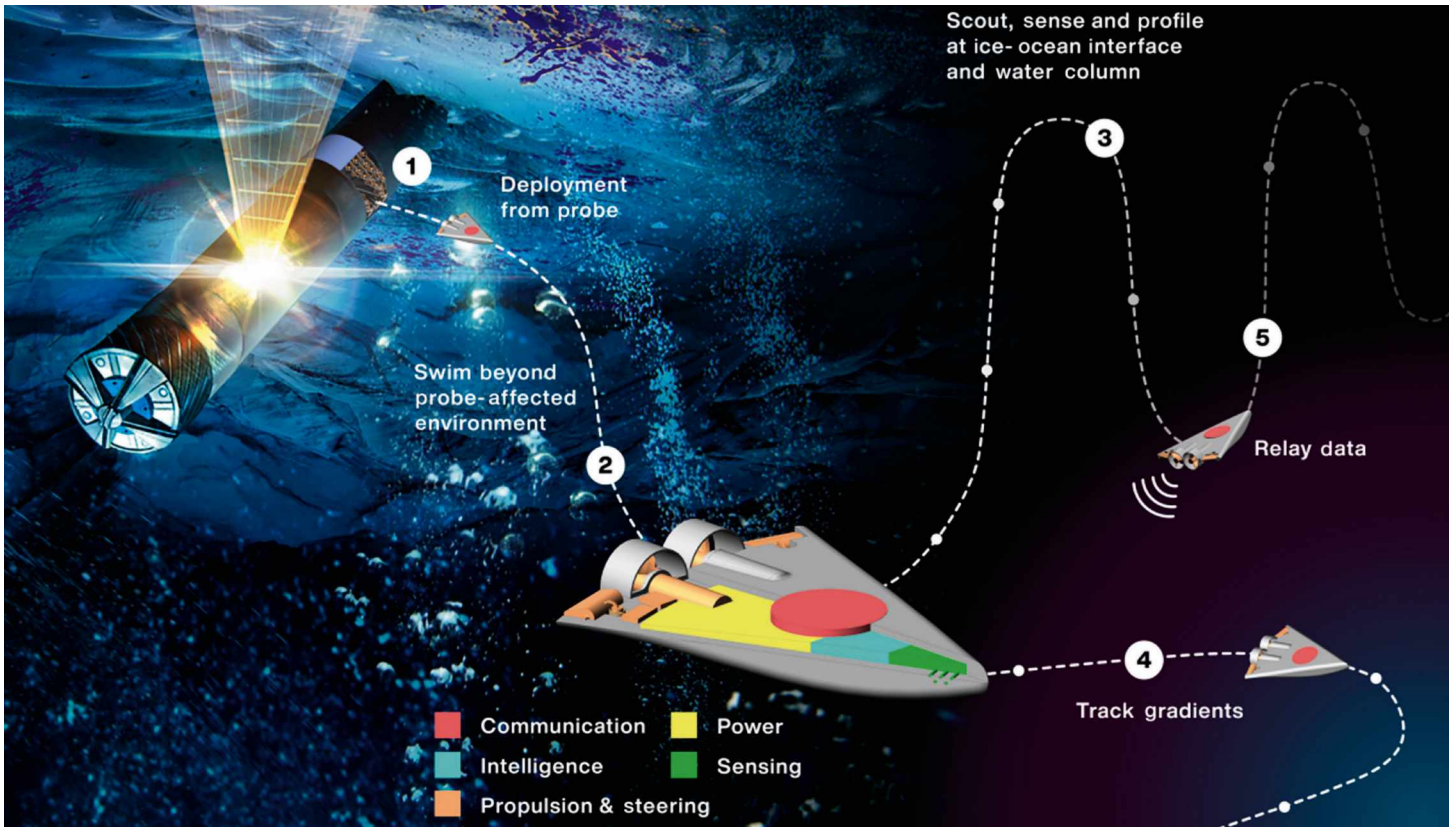
Circling the planet once every four to six days, it would be able to track weather patterns, map out the surface using radar and perhaps even sniff out biomarkers (including the elusive phosphine). As it's inflatable, it's highly compact, so two or three could launch from the same entry vehicle at once, meaning a squadron of BREEZEs could one day float along the winds of Venus.

GETTY IMAGES, JAVID BAYANDOR

ETHAN SCHALER/NASA-JPL X2

IN DEEP, DARK DEPTHS

Piercing through the crust of Europa to explore its hidden ocean



Jupiter's moon Europa hides a secret under its icy crust – a liquid water ocean. Could there be alien life swimming in the deepest depths of this quiet moon? Europa already has two upcoming spacecraft bound towards it – ESA's Jupiter Icy Moon Explorer (JUICE) and NASA's Europa Clipper. Both of these will examine the moon from orbit when they arrive in the 2030s, but the real hope is to one day land on the surface and explore the ocean beneath.

The first step, however, is getting through the ice, which can measure anywhere from a few hundred metres to tens of kilometres. One concept uses heated probes shaped like giant needles to melt through the ice. Microbiologist Dr Jill Mikucki from the University of Tennessee has been using her experience in finding microorganisms inside glaciers to test how feasible this might be on another world.

"There are many challenges when drilling through an icy moon," says Mikucki. "The ice is much colder than on Earth, and how do you supply enough power? Testing melt probes on Earth's coldest ice can help scientists and engineers better conceptualise their parameters. From my experience in Antarctica and other icy places on Earth, a lot can go wrong when you're flying blind in an ice hole!"

Most concepts for an extraterrestrial ice-diving robot, known as a cryobot, use the heat of a radioactive source to melt the ice. Others propose using drills or lasers to cut through the ice. However, most of these have focused on getting through the ice, rather than on what to do once they got there.

Not so the Sensing With Independent Micro-swimmers (SWIM) project, from NIAC. SWIM would stowaway aboard a cryobot, then deploy a swarm of 10cm-long, free-swimming robots to navigate the ocean.

"A swarm of robots can cover a larger volume of water compared to a single vehicle," says Dr Azadeh Ansari from the Georgia Institute of Technology, part of the SWIM team. "If one or a few robots fail, the mission can still be completed."

As Europa is in Jupiter's strong magnetic field, the bots could scavenge all the power they need by creating electromagnetic currents, extending their lifetimes away from the mothership. The SWIM researchers are interested in measuring the temperature, pressure, pH and salinity of the water, but also want to add a chemical gravimetric sensor to detect big molecules that could be indicative of life signs.

Now, the SWIM team is using 3D-printed prototypes to test the bots' steering, propulsion, comms and sensing systems, but one day a swarm of similar robo-space-fish could be swimming through Europa's oceans.

INTO THE SHADOWS

Life on other planets is likely to be found underground, where there is shelter from radiation

In the past, landers on both the Moon and Mars have stayed near the equator, where there's plenty of sunlight for their solar panels. Now, however, attention has moved to the darker shadows of our closest neighbours. The lunar south pole has craters where the Sun never reaches the bottom, potentially allowing for water ice to survive, while Martian cave systems could shelter microorganisms from damaging radiation. These craters and caves might one day serve as foundations for a permanent human base.

Exploring these new terrains requires a new type of vehicle, as the rovers that have so far traversed the Moon and Mars are ill-suited to a cave's rugged terrain. Robots with legs have been suggested since the early days of the Space Age, but are only now becoming technologically feasible. In fact, the first lunar 'scuttler' robot, the spider-like Asagumo from UK-based company Spacebit, is due to take its first steps on the lunar surface within the next year.

Meanwhile, the BRAILLE team (Biological and Resource Analog Investigations in Low Light Environments) at NASA's Jet Propulsion Laboratory are developing the tools such a robo-explorer will need. The bots will need to be autonomous, because the potential of losing communications, not to mention the minute-long lag time between Earth and Mars, makes direct human control impossible. The team use NeBula autonomy software that allows a robot to explore environments and adapt to unexpected scenarios without the need for human oversight.

BRAILLE simulated a mission at the Lava Beds National Monument in California, using the software on a pack of Boston Dynamics SPOT robots. The first robot was armed with LiDAR to map out the complex tunnels and identify interesting targets. A second explorer took a closer look at these, even swabbing samples from the walls. A third SPOT remotely analysed the chemical makeup of the targets. During the test, the trio climbed up rough surfaces that would stop a traditional rover in its tracks, and navigated narrow passages that even a human might struggle with.

But even these nimble explorers could be stumped by deeper crevasses. This is where a NIAC project, ReachBot, could help out. This robot uses extendable boom arms with manipulators on the end to shimmy up and down narrow passageways. Their compactable design means several could be transported together, allowing them to help each other out, pushing against each other to gain leverage. These could be dispatched into tight caves, coming back with samples that would normally be out of reach. It would be easy to carry half a dozen on the backs of Spacebit or BRAILLE descendants, ready to explore every nook and cranny of the rocky surfaces of our Solar System.

SPACEBIT, NASA/JSC

EXPANDING INTO THE SOLAR SYSTEM

Trying to cram a kilometre-sized structure into a metre-wide rocket is no easy feat

In December 1972, Apollo 17 flew to the Moon, marking the last time humans ventured beyond the bounds of low-Earth orbit. At least, for now. In August, Artemis was being readied for its first uncrewed test launch ahead of a future lunar landing. Over the coming decade, NASA will lead a team of global partners to build the Lunar Gateway, a space station that will act as a waystation to the Moon's surface and perhaps even on to Mars. The Gateway – like the ISS and China's Tiangong Space Station before it – is being built piece-by-piece from what can fit in a rocket.

But for interplanetary flight, you need bigger ships. The lack of gravity over a long-term trip through space causes muscle atrophy, heart problems, bone loss, eyesight degradation and immunosuppression. The solution is to build spacecraft that spin to simulate gravity (think *2001: A Space Odyssey*). The trouble is, to spin astronauts around without making them sick you need a craft with arms that are up to one kilometre in length. That would take dozens of costly, tricky traditional launches to build. But a NIAC concept from Dr Zac Manchester of Carnegie Mellon University could potentially do it in just one launch.

"Our goal is to make a structure that can fit inside a single rocket fairing – which limits us to just a few metres across – and can expand out to a kilometre long in orbit," says Manchester. "It turns out structures that only need to work in space don't have to be very stiff or strong because the forces acting on them are very weak. In our case, the large structures we're designing would launch folded up, so they would only need to withstand large forces in their folded configuration."

He has been investigating structures made from interconnected sets of scissor linkages to create complex shaped structures that expand up to 150 times their original size. Such structures require thousands of moving parts, which is something normally seen as foolhardy in spacecraft, given you can't just send out a mechanic if something gets stuck.

"This is one of the most difficult challenges in the project, and we worry a lot about mechanisms jamming during deployment," says Manchester. One of the key parts of his current work on the project is perfecting the design to minimise the risk from any manufacturing errors. "We're thinking about ways to strategically engineer compliance [the opposite of stiffness] into the structure to mitigate the risk of jamming."

Jack-in-the-box spacecraft could soon be popping up across low-Earth orbit, ready to sail on to other planets. SF

by DR EZZY PEARSON
Ezzy is the features editor of BBC Sky At Night Magazine *and author of* Robots In Space: The Secret Lives Of Our Planetary Explorers *(£20, The History Press).*

THE MYSTERY OF MIGRAINES

According to the NHS, around 10 million people aged 15 to 69 in the UK suffer from migraines. But our understanding of them is still incomplete, and there isn't even a pill to make them go away

Words: **DR DEAN BURNETT** Illustration: **SCOTT BALMER**

Why do people get migraines? It's a simple question, but one with an incredibly complicated answer. If 'answer' is even the right word. Because, in truth, as far as the science is concerned, the most honest and straightforward answer to 'why do people get migraines?' would be 'we don't know'. Despite countless years of research and study, it seems that the underlying science of migraines is so nuanced and complex that our understanding is still far from complete.

However, it's always worth emphasising that 'incomplete understanding' is a far cry from 'zero understanding'. Science has revealed many significant things about migraines, why they occur, why they endure, who they affect, and why they hit us so severely.

Is a migraine just a bad headache?

For those lucky enough to not have to deal with them, it's easy to label migraines as a type of headache. However, while 'headache' is an undeniable aspect of the experience of a migraine, migraines are actually much more than just a headache, and have numerous key differences.

For one, headaches are more common than migraines. Estimates suggest that 75 per cent of all people will have experienced at least one headache within the last year. By contrast, evidence suggests that just under 15 per cent of people experience migraines, with less than 10 per cent of those having chronic migraines.

There's also a much clearer gender divide with migraines, with between two to three times as many women enduring them as men (a ratio that fluctuates depending on stage of life).

Also, while there is uncertainty and overlap, headaches and migraines have distinct features. The more common types of headache are tension headaches (the feeling of pressure or tension on both sides of the head), sinus headaches (the result of congestion, where the sinus passages swell and put pressure on tissues behind and around the eyes and nose), and cluster headaches (painful, repeating headaches, often localised to around the eye regions on one side of the head).

While these headaches can be misdiagnosed as migraines, and vice versa, migraines typically have their own unique features that set them apart. They tend to be much more debilitating, with increased fatigue and sensitivity to light. They also last longer (and have a bizarrely reliable form of progression, with distinct stages), and include nausea and, in many cases, sensory distortions, like the perception of 'auras'.

Ultimately, while there is undeniably a lot of overlap, migraines have a different mechanism and expression compared to most headaches, to the extent that they're officially recognised as a neurological disorder, where headaches usually aren't.

The root cause of migraines

The fact that we're still unsure about how and why migraines happen seems even more surprising when you consider how long we have been dealing with them. Texts from Ancient Egyptians and Greeks, dating as far back as 1200 BC, describe specific ailments and experiences that are indicative of migraines.

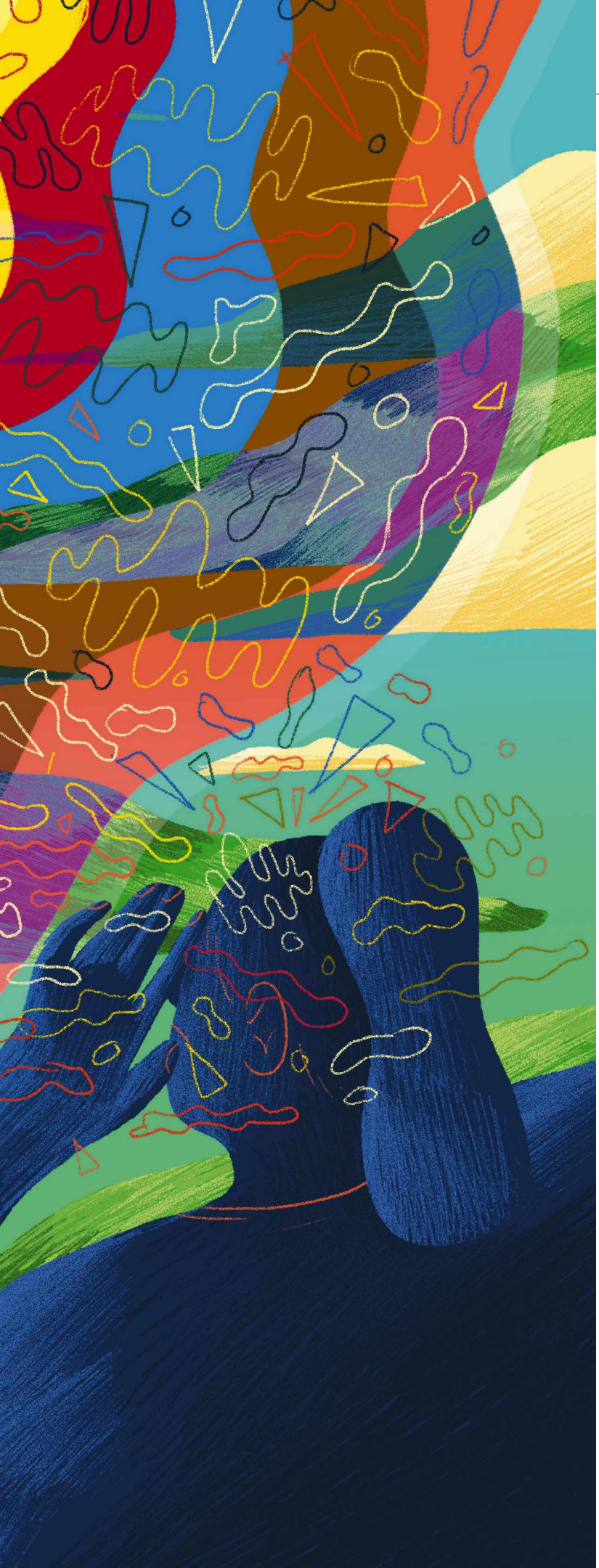
Among the many complicated processes we now know are taking place in the head and brain when a migraine occurs, if there's one that's likely to be at the root of them all, it's what's known as cortical spreading depression, or CSD.

CSD is when a neuron (a brain cell) experiences a sudden burst of activity, known as depolarisation, a brief 'flipping' of the microscopic voltage that exists along the cell membrane of all neurons. This depolarisation is the basis of all the activity and signals that occur within our brain and body. However, it's a demanding process, so after it occurs, neurons are briefly 'depressed', or in a resting state, where they aren't as active as normal.

"THE TRIGGERING WAVE OF CSD SLOWLY TRAVELS THROUGH THE VICTIM'S BRAIN"

Depolarisation is typically initiated and sustained as part of one of the countless processes occurring within the human brain. However, it seems that sometimes, for whatever reason, certain neurons will depolarise... just because. Presumably because all neurons are interconnected, and all their activity ultimately boils down to changes in the concentrations of chemicals in and around them, this unexpected depolarisation 'spreads' to neighbouring neurons, and on to the next ones, and so forth. This process is incredibly slow and can take many minutes, hours even, to travel from one part of the brain to the next. And so, we have CSD.

Unfortunately, anomalous neurological activity in important and delicate brain regions can lead to negative consequences. It's likely that this spreading wave of neurological activity is what causes the unpleasant aspects of migraines, and would explain why migraines have such distinct stages. The wave of CSD begins in one part of the brain, causing one suite of symptoms, and travels along established routes, incorporating more brain regions, and thus causing different (and often more severe) symptoms along the way. Indeed, if the CSD spreads as far as the occipital lobe and visual cortex, you would expect to see visual symptoms, which would explain why some migraines have auras. It would also explain why migraines last so long. The triggering wave of CSD slowly travels through the brain, prolonging the suffering of the migraine victim.



Nerves vs blood vessels

It's all well and good saying that migraines are due to a slow-spreading wave of anomalous neurological activity in the brain, but how do we get from something so 'fundamental' to something as tangible as severe headache pain, nausea, light sensitivity, and all the rest?

That's where the issue becomes trickier. For some time there was a notable debate as to whether the main aspects of migraines were neurological (due to unhelpful activity in and between brain cells) or vascular (due to changes in the blood vessels that supply the brain).

For many years, it was assumed that migraines were more vascular in nature. The throbbing nature of many migraines can be reminiscent of the feeling of your pulse, and suggests tangible changes in pressure, which would obviously point towards an issue with the brain and head's blood supply.

It was thought by many that the blood vessels in the tissue layers that surround and protect the brain underwent vasodilation (expansion), which caused an increase in pressure in the already densely crowded environs of brain tissue, and this pressure increase was perceived as pain. But more recent evidence suggests that vasodilation isn't as prominent a factor in migraines as was previously assumed.

However, lately many have leaned towards a more neurological mechanism when explaining migraines. After all, if it stems from waves of unhelpful activity in neurons, this is bound to have knock-on effects in other neurons, right?

A particular focus for the neurological aspects of migraines is the trigeminal nerve. One of the 12 cranial nerves – the large nerves that connect the brain to the face, neck and torso – the trigeminal nerve is a triple-branched nerve that conveys, among other things, the sense of pain from the face and head, hence the chronic pain of trigeminal neuralgia.

Correspondingly, abnormal activity in the trigeminal nerve is closely linked to the symptoms of migraine, and helps explain why grinding your teeth or clenching your jaw (two actions that depend on the trigeminal nerve) are associated with triggering migraines.

In truth, though, it's extremely unlikely that migraines are exclusively caused by neurological or vascular factors. For instance, some argue that CSD causes vasodilation in the trigeminal nerve, which leads to increased pressure, and therefore pain. This means it's both a neurological and vascular issue, hence some people referring to migraines as a neurovascular condition.

Indeed, at this level, you could argue that differentiating between neurological and vascular aspects is tricky, and ultimately meaningless. Activity in neurons regularly leads to changes in the properties and behaviour of nearby blood vessels, and blood vessels directly affect neurons via the pressure and chemicals they apply. This means that the anomalous activity in the brain would very likely be affecting both nerves and blood vessels at the same time.

Migraines, chemicals, hormones and sex

Thus far, it seems like migraines are the result of waves of anomalous nervous activity, spreading slowly throughout certain areas of the brain. This leads to unhelpful and disruptive changes in the neurons and blood vessels in those areas, which in turn cause the impressively varied – if deeply unpleasant – symptoms of migraine. It makes logical sense that if you induce anomalous activity in several important and fundamental areas of the brain, it's inevitably going to lead to a wide range of physical problems and disruption.

But it's possible to look even deeper than we already have. Even if we accept that migraines arise because of abnormal neural activity that leads to CSD (although another theory points to abnormal activity in the brainstem), what is it that causes this unusual activity in the first place?

As ever, it's hard to be 100 per cent sure, but a lot of data points to it being, at least in part, the result of a drop in the levels of vital neurological chemicals in the relevant brain regions.

One of those is our old friend serotonin, a neurotransmitter with many important roles, most famously in the regulation of mood. However, there's a lot of research that points to drops in serotonin levels being a potential trigger for the onset of migraines. Supporting this is evidence of a link between migraines and major depressive disorder.

But serotonin isn't the only crucial brain chemical that can lead to migraines when the levels of it drop. Another one is oestrogen. And oestrogen is a hormone that has a far more prominent role in female biology than male. This would explain why women are far more prone to migraines than men, and how their reproductive cycle and stage of life can play a big part in their experience of migraines.

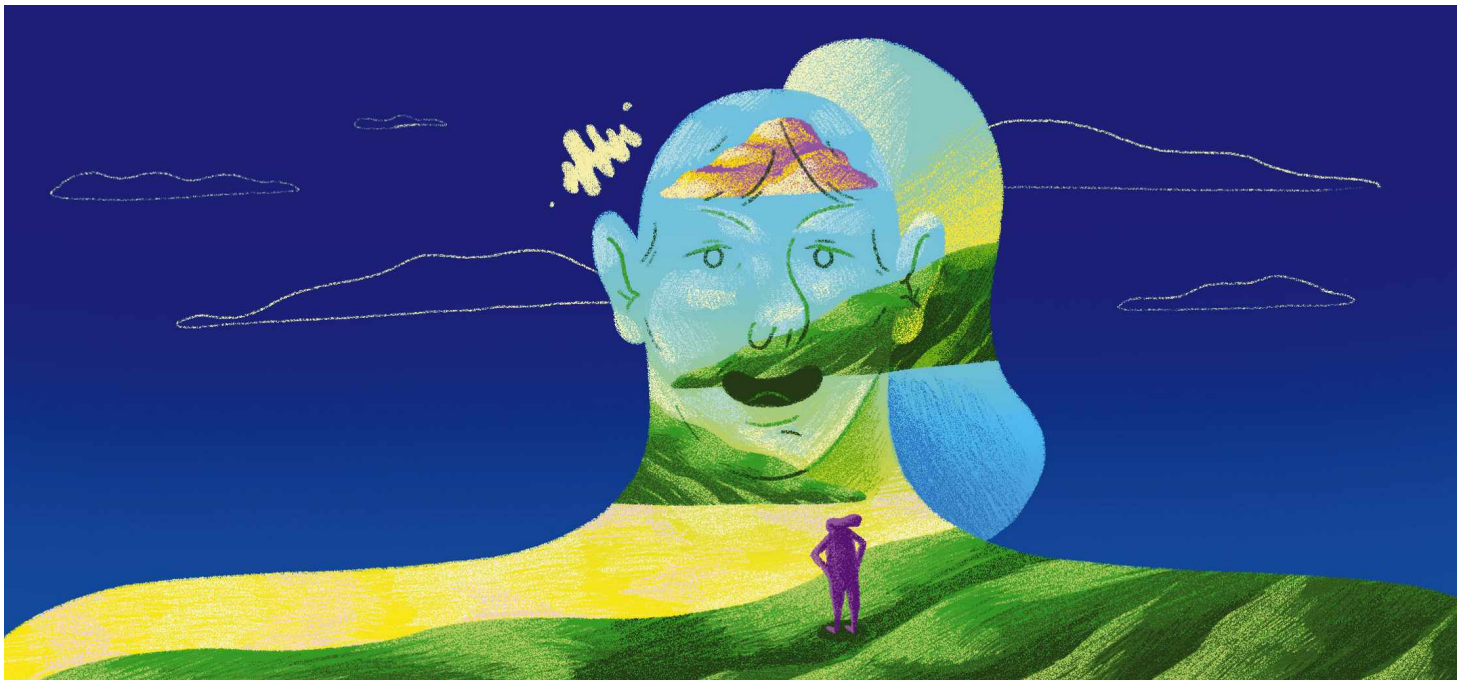
One possibility is that the presence of serotonin and/or oestrogen stabilises the activity in key neurons, so when one or both is depleted past a certain point, the neurons depolarise 'randomly', and we get CSD. And therefore migraines.

Other chemicals play a role too. Stress is regularly cited as a common cause of migraines. Among other things, cortisol (a chemical released during stress) is known to make neurons more sensitive to pain, so severe or prolonged stress could be what tips those vulnerable to migraines into the onset of an attack.

And of course, if stress is a factor in causing migraines, then being regularly incapacitated by migraines is undeniably stressful. So, a vicious feedback loop kicks in.

"A LOT OF RESEARCH POINTS TO DROPS IN SEROTONIN LEVELS BEING A POTENTIAL TRIGGER FOR THE ONSET OF MIGRAINES"

Can we treat migraines?



Because migraines are such a debilitating and enduring problem, it's hardly surprising that there is a great deal of interest in anything that could cure or treat them, or even just provide some relief from the symptoms. As a result, there are a wide range of potential treatments and interventions for migraines. Although some seem rather more credible than others...

Everyday painkillers

The most typical means of tackling a migraine are common over-the-counter analgesics like aspirin, ibuprofen and paracetamol. These can often provide some modicum of relief from migraine symptoms, albeit to a rather limited extent. Interestingly, exactly how they work on migraines remains unclear. But then, we're still not sure exactly how paracetamol works either. We just know that it does.

Triptans

Triptans are an increasingly common go-to for treating migraines. They do not prevent migraines; they are taken once symptoms start. They work on the serotonin neurons (which we now know are key to the migraine process) and block pain pathways in the brain, therefore neutralising the painful migraine headache. They have many potential side effects, and don't do much for the nausea, fatigue, or sensory aspects. But it's better than nothing.

Botox

Unless your migraine is caused by stress over how many wrinkles you've got, most wouldn't consider Botox a potential migraine treatment. But evidence suggests otherwise. Botox is a substance that paralyses nerves, and when administered for migraines, it's injected under the skin or into the muscles around the forehead, ears and neck. Not the most orthodox solution maybe, but something that could bring a smile back to your face.

Surgery

As a last resort, surgery can be used to ease migraines. Nerve decompression surgery, a technique pioneered by plastic surgeons, surgically alters, or relieves pressure on, the nerves responsible for migraine pain in certain patients, thus treating the condition.

As ever, there are risks with any surgery, so it depends on whether the migraine is so bad that submitting to a procedure which involves 'nerves' and 'scalpels' seems like the better option.

Migraine-relieving hand clips

Every part of the body is connected to the other via our nervous system, so I would never *say* that migraine-relieving hand clips are just small bits of inert plastic that have no feasible mechanism of dealing with a migraine. But I'm *thinking* it pretty hard.

Migraine relief cap

The premise of migraine relief caps seems to be that putting something on the head, maybe something that covers the eyes to reduce sensory input, will make a migraine better. If nothing else, the embarrassment of being seen wearing one may distract from painful migraine symptoms. **SF**

by **DR DEAN BURNETT**
(@garwboy)
Dean is a neuroscientist and international bestselling author. His latest book is Psycho-Logical *(£9.99, Guardian Faber).*

Q&A

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ILLUSTRATION: DANIEL BRIGHT

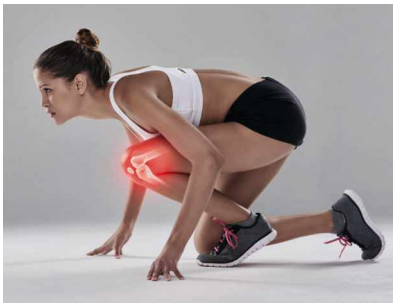
JASMINE HARRINGTON, VIA EMAIL

WHAT'S THE BEST THING TO DO WHEN YOU CAN'T SLEEP?

If you've been lying in bed unable to sleep for 15-20 minutes or more, it's a good idea to get out of bed and do something else (ideally in another room). The logic of this tip comes from considering stimulus-control (we learn to behave in a certain way in the presence of certain stimulus). We want to pair sleep (rather than being awake) with the bedroom environment. Only return to the bedroom when you are ready to sleep.

Although people will differ in terms of what they want to do while up at night, some might be keen to try out relaxation techniques. Breathing exercises come in different forms, but one technique is to breathe in through your nose for the count of four (feeling your tummy fill with air) and then breathe out through your mouth for the count of four (stop immediately if you feel faint).

Mindfulness, which involves being in the moment, without judgment, can also help to reduce stress and support sleep, and some people enjoy taking part in guided meditations. Mental imagery can also be helpful, and in a study by the eminent psychologist Dr Allison Harvey from the University of California, Berkeley, it was found that the participants of a study who were asked to remember a relaxing scene in detail (and considering how it impacted their different senses) fell asleep more quickly than those who were not asked to do this. One explanation is that the relaxing scene filled up 'cognitive space' that could not then be used to engage in stressful or distressing thoughts which could interfere with sleep. ***AGr***



CAITLIN BYRNE, DUBLIN

WHY ARE OUR KNEES SO PRONE TO INJURY?

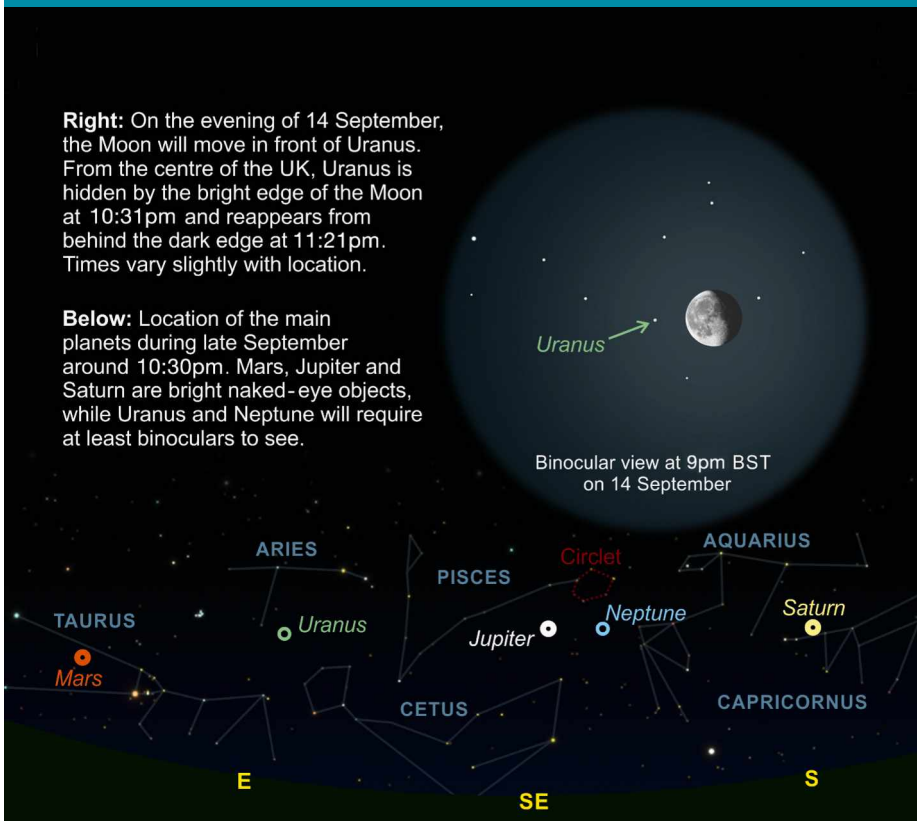
Unlike, for example, the hip joint, which is a ball and socket joint, the knee is a hinge joint. The bottom of your thigh bone sits on top of the shin bone, and the joint is held together by ligaments and muscles that can easily be sprained and torn. As well as being structurally less stable, the knee joint is also far more restricted as it can only move forwards and backwards with a very limited amount of twisting. The moment the knee is no longer aligned with the foot, it relies on the ligaments and muscles for stability – which can easily be pushed too far and cause injury. ***NM***

TIM MANNING, VIA EMAIL

HOW DOES A SMART WATCH MEASURE YOUR STATS?

Smart watches are packed full of sensors. They have accelerometers that measure the direction of your movement and allow the software to figure out if you're walking or running. They have GPS to work out how far you travel, which helps establish your stride length. They have altimeters that figure out if you're climbing up or down. Some smart watches also measure your pulse or detect irregular heartbeats. Your heart causes your blood vessels to dilate and contract every time it pushes blood. Using a process called photoplethysmography, green LEDs on the watch shine light through your skin and measure the reflection from the changing amounts of red blood cells within your wrist. ***PB***

ASTRONOMY FOR BEGINNERS



A PARADE OF PLANETS

WHEN: MID TO LATE SEPTEMBER

After residing in the morning sky for the first half of 2022, the bright and not-so-bright planets can now be seen in the late evening sky. The progression starts with Saturn, which is visible 20° above the southern horizon at 11pm BST on 14 September, progressively getting to this position earlier each night to arrive there by 10pm on 30 September. For reference, the horizon is 0° and the overhead point, or zenith, is 90°, with 20° representing a height approximately one-fifth up the sky.

Jupiter follows Saturn higher across the sky and is unmissable because of its brightness. Less obvious is dim Neptune, which requires binoculars to see. It's located west-southwest of Jupiter below a circular pattern of stars known as The Circlet.

Later in the evening, it's the turn of Mars and Uranus to make an appearance. Like Neptune, Uranus is dim and benefits from binoculars. If it's clear on the evening of 14 September, the waning gibbous Moon, which is 77 per cent lit, moves in front of Uranus. This is a rare event known as a lunar occultation. The bright edge of the Moon hides Uranus at 10:31pm, as seen from the centre of the UK, a time which varies slightly with location. It'll pay to start viewing from around 10pm so you don't miss anything. Reappearance occurs from behind the Moon's dark edge at 11:21pm. Start looking for reappearance from around 11:10pm onwards.

Mars is located further east (left) and unmissable because it's bright and distinctly orange in colour. Mars will improve in appearance until around 8 December when at opposition, on the opposite side of the sky to the Sun. Excitingly, on 8 December the Moon will also occult Mars, something which should be very spectacular to watch if the sky is clear. *PL*

GETTY IMAGES X3 ILLUSTRATIONS: PETE LAWRENCE, DANIEL BRIGHT

ELLA BRADBURY, VIA EMAIL

WHAT IS ASH DIEBACK?

Ash dieback is a disease that affects the UK's native ash species, the European ash. It is caused by a fungus called *Hymenoscyphus fraxineus*, which typically enters through the leaves before spreading throughout the tree, eventually strangling its water transport system and causing it to die. *H. fraxineus* spores spread on the wind, travelling distances up to 16km (10 miles). Ash dieback, which originated in Asia, was first spotted in nurseries in eastern regions of the UK in 2012. Since then, it has spread westwards and is now found throughout the British Isles. There is no cure for the disease, and experts predict that it has the potential to obliterate up to 90 per cent of the UK's 150 million mature ash trees, threaten dozens of species that rely exclusively on ash, and cost the economy an estimated £15bn. ***CP***

SARAH WEITZMANN, PENZANCE

WHAT MAKES SOMEONE AN ADRENALINE JUNKIE?

Adrenaline is a hormone that sends the 'battle stations!' signal to your body. Blood flow increases to your muscles, your attention sharpens, and your pupils dilate. Adrenaline is chemically related to the pleasure hormone dopamine, and dangerous situations can also cause your body to produce endorphins, which suppress pain and heighten pleasure. These systems may have evolved because a certain amount of risk-taking has survival value – we are descended from people brave enough to hunt mammoths, after all. There are specific genes that increase the 'adrenaline high' for some people, and a 2002 study for the World Health Organization found these genes in both adrenaline junkies and drug addicts. ***LV***

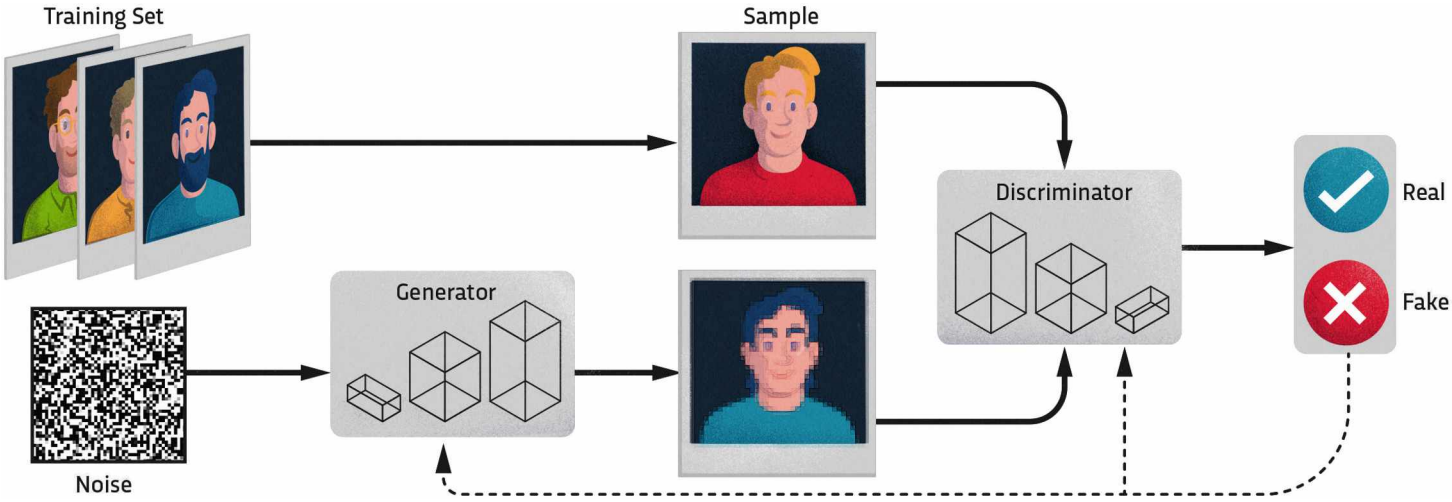
DAVE HOLROYD, BIRMINGHAM

HOW DO MACHINE LEARNING GANS WORK?

GAN stands for generative adversarial network. These are clever machine learning (ML) algorithms that use neural networks (simplified computer models of the brain) in a specific way. We call them 'generative' because once they have been trained on a dataset, they can generate new examples that resemble what they've seen. Train a generative ML algorithm on a dataset comprising millions of photos of faces and it will be able to generate new photorealistic faces.

Many ML algorithms need supervision, like teaching a student in a classroom. We must tell them what the data represents, and tell them if they get the answer right or not. GANs don't need supervision – they teach themselves. This kind of unsupervised machine learning is achieved because a GAN has a split personality. It uses two neural networks to compete against each other (hence the name 'adversarial'). While one neural network looks at the training data and then tries to generate something new, the other neural network tries to discriminate between this output and the training dataset. The first network is rewarded every time it fools the second one. The second one is rewarded every time it is not fooled. Both networks are improved, by repetition, with the aim of maximising those rewards. The resulting internal arms race causes the first network to become extremely good at generating outputs that are indistinguishable from the training set.

When we give a GAN additional information (such as 'this image is a painting by Pollock' or 'this photo is shot at night') or we augment its data by messing with it ('here's the image rotated 75°', 'here's the image zoomed in') then it can do remarkable things. GANs can generate higher-resolution versions of images, or convert one into another style – or even convert day to night, or summer to winter in an image. ***PB***



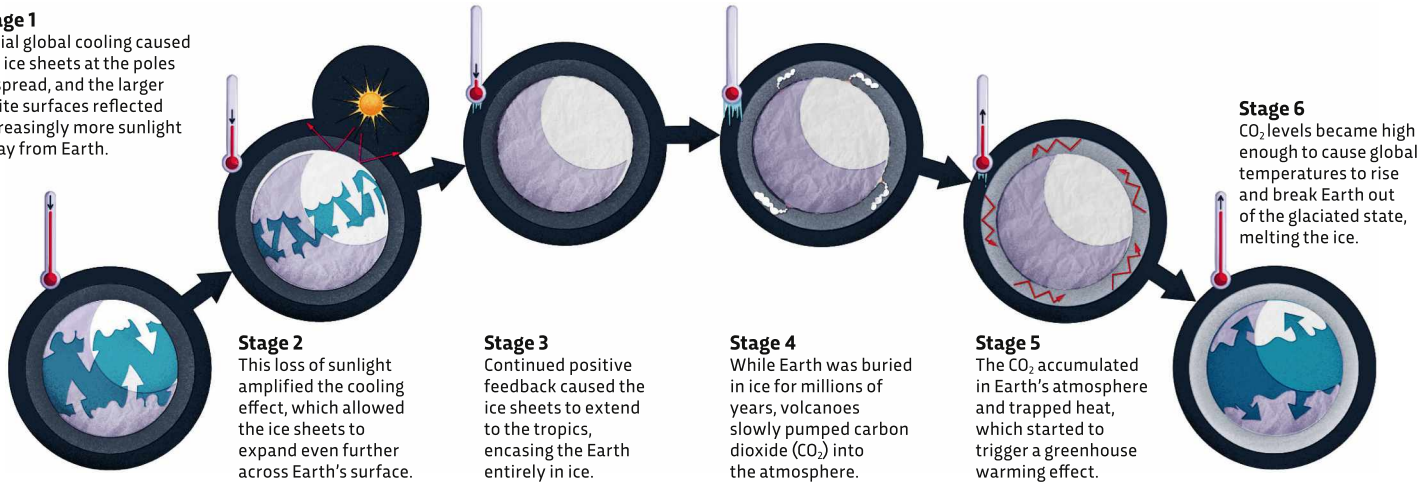
KERRY RYDER, ABERDEEN

WHAT IS THE SNOWBALL EARTH HYPOTHESIS?

The snowball Earth hypothesis proposes that at least twice in Earth's history, sometime between 2.4 billion and 580 million years ago, the planet became entirely frozen from pole to pole, including the oceans. Although no single driving process has so far been identified, some scientists believe this best explains deposits of material of potential glacial origin found in low latitudes.

The hypothesis is an example of how feedbacks in Earth's climate geosystem – in this case the ice albedo feedback – can create extreme change on a global scale. The basic idea is that when a planet cools it becomes more reflective – ice is more reflective than land or open ocean – so it absorbs less solar radiation and becomes cooler still, and a runaway cooling effect takes place.

The term 'snowball Earth' was originally coined by the American geologist Joseph Krschvink in 1992, but perhaps unsurprisingly, the hypothesis is hotly contested among experts in this field. It has led to an alternative theory being proposed which challenges the suggestion that Earth was completely frozen over – the slushball Earth hypothesis.



Stage 1
Initial global cooling caused the ice sheets at the poles to spread, and the larger white surfaces reflected increasingly more sunlight away from Earth.

Stage 2
This loss of sunlight amplified the cooling effect, which allowed the ice sheets to expand even further across Earth's surface.

Stage 3
Continued positive feedback caused the ice sheets to extend to the tropics, encasing the Earth entirely in ice.

Stage 4
While Earth was buried in ice for millions of years, volcanoes slowly pumped carbon dioxide (CO_2) into the atmosphere.

Stage 5
The CO_2 accumulated in Earth's atmosphere and trapped heat, which started to trigger a greenhouse warming effect.

Stage 6
CO_2 levels became high enough to cause global temperatures to rise and break Earth out of the glaciated state, melting the ice.

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

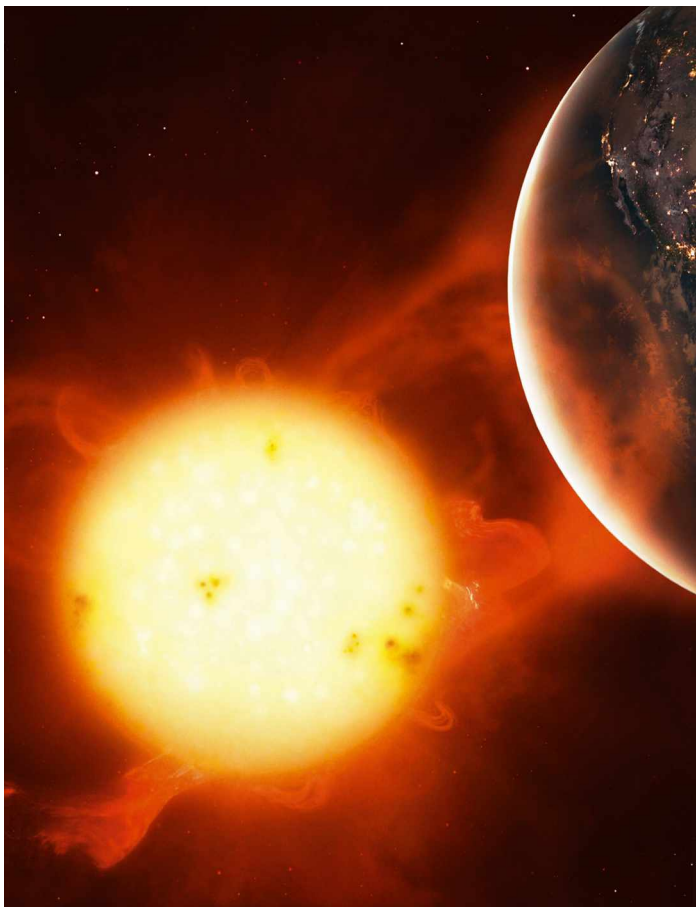
HOW DO YOU GET HEALTHY HAIR?

"Get hair that's glossy, vibrant and full of life!". We've all seen the shampoo ads. 'Healthy' hair is surprisingly important to our personal identities – just ask balding men or people who embrace the kinky or coily texture of natural Afro hair. But isn't hair mostly just dead protein? And how can something that isn't alive be considered healthy? It all comes down to the integrity of the cuticle.

The cuticle is the outermost layer of each individual hair, and it acts like a suit of armour. It's made up of dead cells, neatly overlapping like roof tiles. Over time, heat, chemical styling, UV light, pollution and swimming in chlorinated pools can all prevent these cells from lying flat – creating gaps in the armour. This allows damaging elements to penetrate the core of the hair shaft and weaken it, making hair dull, dry and brittle. Compare the ends of your hair to the part nearest your scalp and the environmental damage will likely be obvious.

Keep your cuticles in tip-top condition by finding the right combination – and frequency – of cleansing and moisturising for your hair type. Focus shampoo near your scalp, where it can do its job of removing the natural oils that build up there. Use conditioning products along the hair shaft, all the way to the ends, to replenish any moisture stripped by the shampooing process and help seal the cuticle shut. Lastly, limit how often you use heat to style your hair. At temperatures above 180°C the proteins in hair start to break down, and heat damage is irreversible. Straightening irons can reach 230°C, so proceed with caution! *CP*

GETTY IMAGES X2, ALAMY. ILLUSTRATION: DANIEL BRIGHT



BILL ORZEL, VIA EMAIL

HOW DO SOLAR FLARES AFFECT THE EARTH?

Solar flares are energetic releases of electromagnetic radiation (and sometimes matter) from the surface of the Sun, thought to be caused by the localised twisting and realignment of the Sun's magnetic field. Most of this electromagnetic radiation is absorbed by Earth's dayside ionosphere and has little effect on the planet.

However, strong solar flares can increase the ionisation of the upper atmosphere, knocking electrons out of their atoms, which then interferes with the propagation of short-wave radio signals used for communications. Solar flares also heat the ionosphere, causing it to expand, which is a potential threat to artificial satellites in low-Earth orbit.

A more dangerous scenario is when a solar flare releases a stream of energetic subatomic particles towards Earth. These 'coronal mass ejections', or CMEs, buffet Earth's magnetic field, squeezing and shaking it, and can induce enormous electric currents in telephone lines and electrical distribution networks on our planet's surface. CMEs can also expose astronauts to dangerous levels of radiation.

One positive outcome of CMEs is that they are often responsible for spectacular auroral displays at Earth's polar regions. Overall, though, there are no long-term effects of solar flares or CMEs, either to humans or to planet Earth. ***AGu***

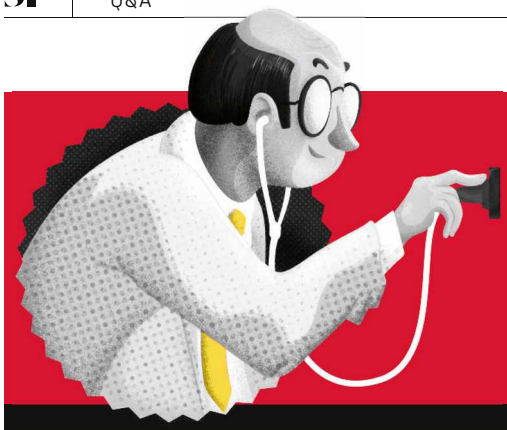
NATURE'S WEIRDEST ANIMALS...

THE HONEYPOT ANT

Bees aren't the only insects to make honey, some ants can make the sweet treat too. The honeypot ant, *Camponotus inflatus*, lives in the deserts of Australia where worker bees harvest nectar from the flowers of the mulga tree. The bees carry it underground and feed it to specialised workers known as 'rotunds' whose job it is to dangle upside down and eat. Indeed, the tubby little insects are fed so much nectar that their abdomens swell up to the size of a small grape, and the abdomen wall is stretched so thin that the honey can be seen inside.

These literal honeypots are an insurance policy against hard times. When the regular workers run out of food, they stroke the rotunds' antennae, causing the ants to regurgitate the stored honey. They also groom and clean the honeypots to keep the living larders in good condition.

The rotunds form roughly 50 per cent of the colony, and live in cool, underground galleries. They are highly prized by Indigenous Australians who have been excavating and eating them for thousands of years. In the 1990 documentary, *Trials Of Life*, David Attenborough was filmed quaffing one. The honey is said to be runnier and less sweet than the better-known bee alternative, but remains rich in antioxidants. ***HP***



DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY OUR EXPERTS

I CAN'T STOP SQUEEZING MY SPOTS, IS THERE A BETTER WAY TO GET RID OF THEM?

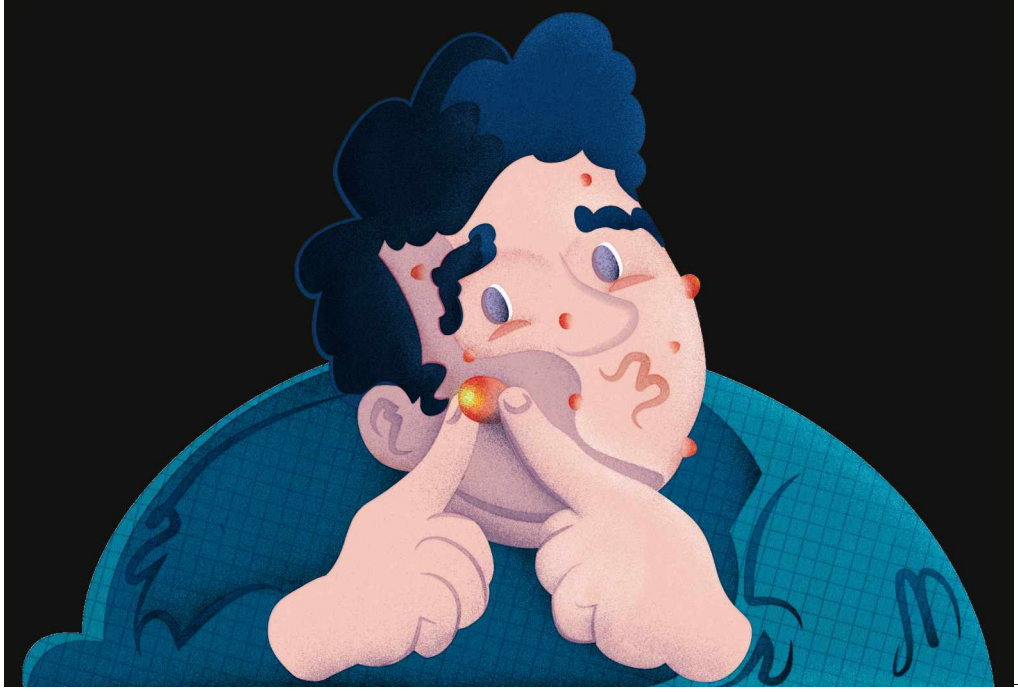
Squeezing spots can make them worse and increase the likelihood of permanent scarring, so do try to avoid this, however tempting it might be. There are lots of other things you can try yourself at home, and some medications which you can get from a pharmacy or from a GP.

Simple things to try at home include avoiding oily make-up and moisturisers, removing make-up completely before bed, washing the affected area with a mild soap or cleanser and lukewarm water (not too hot or cold) no more than twice a day, washing hair regularly and trying to avoid letting hair fall across your face. To date, despite what most people think, there is little evidence that diet has an impact, and acne is certainly not due to a lack of cleanliness!

Lots of people try to manage acne for too long at home themselves. Even if acne is mild, if it's bothering you then it's a good idea to speak to a pharmacist as there are several creams, lotions and gels for treating spots available to buy that can make a big difference. Usually, products containing a low concentration of benzoyl peroxide are recommended.

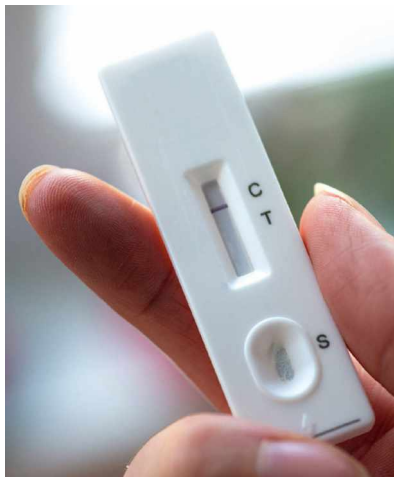
If these products don't work, or your acne is more severe, or appears on your chest and back, you may benefit from a course of antibiotics or stronger creams that are only available on prescription. Sometimes women find acne is worse around their period, and contraception can be used to help (even if the person is not sexually active). The side effects of these treatments are usually minimal, and they can be very effective.

Please see your GP sooner rather than later, and there is no need to feel self-conscious. It's a common condition and can often be treated effectively with a short course of treatment. ***NM***

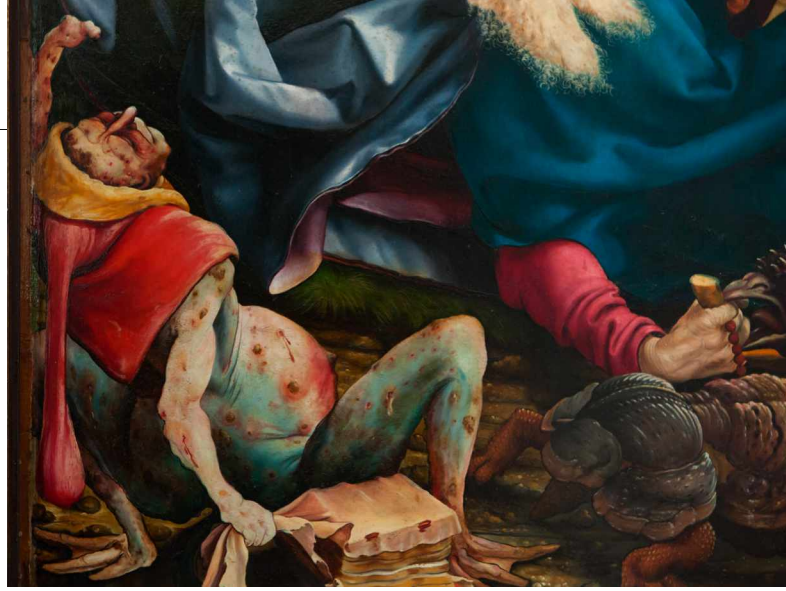


JOHN BOTHWELL, VIA EMAIL

CAN YOU PASS ON COVID-19 IF YOU'RE TESTING NEGATIVE?



Yes, it is possible to still spread COVID-19 if you test negative but have cold-like symptoms. This is true if you just started having symptoms, as well as if you're testing negative after a COVID-19 infection. Rapid COVID-19 tests are quite good at telling if someone is infected and can spread the virus to others. However, these tests are not very good at detecting low amounts of the virus and can show a negative result even if someone is infected. This is because early and late in the infection the amount of virus present in the nose may be very small, not enough to test positive but possibly enough to spread to others, especially if symptoms are present. So, if someone has low amounts of the virus, they may test negative but still be infectious, especially if symptoms are present. Also, at the start of the infection the amount of virus may be very small but can rapidly increase over a matter of hours. Because of this, some people may test negative but then positive several hours later. With a positive test it is important to then isolate to prevent spreading the virus. If you get a negative test but have symptoms, remember to use extra precautions and test again later, as you still may be infectious. ***JR***



JENNY WARWICK, VIA EMAIL

WHAT IS HOLY FIRE DISEASE?

Holy fire disease, also known as St Anthony's fire or ergotism, is a medical condition that causes a burning sensation in the limbs and, if left untreated, can cause gangrene (tissue death) and seizures. It is caused by eating cereal grains such as rye that have been infected by the purple club-headed fungus *Claviceps purpurea*. The fungus releases alkaloid substances into the grains, which stimulate serotonin, dopamine and epinephrine hormone receptors when consumed, making blood vessels constrict. This reduces blood flow to the organs and limbs, causing tissues to die.

The earliest historical references to the disease date back to 857 AD, but its cause wasn't identified until the 17th Century. By the late 19th Century, agricultural practices, put in place to prevent the fungal infection and remove infected grains, had almost entirely eliminated the disease in humans.

As early as the 1500s, midwifes realised that consuming grains infected by the ergot fungus could induce labour in pregnant women, and by the 1750s, they were stocked by pharmacies as a treatment for stalled labour. However, consuming infected grains made it difficult to give precise doses and the practice became associated with stillbirths. The active ingredient – ergometrine – was purified in 1935 allowing for the medicine to be prescribed more precisely and it remained a popular method for inducing labour, until it was replaced by safer alternatives like oxytocin.

Today, ergometrine is still used medically to prevent bleeding after childbirth, as well as to treat severe migraine headaches. In rare cases, these ergot-based medicines can cause Holy fire disease, especially if the drug is combined with other medications. For example, a case of ergotism was reported in 2020 as a result of combining an ergometrine migraine treatment with HIV medication, causing ergometrine to build up in the body to dangerous levels. ***CA***

QUESTION OF THE MONTH

HADDEN DIAMOND HOLGATE, AGED 7, VIA EMAIL

IF THE UNIVERSE IS EXPANDING, HOW IS IT POSSIBLE THAT THE MILKY WAY AND THE ANDROMEDA GALAXY ARE GETTING CLOSER TO ONE ANOTHER?

The Universe is certainly expanding in the aftermath of the Big Bang 13.82 billion years ago, but you yourself are not expanding. Neither is the Earth nor our Solar System nor our Milky Way nor the local group of galaxies of which the Milky Way and Andromeda are the two most prominent members. This is because only on the largest scales is cosmic expansion strong enough to overcome the gravity that's binding together astronomical objects. On the smaller scales – masses equivalent to stars and galaxies and even galaxy clusters – gravity is strong enough to hold things together and defy the expansion of the Universe.

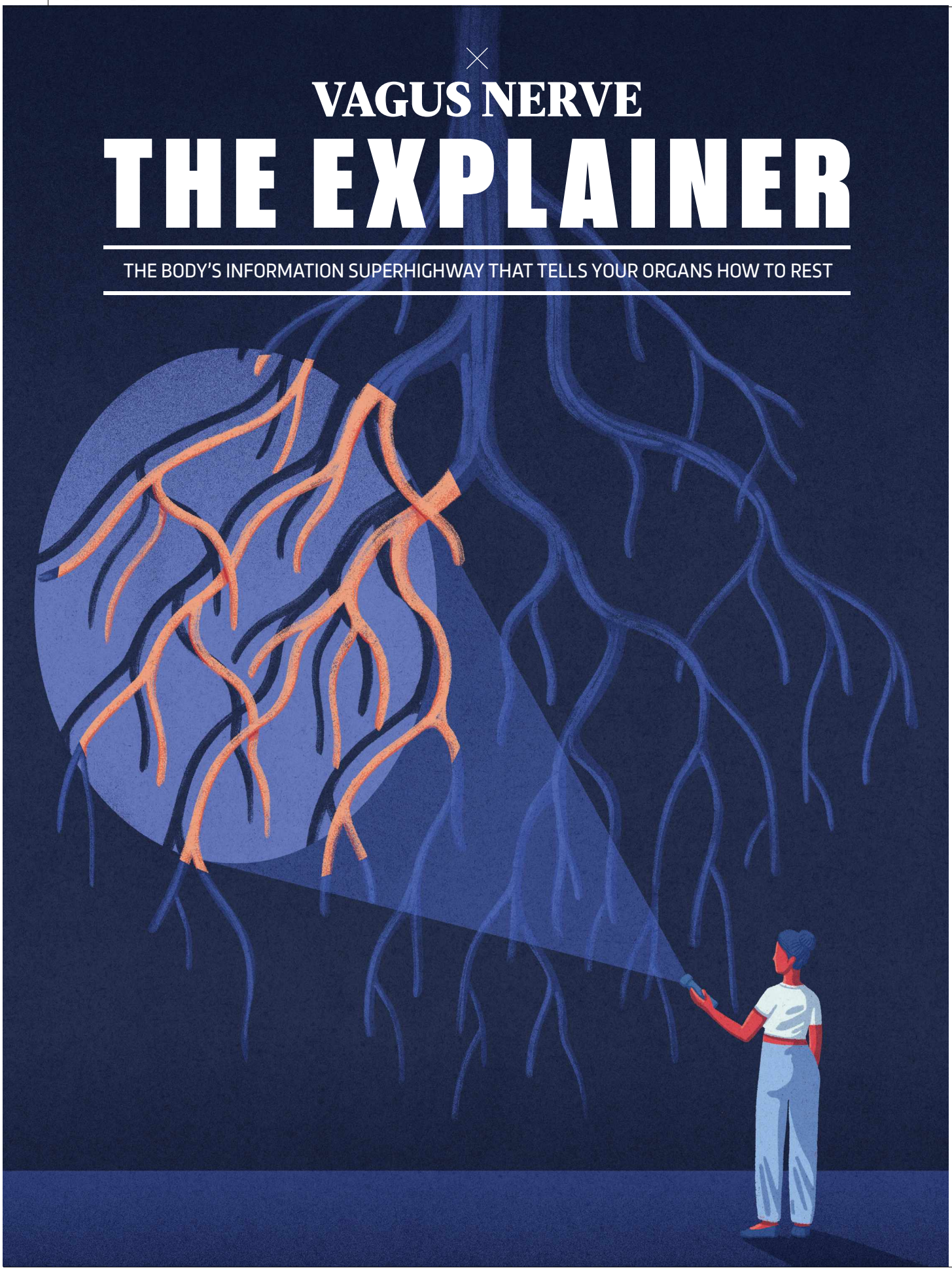
The Milky Way and Andromeda are not only bound to each other but approaching each other. In about five billion years' time, it is estimated that they will collide and form a new galaxy, already dubbed 'Milkomeda'. ***MC***

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

ALAMY, GETTY IMAGES, NASA/STSCI. ILLUSTRATION: DANIEL BRIGHT

VAGUS NERVE
THE EXPLAINER

THE BODY'S INFORMATION SUPERHIGHWAY THAT TELLS YOUR ORGANS HOW TO REST



ILLUSTRATIONS: MYRIAM WARES

What is the vagus nerve?

Your brain is connected to your body through a set of 12 crucial nerve networks that descend through your spine and branch out into your body. Of these, the vagus nerve is probably one of the most important. Its tendrils influence digestion, your heart, your reflexes and your breathing. So you can see why scientists are so interested in what it does – especially when you consider how all of the above affect your mood. You could call the vagus nerve a superhighway between our brains and bodies.

In contrast to the rapid 'fight or flight' responses that are under the control of the sympathetic arm of the nervous system, the vagus nerve is responsible for many of the slower, 'rest and digest' responses that we collectively call the parasympathetic arm. The nerve itself is actually two thick bundles of individual neurons (nerve cells) that originate in the brain and pass out to the rest of the body through left- and right-sided openings at the bottom of the skull.

Most of the individual neurons that make up the vagus nerve are sensory ones – about 100,000 on each side of the body in humans – which pass messages from the organs to the brain, and are activated by sensory input from the environment. The remainder are motor neurons, which send messages in the opposite direction, from the brain to organs, and directly control all of our muscle movements.

Why is the vagus nerve so important?

The vagus nerve is a sort of polymath of the parasympathetic nervous system, getting involved in everything from breathing, heart rate, swallowing, sneezing, digestion, appetite, immune responses and even orgasm. The vagus nerve's wide-ranging skill set comes from having a diverse array of neuron cell types at its disposal. These allow the nerve to pick up different types of sensory signals from different organs. Some, for instance, sense chemical signals like oxygen levels in the blood or the secretions of bacteria in the intestine, while others sense mechanical signals like stretching of the blood vessels and gut.

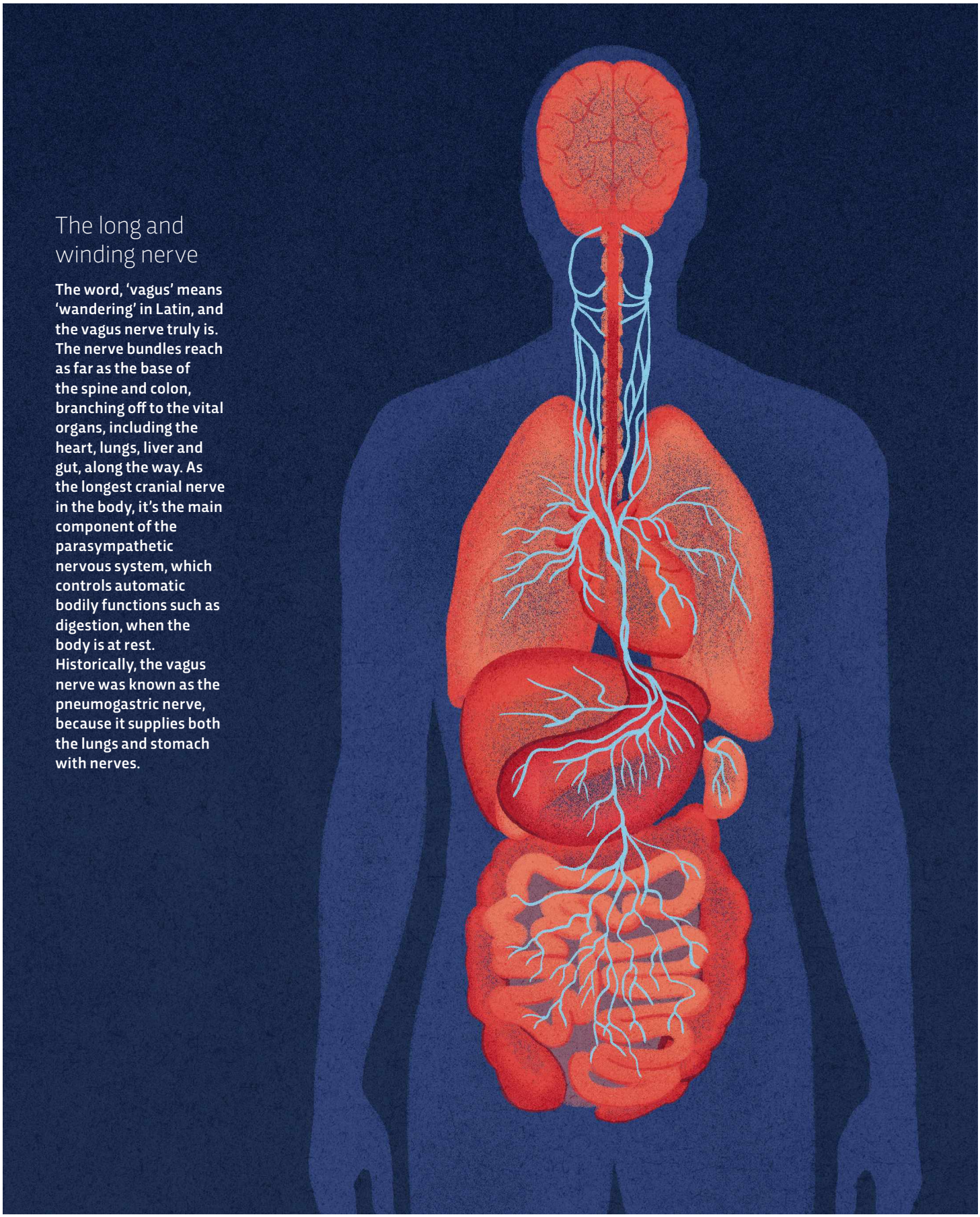
Therefore, the neurons in the vagus nerve mostly give the brain information about what is going on in the rest of the body. The brain interprets this information and acts upon it to help maintain the internal status quo. But there are also important functions associated with the less numerous neurons that send signals the opposite way, including in communications between the brain and gut, and in select muscles in the mouth and throat that are responsible for speech and the gag reflex.

The functions of the vagus nerve are so numerous and varied that it's very likely there are roles that we have yet to uncover. We do know, however, how we can tap into it. Doctors sometimes prescribe 'valsalva manoeuvres' to activate the vagus nerve and slow a fast-beating heart or calm heart palpitations. These might involve activities like coughing, straining like you're on the toilet or, perhaps most bizarrely, doing a handstand.

"The vagus nerve is a sort of polymath of the parasympathetic nervous system, getting involved in breathing, heart rate, swallowing, sneezing and digestion"

The long and winding nerve

The word, 'vagus' means 'wandering' in Latin, and the vagus nerve truly is. The nerve bundles reach as far as the base of the spine and colon, branching off to the vital organs, including the heart, lungs, liver and gut, along the way. As the longest cranial nerve in the body, it's the main component of the parasympathetic nervous system, which controls automatic bodily functions such as digestion, when the body is at rest. Historically, the vagus nerve was known as the pneumogastric nerve, because it supplies both the lungs and stomach with nerves.



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How is the vagus nerve connected to our wellbeing?

When we're in a high-stress situation, our sympathetic nervous system's fight or flight responses kick in, enabling us to deal with it quickly. The parasympathetic nervous system, meanwhile, comes into play more slowly to promote a more restful state, so it is crucial for helping us relax and calm down after experiencing stress. With help from the vagus nerve, our brain recognises that, for example, our breathing and heart rate have accelerated and puts the brakes on. While the sympathetic and parasympathetic arms aren't always in sync – they can operate separately or in a more coordinated way – in theory, there is a balance to their activities that can be upset in certain circumstances. These include bowel disorders and mental health conditions. Persistent stress is thought to be a cause of sympathetic overdrive and researchers say they can detect this in people with depression, for example.

One key metric that is often used is heart rate variability – the variation in the gaps between consecutive heartbeats. A healthy heartbeat is slightly more chaotic in its rhythm, so low variation is said to be associated with a jacked-up sympathetic system, where the body is in constant fight or flight mode, with the vagus nerve and parasympathetic response struggling to keep up.

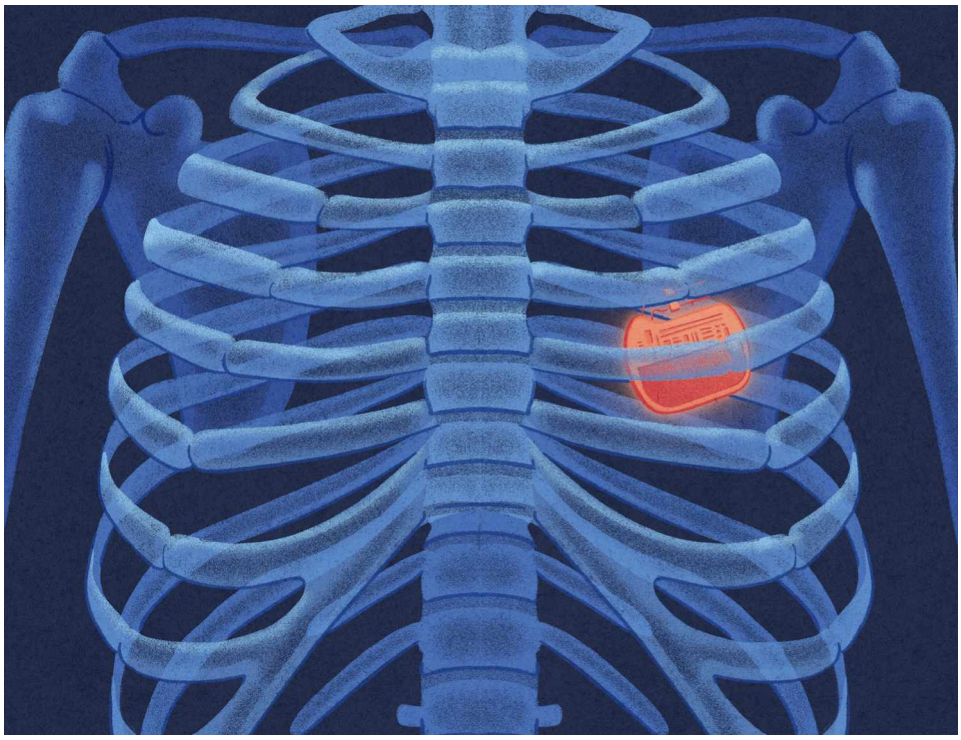
Despite its widespread use, however, there are still some questions about how useful heart rate variability can be as an indicator of balance between the parasympathetic and sympathetic systems. Although heart rate monitors can give us this information, we shouldn't obsess about the numbers.

> "Early data collected by Spanish researchers suggests that some of the symptoms of long COVID may be related to vagus nerve damage"

What happens if the vagus nerve is damaged?

In the past, stomach ulcers were often treated by cutting the fibres of the vagus nerve below the rib cage. The thinking was that the vagus nerve plays a central role in producing the stomach acid that causes the sores. With modern drugs, the need for this type of surgery has decreased, but it demonstrates what can happen when a nerve with so many branches is compromised. Indeed, 'vagatomies' cut off the vagal nerve supply to the stomach, pancreas, small intestine and part of the colon, meaning that without further surgery to the gut, the patient may be unable to pass solid waste. People with gastroparesis suffer from a similar problem, but in this case the symptoms are usually due to vagus nerve damage caused by diabetes, drugs or an infection.

However, when the vagus nerve is damaged higher up, the effects can be completely different. The chicken pox virus, for example, attacks the nervous system and though rare, it has been known for the virus to cause vagus nerve lesions that result in a patient losing their ability to swallow – they may also get a headache and an inflamed ear. Early data collected by Spanish researchers also suggests that some of the symptoms of long COVID may be related to vagus nerve damage, including breathing, voice and bowel issues.



Do I need to get myself a vagus nerve stimulator?

The evidence we have so far suggests these devices are safe. However, researchers are still concerned about the increase in at-home use of nerve stimulators, which may come with risks that we're not yet aware of. Those who prefer mindfulness to being hooked up to machines are turning to activities such as yoga, meditation, hypnotherapy and deep breathing, all of which are thought to boost the functioning of the parasympathetic nervous system and vagus nerve. There is also evidence to suggest that cold water swimming or bathing, or even just splashing your face with cold water, can activate the parasympathetic system.

Of course, buying a cheap device to attach to your ear, or signing up to take part in yoga retreat, may seem like an appealing fix when you're not feeling quite right, but it's always best to get serious health complaints checked by a doctor.

"Evidence suggests that splashing your face with cold water can activate the parasympathetic system"

HAYLEY BENNETT
(@gingerbreadlady)
Hayley is a freelance science writer and editor.

What is vagus nerve stimulation?

The concept of vagus nerve stimulation goes back as far as the late 19th Century, when the neurologist James Leonard Corning developed an electrical stimulator to treat epileptic patients. Although it was discarded as a treatment back then, over 100,000 people have now had vagus nerve stimulation – by implant in the chest or, less often, brain – to treat epilepsy when the drugs they've tried haven't worked. Some people are able to get as much as a 75 per cent reduction in their seizures with an implant, with multiple studies showing the benefits increase the longer the implant has been installed. An implantable device made by the US medical technology company Cyberonics is also approved for severe depression and headaches.

Nerve stimulation doesn't have to mean surgery, though. It's possible to access the vagus nerve through its branches in the ear and neck, for example, using devices similar to the inexpensive TENS machines more commonly used for quelling labour pains. Ear clips are widely sold as TENS attachments, while companies like Nurosym make stylish neuromodulators targeted at people who want to try the approach for anxiety, depression or fatigue.

Scientific research on vagus nerve stimulation is exploding currently, with trials covering burns, obesity, high blood pressure, rheumatoid arthritis, Alzheimer's, tinnitus... the list goes on. Due to the close connection between the vagus nerve and gut function, it's also touted as a potential treatment for common bowel disorders like IBS. Although, as with other conditions, the process of gathering evidence from trials to support its use will take time.

FIVE FASCINATING FACTS ABOUT THE VAGUS NERVE

1. It's the longest cranial nerve, running from the brain to the large intestine, and sends signals in both directions via neurotransmitters and gut hormones.

2. The fibres of the vagus nerve contain 200,000 sensory nerve cells. Our ears are the only place where sensory vagus nerve fibres reach the surface of our bodies.

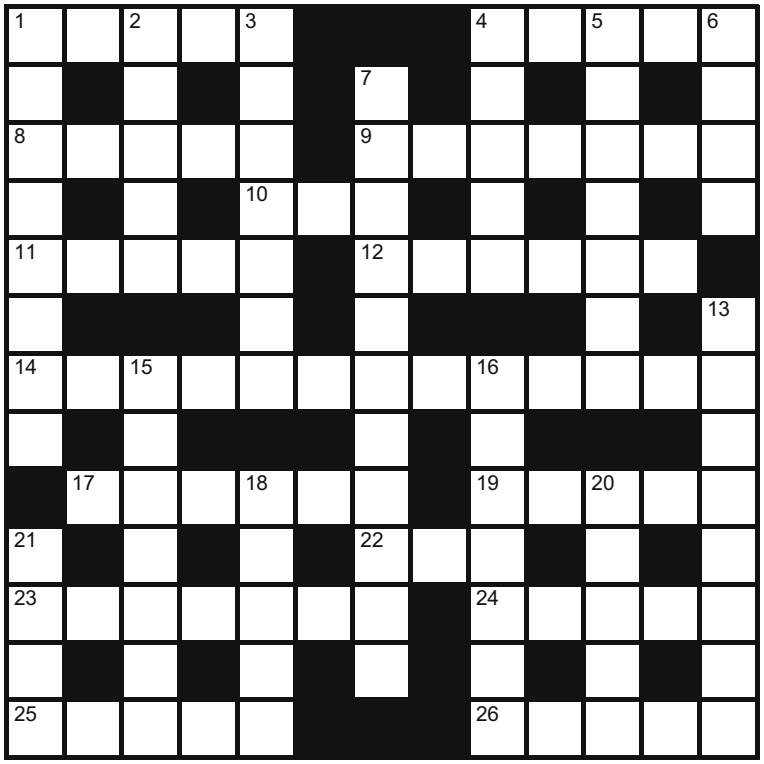
3. A vagus nerve 'bypass' that carries impulses directly between the uterus and brain is thought to allow women with spinal cord injuries to have orgasms.

4. Vagus nerve stimulation affects the gamma-aminobutyric acid neurotransmitter associated with ADHD , leading scientists to propose it as a potential treatment.

5. The scientific name for fainting is vasovagal syncope, which occurs when the vagus nerve is overstimulated, causing a sudden drop in heart rate and blood pressure. SF

CROSSWORD

PENCILS AT THE READY!



ACROSS

1 Cyril's lost for words (5)
4 Insult didn't start as frivolous (5)
8 Honour for being lamed, unfortunately (5)
9 Mark follows sailor in refrain (7)
10 Departing during coffee (3)
11 In extremis, too readily returning to origins (5)
12 Wear out soldier, coming back for insect (6)
14 Bag one wasted following swine messenger (7,6)
17 Sluggish form of electricity (6)
19 Some insects are small and affectionate (5)
22 Equipment acquired from obelisk itself (3)
23 Prevaricating woman has visa to get back (7)
24 Old performance is not approximated in any way (5)
25 The riddle of the kitchen? (5)
26 Fear adder moving around (5)

DOWN

1 City appearing in five lines (8)
2 Travelled to see old cowboy contest (5)
3 Firm defeat by current giants (7)
4 Roles rewritten for no-hoper (5)
5 Tearing off – that's hard (7)
6 Fuel storage for vehicle (4)
7 Criminal has a firework that's not dangerous (4-7)
13 Lively as a cartoon (8)
15 Artist to track competitive struggle (3,4)
16 At home, dates used as a substitute (7)
18 Nonsense food (5)
20 Humiliate a centre of operations (5)
21 Officers' room in confusion (4)

ANSWERS

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POPCORN SCIENCE

Could *Star Wars* blasters exist?

Pew pew pew! Delve into the science of how a Stormtrooper's weapon of choice could work

by **STEPHEN KELLY**

As the late, great Han Solo once said, "Hokey religions and ancient weapons are no match for a good blaster at your side, kid." A bit disrespectful, in retrospect, but a good point nonetheless. Just take new series *Star Wars: Andor*, which is based around the struggle of ordinary people – those who are born without space magic – who must stand up to the Empire with nothing but firearms that, according to Wookieepedia, are fire bolts of 'particle-based energy'. But what does that mean? Patrick Johnson, author of *The Physics Of Star Wars*, has a few ideas.

"A lot of people assume that blasters fire lasers, but the blaster beams travel at a speed where we can watch them move," he says. "Lasers, meanwhile, move at the speed of light, which is so fast that we wouldn't be able to see anything move. If blasters were lasers, it would be nearly instantaneous from pulling the trigger to arriving at a target. People would seem to suddenly fall down for no reason." Johnson also points out that lasers would not resemble 'bolts', but would travel in one continuous stream. "And if it didn't kill you, it's likely that a high-powered laser could radiate you enough to give you cancer in 15 years' time."

A more plausible answer, suggests Johnson, is that blaster bolts are made out of plasma, the electrically charged matter that makes up lightning, the Sun and – in his opinion – lightsabers. Beyond the fact that plasma would travel at a speed that could be observed, Johnson also highlights the fact that in *Star Wars*, blaster ammunition is said to derive from gas (more specifically, the fictional tibanna gas), much like real-life plasma. "The temperature at which materials turn into a plasma is fairly consistent, so we could estimate that tibanna gas becomes a plasma at 360,000°F [200,000°C]," he says. "That would vaporise whatever it touches".

As for whether this plasma could be launched from a blaster in the form of a bolt, Johnson cites the Large Hadron Collider (LHC) as an example of how it could work. "At the LHC, they send beams of plasma around in circles very fast, in a magnetic containment field," he says. "But if you turned off that field, the beam would shoot off in a straight line." Reduced down to a handheld blaster, he adds, it would be like "taking a can of soup, opening the lid and throwing it outwards really fast."

Plasma's susceptibility to magnetic fields also feeds into two quirks of the *Star Wars* universe. The first is how lightsabers are used to swat away blaster bolts. "If a lightsaber beam is being contained in a magnetic field, then a different plasma entering that field could in principle lead to a deflection away. It's more likely to just absorb it, though," says Johnson. The second quirk is the terrible aim of Stormtroopers, who can't hit a bantha in a barrel! But there could be a scientific reason for this, suggests Johnson.

"Plasma is a soup of charged particles," he says. "And so it is going to experience forces from electric and magnetic fields. If we were on a planet with a large magnetic field, or if there were a lot of stray fields in a structure like a Death Star, it could lead to a bolt's path being altered along the way."

This would mean that everyone's aim is affected, but we're going with the simple theory that magnetic fields hate fascists! **SF**

VERDICT

Blasters, if they shoot out plasma, behave according to the laws of physics, so these weapons aren't beyond the realm of possibility.

by **STEPHEN KELLY** *(@StephenPKelly)*
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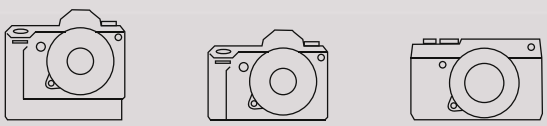

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