New Scientist

WEEKLY August 28 - September 3, 2021

POST-BABY FITNESS
Why it's hard to get back into shape

GREEN CONNECTIONS
The apps that can intensify our relationship with nature

WORLD ABLAZE
How much does climate change really fuel wildfires?

SPECIAL ISSUE

QUANTUM FRONTIERS

What our greatest theory does...

and doesn't

...tell us about reality

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A scientist's guide to a rational life

How can we cope with the complexities of modern life? What should we believe, and in what and whom should we trust? In this talk, Jim Al-Khalili explains how lessons drawn from the scientific method can help us navigate life. Join us on 16 September from 6pm BST/1pm EDT or watch on demand. Tickets available now.

newscientist.com/ns-events

Podcasts

Weekly

This week, the pod team get excited about a breakthrough in fusion research. Jeremy Chittenden at Imperial College London drops in to give us the latest. Plus, there's an artificial "minimal cell" that can adapt and evolve dramatically and rapidly. And with the new school year in England not far away, the team explain why good ventilation must be a top priority when indoors this autumn.

newscientist.com/nspod

Online

Covid-19 daily update

Stay on top of all the latest developments in the pandemic with our daily briefing, updated at 12pm BST every weekday. We round up the day's most crucial stories, plus links to exclusive news, features and interviews.

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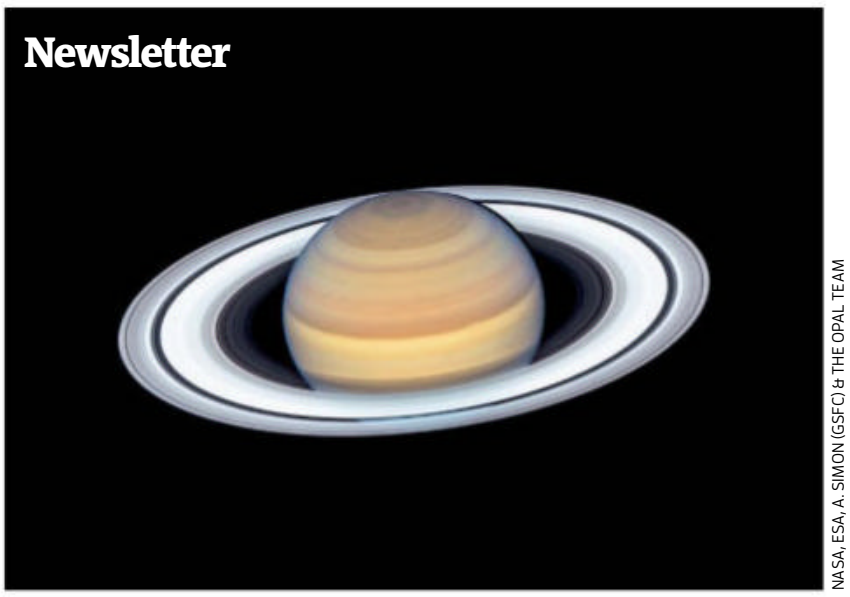

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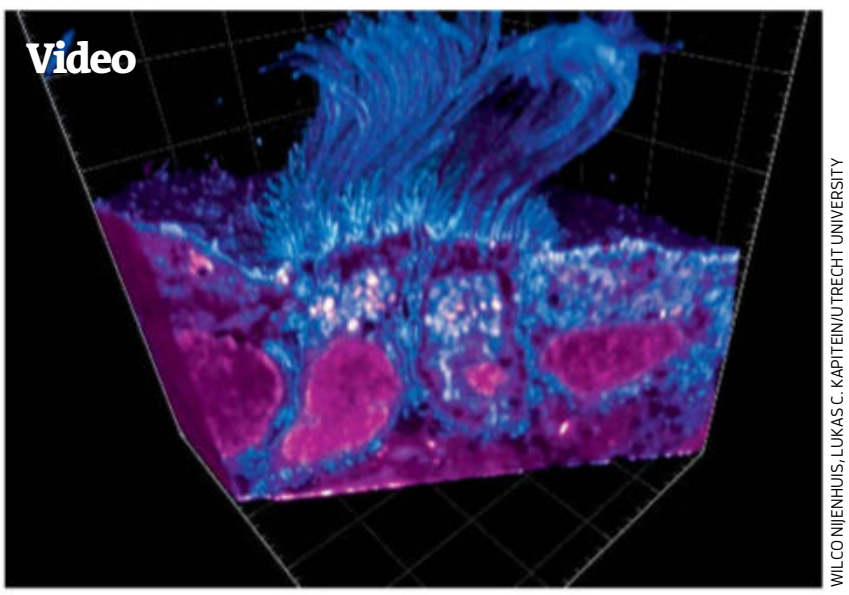
Rings of Saturn Studying them can help us look inside the gas giant



WILCO NIJENHUIS, LUKAS C. KAPITEIN/UTRECHT UNIVERSITY

Inside the lungs Stunning pictures show coronavirus in our airways

Video

Covid-19 in lungs

Researchers at Utrecht University in the Netherlands have created incredible 3D images that show how SARS-CoV-2 infects cells in our airways. The work gives an unprecedented view of how the virus alters the cells' structure, and might help drug development. For more amazing discoveries caught on film, subscribe to our channel.

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Newsletter

Launchpad

Get reporter Leah Crane's unmissable weekly newsletter on all things space delivered free to your inbox. The latest edition looks at the solar system's second largest world, Saturn. Measuring the curious behaviour of its rings can tell us more about what's going on in the planet's mysterious core.

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Newsletter

"Saturn's beautiful rings can reveal the secrets of the swirling world they encircle"

Essential guide

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A frontier of knowledge

Quantum theory continues to challenge our conception of reality – and ourselves

IT IS one of those delicious ironies of history that Albert Einstein received the 1921 Nobel prize in physics not for general relativity, the theory of gravity for which he is now justly most famed, but largely for his contribution to a theory that he spent much of his later career trying to disown.

Perhaps that's only right. After all, quantum theory notoriously allows things to be in two states at once, and divides minds as well as it – potentially – divides worlds.

At the time of Einstein's award a century ago (in another irony, delayed for a year as the Nobel committee were initially unsure whether the contributions of any of that year's nominees truly merited the honour), quantum mechanics wasn't yet even a fleshed-out mathematical theory. Its greatest assaults on our ideas of how reality should work – Erwin Schrödinger's dead-and-alive cats, the "spooky action at a distance" of quantum entanglement – were yet to come.

Entanglement was another of Einstein's contributions, which, as we set out in our special feature on the frontiers of quantum theory (see page 34), he introduced in 1935 very much in the spirit of pointing out the theory's supposed deficiencies. Today, we can say that entanglement is very much a thing, the basis of technologies such as quantum computers – although the questions of when and for what quantum computers will be of practical use remain themselves hanging in an appropriate state of fuzziness.

"A century on from Einstein's Nobel prize, quantum theory's mysteries remain a gift"

Einstein's prize heralded the beginning of the golden era of quantum theory's development. It's hard to overstate just what a seismic shift that has brought about, not only in our conceptions of how reality works, but of our role in it. Because it works on scales we cannot directly see, it raises still seemingly insoluble questions about how much we think we observe is actually there, or whether it merely seems to be there because of the way we, as large lumps of classical reality, interact with it.

A century on, quantum theory's mysteries are a gift that is still giving – a true frontier of knowledge always worthy of exploration and celebration. ▮

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8 days | 30 October and 6 November 2021

Land of fire and ice: Iceland

Join an unforgettable tour of Iceland's majestic landscapes, scheduled to maximise days filled with volcanic and geological adventure, and evening opportunities to see the Aurora Borealis.

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Highlights

- Join talks and walking seminars from Oliver Shorttle.
- Tour Þingvellir National Park, the site of Iceland's first parliament, founded in 930, and a geological wonder where the American and Eurasian tectonic plates are pulling apart.
- Visit Iceland's Geysir geothermal area, where you'll see the Strokkur geyser shoot water 30 metres into the air. Be spellbound by the immense beauty and sheer power of the Gullfoss Waterfall.
- Super jeep drivers will take you to the elegant Seljalandsfoss waterfall, which is unique in its kind, as you can walk behind the plummeting falling stream without getting (too) wet, for a unique viewing angle.
- Cross the deep and roaring rivers that guard the wooded surroundings of Thórsmörk, where you will have time to hike around the area and admire some of the many viewpoints it offers.
- A trip to the eerily beautiful Skógafoss waterfall, one of the biggest waterfalls in Iceland. 25 metres wide with a 60-metre drop. You will feel the immense power of the waterfall close-up, as you climb a long windy set of stairs to a truly stunning viewpoint.
- Visit the famous Jokulsarlon Glacier Lagoon, a stunning sea of floating icebergs. Weather permitting, there will be an opportunity to step outside and witness the natural wonders of the Northern Lights.
- Walk on Europe's biggest ice cap – Vatnajokull, which has around 30 glaciers flowing out from it.
- Enjoy lunch in the black sand seaside town of Vik. The sea on one side and high cliffs on the other, dramatically positions this quaint little village as Iceland's most southerly mainland settlement.
- Visit the Lava Centre, an interactive, high-tech educational exhibition depicting volcanic activity, earthquakes, and the creation of Iceland over millions of years.
- Relax in the warm thermal waters of natural hot springs in the village of Fludir.

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News

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Climate Change

Fortnight of protest starts

Extinction Rebellion protesters have begun two weeks of climate change demonstrations in London, reports **Adam Vaughan**

A GIANT pink table was blocking a street in central London as *New Scientist* went to press. Climate change protest group Extinction Rebellion says it represents the need to include more people in action to reduce carbon dioxide emissions.

Deposited in Covent Garden on Monday, and leading police to close the surrounding roads, the 4-metre-high table has become the centrepiece for the start of a fortnight-long protest in the city.

"It's a symbol of the climate crisis," says Alanna Byrne of Extinction Rebellion. "Our message was people deserve a seat at the table. The stagnation at Westminster is not getting it done, let's bring people to the table in a citizen's assembly to work out where we go from here."

The protest was announced in the wake of the report published by the Intergovernmental Panel on Climate Change earlier this month. Thousands of campaigners attended on Monday, which is the fifth Extinction Rebellion protest in London since October 2018. Campaigners walked up Charing Cross Road, saying they will protest until their demand – ending new fossil fuel investments in the UK – is met.

Asked why the group is protesting now, Byrne says: "The climate crisis is happening now." She adds that while Extinction Rebellion has plans for when heads of state are in Glasgow for the COP26 climate summit in November, "we are saying don't wait until COP26 and [for] world leaders".

Monday saw 52 arrests by the Metropolitan Police. The force said it would try to remove the table structure "as soon as possible".

While London is the focus for protests on the ground, Byrne says Extinction Rebellion hopes the event will galvanise people in other cities. ▮

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Animal behaviour

Soil physics helps ants dig tunnels

ANTS dig tunnels that can extend metres underground and last decades – and doing so is easy for the insects because of the "behavioural algorithm" they follow.

José Andrade at the California Institute of Technology and his team put 15 western harvester ants in a container filled with soil.

The position of every ant and grain of soil was then captured by high-resolution X-ray scans every 10 minutes for 20 hours, and the results used to create a computer model of the forces acting on – and in – the soil as the ants tunnelled.

The results suggest that forces within the soil tend to wrap around the tunnel axis as ants excavate, forming what the team call "arches" that have a greater diameter than the tunnel itself. This reduces the load acting on the soil particles within the arches, making it easy for the ants to excavate them (*PNAS*, doi.org/gsdh).

"We had naively thought that ants perhaps were playing Jenga, that they were… grabbing the grains of least resistance," says Andrade.

He says it is now clear the insects follow a behavioural algorithm: they dig tunnels that descend at the angle at which granular material naturally forms mounds and they pick the right grains to remove to create a protective arch. "They've stumbled upon a technique that is in line with the laws of physics," says Andrade. ▮

Matthew Sparkes

Technology

Possible flaw in protection algorithm

Apple's child abuse detection software may be vulnerable to attack

Matthew Sparkes

APPLE's soon-to-be-launched algorithm to detect images of child sexual abuse on iPhones and iPads may incorrectly flag people as being in possession of illegal images, warn researchers.

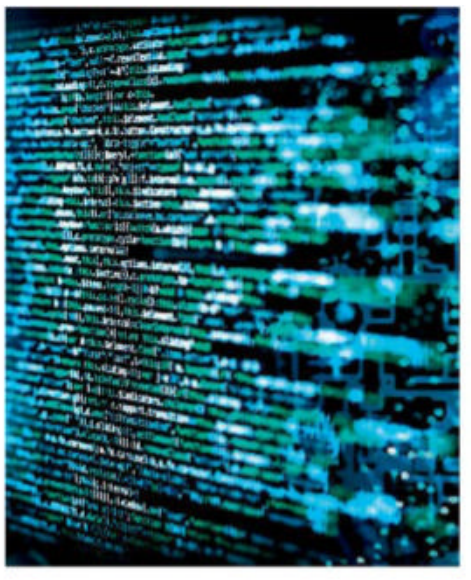
NeuralHash will be launched in the US with an update to iOS and iPadOS later this year. The tool will compare a hash – a unique string of characters created by an algorithm – of images uploaded to the cloud with a database of hashes for known images of child sexual abuse. Matches should mean that the images are the same and so would be flagged to police after a series of checks.

When NeuralHash was announced earlier this month, Apple said the system will see less than one in a trillion false positives every year. This was disputed at the time by computer scientists, who said there was no way to judge until it was launched.

A user on the code-sharing website GitHub now claims to have reverse-engineered the algorithm behind NeuralHash, which has been present in iOS versions 14.3 onwards despite not yet being activated, and released it online. The algorithm matches descriptions in a technical document released by Apple.

Soon after that code was published, other users found examples where two real photographs had the same hash. This could lead to innocuous images being flagged as images of child sexual abuse. It also opens the door to attacks where carefully crafted images are sent to a user's phone to trigger a match, although that would require the target to save the image to the cloud.

Apple plans to launch software that will detect child sexual abuse images



KLAUS OHLENSCHLAEGER/ALAMY

Jonathan Mayer at Princeton University says the ease of finding matches comes as "zero surprise". The type of hash function Apple is using doesn't have strong properties for preventing images getting the same hash, he says. "Apple should have been clear about those limitations."

Any positive matches using NeuralHash will trigger a human double-check of the photo's hash within Apple. If this confirms a match with the signature of a known image containing child sexual abuse, the information will be reported to the US non-profit organisation National Center for Missing and Exploited Children. NCMEC will then pass the details to the police to decide whether to make a legal request either to see the images or for information about the device's owner.

"The best case is that this causes extra work for Apple's human assessment team. The worst case is that a further error leads to someone being arrested for possession of child sexual abuse images without cause," says Neil Brown at law firm decoded.legal.

An Apple spokesperson confirmed to *New Scientist* that the perceptual hashes of the sort used by NeuralHash can be tricked into believing two different images appear to be the same, but says that Apple's system is designed to be secure despite this.

The spokesperson says that a database of hashes for known child sexual abuse images will reside on users' phones, but that it is encrypted. So while a theoretical demonstration of two different images with the same hash can be made, it would be impossible for an attacker to know what hash they would have to match to trigger a false positive.

They add that at least 30 positive matches would be needed to trigger an investigation – something that child welfare charities have criticised as too high a bar – and that once triggered, a second algorithm performs another check to rule out false positives. ▮

Nuclear physics

Pinning down the origin of possible Nazi-made uranium

A METHOD to prove the origin of uranium cubes believed to have been salvaged from the Nazi atomic bomb programme could help law enforcement investigate illegal trafficking of nuclear material.

The Nazis had two nuclear weapons programmes during the second world war. Some 1200 cubes of uranium were created, and approximately 600 made their way to the US in the closing stages of the war, according to Jon Schwantes at the Pacific Northwest National Laboratory in Washington state. He estimates that the location of only a dozen of the cubes is known today, and that the vast majority of those brought to the US were folded into its own nuclear programme. One of the cubes now belongs to his lab, but nobody knows how it came to be there. His team is working on techniques to prove its provenance.

Radio chronometry is often used to date ancient samples of naturally occurring radioactive material in rocks and minerals, but methods that are accurate enough to date rocks billions of years old may not be sufficient to distinguish between a metal processed in 1939 or 1940, for example. Instead of measuring the amount of a single radioactive element that has decayed into another to date a sample, the researchers analysed pairs of "parent" and "daughter" radioisotopes. For instance, they can measure the amount of thorium-230 produced from the decay of uranium-234, as well as the protactinium-231 produced from the decay of uranium-235.

"1200 cubes of uranium were created but the whereabouts of only a dozen are known today"

They are also developing new techniques to speed up and simplify the process of preparing samples for such analysis. This process isolates rare earth elements that can then be used to shed light on where the ore was mined.

The researchers hope to show that the cube is a genuine artefact from the Nazi nuclear programme. They presented their findings at a meeting of the American Chemical Society on 24 August. ▮

Matthew Sparkes

Data security

The Taliban seizes US biometrics equipment in Afghanistan

Lynzy Billing

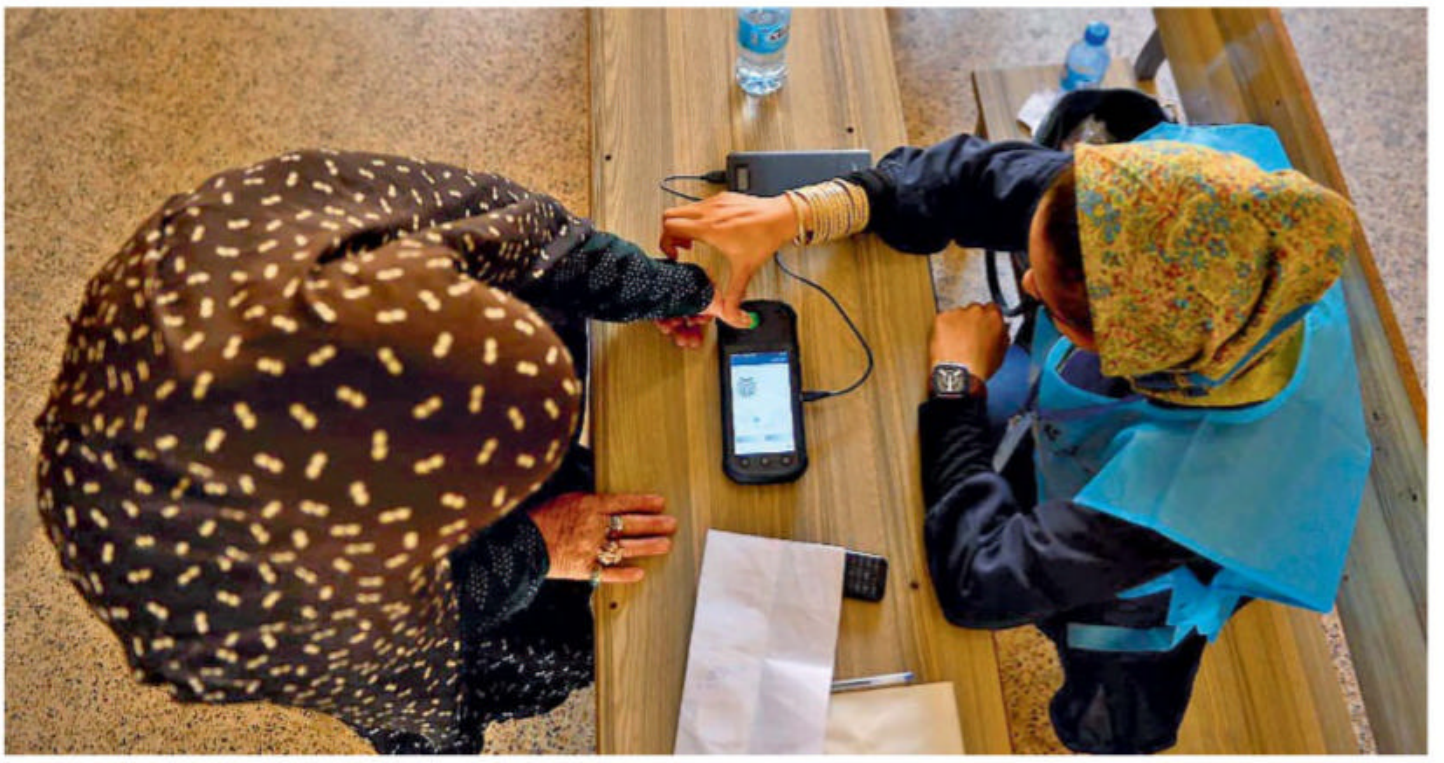
THERE are growing concerns about how the Taliban might use the data from a huge biometrics programme now that the group has taken over Afghanistan. An extensive database of people was built up during the previous regime, and the quick transition has meant much of it is still intact.

The US first established a programme to collect the fingerprints, iris scans and facial images of Afghan national security forces after testing prototypes of the system in 2002. The initial goal was to keep criminals and Taliban insurgents from infiltrating the army and police. To collect and store this data, the US Department of Defense launched its Automated Biometric Identification System (ABIS) in 2004.

Over the years, the biometrics initiative has had coalition and Afghan troops from multiple biometric task forces collecting fingerprint, iris and genetic biometric data from as much of the population as possible. It now has data on millions of people. In 2020, the Afghan government launched a biometric system for licensing businesses in order to improve the ease and efficiency with which licences are processed. In January, the Afghan government shared its plans to conduct biometric registration of students and staff at 5000 madrassas around the country.

Some of this biometric equipment is now in the hands of the Taliban, one senior Afghan government official, who worked closely with the biometric gathering initiative for four years, told *New Scientist*. The equipment includes some specially made portable toolkits consisting of a laptop, digital camera, fingerprint scanner and an iris reader.

"Just think, they now have everything from the police, defence ministry and election commission," said the official, who wished to remain anonymous. The Taliban has also seized equipment from facilities used by the National Directorate of Security, Afghanistan's intelligence and security agency, he says. "It was left behind in the rush to exit. They have everything." A US military official confirmed that biometric devices have been seized by the Taliban, but how many isn't known.



HOSHANG HASHIMI/AFP VIA GETTY IMAGES

A voter gets their fingerprint scanned in Herat in 2019

"We understand that the Taliban is now likely to have access to various biometric databases and equipment in Afghanistan," wrote US-based Human Rights First this week. "This technology is likely to include access to a database with fingerprints and iris scans, and include facial recognition technology."

The worry is that the Taliban will use the biometric equipment and data to carry out reprisals against people who worked in the coalition-backed regime. A former interpreter who worked with US forces in Bagram Air Base, who also had his biometrics taken, says the Taliban is listening in on phone calls and conducting door-to-door searches for those who worked alongside the US in the city of Kandahar. "We just don't know what they have on us."

Sean McDonald, who has worked in humanitarian data governance for the past 10 years, says: "The Taliban have a demonstrated interest in hunting, killing and scaring those who have worked with the government and global community."

$8 billion

The amount the US has spent on biometrics in Iraq and Afghanistan

Annie Jacobsen, author of *First Platoon: A Story of modern war in the age of identity dominance*, says that the US has spent more than $8 billion on biometrics programmes in Iraq and Afghanistan and these have failed to produce anything close to a successful outcome. However, she says that while many biometric tools have fallen into the hands of the Taliban, it doesn't yet have the equipment to process or use the data.

One officer who has been involved in intelligence gathering in Afghanistan, and also wished to remain anonymous, says that the safety of Afghan people is paramount.

Data collected by the US could be used to get some people out of the country, he says, as biometric data was widely used in identification cards for people who helped the US. Though this could have happened sooner, he says. "The US has ample data to have identified long ago who had worked for them and could have prepared for evacuations sooner in my opinion and morally should have."

The US Department of Defense didn't respond to a request for comment. ▮

For more on events in Afghanistan, see page 23

Health

Fitness is hard to recover after birth

Even the fittest women struggle to regain their physical health after being pregnant

Alice Klein

GETTING back into shape after having a baby is hard, even for women who were fit and strong before becoming pregnant, a new study shows.

Pregnancy is known to put stress on many parts of the body, including the heart, lungs, muscles and joints. But little research has been done to assess the long-term effects of pregnancy on people's fitness.

David DeGroot at Martin Army Community Hospital in Fort Benning, Georgia, and his colleagues studied the impact of pregnancy on the fitness of 460 women who became pregnant while in the military.

Before they became pregnant, the women had high levels of fitness as a requirement of being active-duty soldiers. They continued modified fitness training during pregnancy and most returned to regular training by 12 weeks after giving birth.

Even with this dedicated training, many of the women struggled to regain their fitness. One year after giving birth, only 30 per cent were able to obtain the same score as they had pre-pregnancy in the US Army Physical Fitness Test, which involves sit-ups, push-ups and a timed 2-mile (3.2 kilometre) run. By three years after delivery, 75 per cent matched their pre-pregnancy scores (*PLoS One*, doi.org/gr9r).

The soldiers' sit-up abilities and running times declined the most. "For push-ups, it's relatively easy to retrain your shoulders and pecs, but sit-ups are harder because your abdominal muscles are really stretched during pregnancy," says Wendy Brown at the University of Queensland in Brisbane, Australia. "It can take a long time – if ever – for them to get back to how they were before."

The women's running times probably slowed because it takes a while to shed excess pregnancy weight, says Brown. They were carrying 2 extra kilograms on average when weighed six months after giving birth compared with pre-pregnancy.

A woman works out with a young baby strapped to her front

ANR PRODUCTION/GETTY IMAGES

In the general population, lifestyle factors like lack of time to exercise, disrupted sleep and negative self-image have also been found to hamper new mothers' fitness recovery, the study authors note. "[These] factors are more nuanced but likely as impactful as the physical changes of pregnancy," they write.

Getting fit before becoming pregnant and staying active during pregnancy also help women to regain their fitness faster after their babies are born, says Brown, who recently co-authored the Australian government's exercise recommendations for people who are pregnant.

She advises doing up to 5 hours of moderate intensity or 2.5 hours of vigorous intensity activity per week plus regular muscle strengthening exercises for as long as possible while pregnant. "Women sometimes worry that vigorous exercise might harm their baby, but we found you can basically carry on doing anything you want to do as long as it's comfortable," she says. ▮

Astronomy

Half a million new asteroids found in the asteroid belt

A PAIR of astronomers have spotted half a million new asteroids lurking in old data. Figuring out exactly where these objects came from could be crucial to understanding the early solar system.

Alexey Sergeyev and Benoit Carry at Côte d'Azur University in France found the space rocks in images from the Sloan Digital Sky Survey (SDSS). This survey, which uses a telescope at the Apache Point Observatory in New Mexico, took images of a huge swathe of the sky from 1998 to 2009. It also measured the colours of the objects it spotted.

Sergeyev and Carry examined the images for fast-moving objects, which could be asteroids or comets. They discovered more than 1 million such bodies that we already knew about, along with 506,200 that weren't linked with anything we have observed before, most of them asteroids (arxiv.org/abs/2108.05749).

The number of uncatalogued asteroids was surprising, says Carry. "We were expecting maybe 30,000 or 40,000 more asteroids and suddenly we had this monster catalogue," he says. "It was supposed to be a few weeks' work and it turned out to be one year."

The pair used SDSS colour and brightness measurements to categorise the asteroids by what their surfaces are made of. The next step is to figure out their origins.

"Understanding the distribution of these asteroids – not only their orbits but also their compositions – gives you the key to understanding what happened in the solar system in the past, such as the planetary migrations that pushed them into the asteroid belt," says Carry.

"We expected 30,000 or 40,000 more asteroids and suddenly we had this monster catalogue"

Continuing observations will allow researchers to find millions more asteroids, he says. In the meantime, these ones will have to be monitored to find out their trajectories, both to determine whether they really are new or have been observed before and to figure out if any of them might be hazardous to Earth. ▮

Leah Crane

Animal behaviour

Bat pups babble in a similar way to human babies

Michael Le Page

YOUNG greater sac-winged bats babble just like human babies. A detailed analysis of the sounds has shown that they share many similar features with the babbling of babies.

The greater sac-winged bat is known for its complex songs. Adult males sing to mark their territories before leaving their roosts in the evening and on returning in the morning. They also sing during courtship displays. "It has a very large vocal repertoire," says Ahana Fernandez at the Museum of Natural History in Berlin, Germany.

In 2006, team member Mirjam Knörnschild, also at the museum, noticed that young bat pups of the species babbled. Now, Fernandez, Knörnschild and their colleagues have recorded and analysed hundreds of babbling bouts by bat pups, and shown that this resemblance is no coincidence.

For instance, all bat pups start babbling at a young age, and the behaviour continues for a while, gradually becoming more sophisticated before ceasing (*Science*, doi.org/gsbc). As with humans, the behaviour appears to be innate and not a result of culture. In the case of bats, babbling starts at around two weeks of age and continues for about seven weeks.

The pups repeat the same sounds over and over again in a rhythmical pattern, says Fernandez. It isn't a form of communication with other bats, as the pups don't respond to each other or to adults. Over time, the babbling starts to include more of the sounds used by adults.

All this suggests that bats babble for the same reasons as human babies: to practice making sounds and to gain motor control over their vocal apparatus. Female bats stop vocalising when they become adults. But the team speculates that babbling as pups helps them pick the best males that can produce the most difficult courtship songs. ▮

Military technology

Sneaky feedback device could silence political speeches

David Hambling

A NON-LETHAL device developed by the US Navy aims to surreptitiously render a person unable to speak.

The device, called a handheld acoustic hailing and disruption (AHAD) system, records a target's speech with a long-range microphone and plays it back to them with a tiny delay. As anyone who has spoken on a phone or internet call that echoes their voice back at them will know only too well, such delayed auditory feedback can be highly disruptive to speech.

The device is described in a patent granted this month to Christopher Brown at the Naval Surface Warfare Center, Crane division, near Bloomington, Indiana.

It beams back two versions of the recorded speech, one with a slight delay. The patent suggests using a parametric speaker, which emits directional sound so that only people who are targeted can hear it. This makes it inaudible to anyone else, so as far as any bystanders can tell, the target will seem to have trouble speaking for no obvious reason.

The patent's application was filed by the US Navy in 2019 and it isn't clear whether the device has been built or tested yet.

A similar concept was tested by researchers at Japan's National Institute of Advanced Industrial Science and Technology in Tokyo with the aim of "controlling and facilitating discussions", but didn't advance beyond the lab.

"As far as bystanders can tell, the target will seem to have trouble speaking for no obvious reason"

Sophie Scott, a cognitive neuroscientist at University College London, says that delayed feedback interferes with a speaker's ability to control their voice. Some people simply stop talking, some find their speech distorted with lengthened vowel sounds, while others might start stammering. However, there are people who seem able to carry on regardless.

"It will be very incapacitating for a handful of people, but by no means everyone," says Scott.

Some individuals, probably those used to speaking to crowds and in varied acoustic environments, can continue to talk through the disruption. There is a risk that the presumed targets, public speakers, are those least likely to be affected, she says.

Scott says auditory feedback causes the most disruption when the delay in playback is about 200 milliseconds, roughly the typical time it takes to speak one syllable. With AHAD, there will be an additional delay due to the distance the sound travels. If the device was more than 30 metres away from the target, this will be more than 200 milliseconds, reducing its effectiveness.

The US Navy has already pioneered the use of long-range acoustic devices, powerful speakers used for hailing or for broadcasting extremely loud, disruptive noise to disperse crowds.

By contrast, the new AHAD may operate at low volume. Scott says that delayed auditory feedback can disrupt speech even if it is just loud enough to be heard. But as well as not working on everyone, for some, it might actually have the opposite effect. "The paradox is that it might make some people more fluent," says Scott.

Delayed auditory feedback can be an effective therapy for people who stammer. The exact reasons aren't well understood, but it seems to relate to how the brain handles feedback.

Scott is concerned that the development of Brown's device could prevent people speaking out. "The desire to stop people from talking is chilling," she says. ▮

A long-range acoustic device in use by the US Navy

AB FORCES NEWS COLLECTION/ALAMY

Coronavirus

Do covid passports work?

Vaccine passes are becoming part of life, but questions remain over their effectiveness and ethics

Michael Le Page

MORE and more countries are moving towards requiring a form of covid pass for international travel or attending large events or nightclubs, bars and restaurants.

Their introduction is provoking protests in countries including France and Italy, however. So what are covid passes, how effective are they and are they ethical?

HOLLANDSE HOOGTE/SHUTTERSTOCK

Paradiso in Amsterdam, the Netherlands, opened at full capacity in June

What is a covid pass?

The basic idea is that people who are immune to the coronavirus can come into close contact with each other without catching the virus or spreading it. We don't have any easy way to measure immunity, though, so covid passes are intended to act as a proxy, providing evidence that someone has had an approved vaccine.

Many passes can also be obtained on the basis of a positive covid-19 test in the past six months or so, suggesting that a person has natural immunity. For people who haven't been vaccinated or infected naturally, a lot of schemes will also provide a short-term pass on the basis of a negative test in the past day or two, to show that an individual isn't currently infected.

"A vaccine pass sounds like it's restricting liberties, but it's actually restoring people's freedom"

These three criteria are what countries are starting to converge on, says Christopher Dye at the University of Oxford, one of the authors of a February report on vaccine passports. "I think we are moving towards a system that makes sense," he says.

While the term "vaccine passport" is often used, it isn't an accurate description of passes that can also be obtained on the basis of a negative test or past infection, such as the EU Digital COVID Certificate.

"I think it's a misnomer to call it a vaccine passport," says bioethicist Nancy Jecker at the University of Washington School of Medicine in Seattle.

What you need to do to get a covid pass depends on where you live. In England, the National Health Service Covid Pass can be obtained from the NHS App. A travel pass can be obtained if you have been vaccinated, or had a positive PCR test in the past six months. These or a negative test in the past two days can also get you a short-term pass to attend domestic events. Passes are also available in paper form.

Covid passes are already required for travel to many countries, or for avoiding quarantine. In some places, they are also needed for other activities. From September, for instance, people in New York City will have to show they have had at least one vaccine dose to eat inside a restaurant or go to theatres.

How effective are they?

If vaccines provided complete protection against transmission, if tests for infection were completely accurate and if everyone stuck to the rules, covid passes would be 100 per cent effective at, say, preventing people going to nightclubs infecting others there.

But not everyone follows the rules, not all tests for infection are highly accurate and some vaccinated people can still get infected and infect others.

This means covid pass schemes will only lower the risk of infection rather than stop it. By how much isn't clear. Surprisingly, there have been no real-world trials, nor even any modelling studies relevant to the current situation in wealthy countries, as far as *New Scientist* can establish. "Analytical studies have not been done," says Dye.

For instance, when the Netherlands reopened nightclubs for people with negative tests, there were several superspreader events and a surge in cases. Some politicians blamed this on people using fake passes, while others blamed it on false negatives due to the rapid tests used, which are less accurate than slower PCR tests.

However, if nightclubs had been reopened without the negative test requirement, there could have been an even bigger increase in cases. No country is deliberately doing such an experiment, but by looking at what happens in the US, say, where only some cities and states are introducing covid passes, it might be possible to compare areas to get an idea of how much passes reduce the risk.

One modelling study did look at what would happen if lockdowns and face coverings are keeping infections at a low level and restrictions are relaxed only for those who are vaccinated. It concluded that a vaccine needs to be about 80 per cent effective at blocking transmission – not just at preventing symptoms – to prevent another wave of infections.

According to a large UK study, the Pfizer/BioNTech vaccine is 85 per cent effective at preventing infection by the delta variant two weeks after the second dose, but by three months, its efficacy wanes to 75 per cent (see page 16). The Oxford/AstraZeneca vaccine is 68 per cent effective against delta initially and wanes to 61 per cent over this period.

These studies together suggest that if the aim is to prevent outbreaks, many vaccines aren't effective enough for vaccine passports to work and even those that are don't remain so for long. However, if the aim is just to keep case numbers lower when easing restrictions, vaccine passports will help, says B. Shayak at Cornell University in Ithaca, New York. "There's no denying that vaccine passports are better than no vaccine passports," he says.

Can passes boost vaccination rates?

When Israel introduced its green pass in February, allowing people with it to go to gyms, restaurants and so on, one of the aims was to boost vaccination levels. The scheme was stopped as cases fell but was reintroduced as they rose again due to the delta variant. This time, people who get the pass on the basis of a negative test when they are eligible to be vaccinated have to pay for the test.

With no controls to compare, it isn't clear if this kind of approach increases vaccination levels, but one survey in the UK suggests it might backfire. In April, Alexandre de Figueiredo at the London School of Hygiene & Tropical Medicine and his colleagues asked nearly 18,000 people how the introduction of vaccine passports would affect their intention to get a first or second dose.

People who were already intending to get vaccinated said they would be more likely to do so, but those who were opposed or hesitant – including many younger and Black people – said they would be less inclined. Overall, the findings suggest there may be a net negative impact.

Even making vaccinations compulsory might not increase uptake. A 2014 study comparing countries in Europe found no evidence that vaccination levels are higher where childhood vaccines are mandatory.

Rebecca Brown, an ethicist at the University of Oxford, is sceptical about the survey results. She thinks covid passes will increase vaccination, but doesn't think they should be used for this. "I don't think that would be a legitimate use of the passport scheme. It might have this extra benefit, but that is not what justifies introducing it," she says. "If it's safe for people to have those freedoms, then they should absolutely be able to access those freedoms."

Are covid passes ethical?

Many people have questioned whether covid passes can ever be ethically justified even for reducing infection rates.

"A vaccination passport sounds very frightening. It sounds like we are introducing further restrictions on people's liberty," says Brown. "My view is that people are getting things the wrong way round. An immunity passport is a way of restoring freedom."

Dye compares covid passes to driving licences. We accept these are necessary to keep everyone safe, he says, and the principle is the same for covid passes.

Jecker broadly agrees. "In the US, there are people that are really opposed to any kind of interference with individual liberty," she says. "But we are in an era now where we have responsibilities to every other person on the planet. Respect for individual autonomy needs to be balanced against these other values, whether we're talking about emerging infectious diseases or climate change."

One objection to vaccine passports is that they can be discriminatory. Not all firms give workers time off to get vaccinated, for example. Vaccine passports can also make travelling harder for people in low-income countries, where far fewer people have been able to get vaccinated.

For these reasons, Jecker is opposed to any system based solely on vaccination, but supports schemes that allow alternatives such as a negative test.

Brown agrees that requiring vaccine passports for international travel can be discriminatory, but doesn't see this as a valid argument against them. "What people who are objecting to vaccine passports under those circumstances are doing is that they are advocating some kind of levelling down," she says. "You're saying, 'not everybody can access this, so nobody should access it'. I don't think that's justified." ▮

Covid passes differ depending on where they are issued

Place	Scheme	Requirements	What is it for?
European Union	EU Digital COVID Certificate	Vaccination, recent negative test or recovered from covid-19 in past 180 days	Travel within the EU and to some other countries
France	Pass sanitaire	Vaccination, negative test in past three days or recovered from covid-19 in past 180 days	Mandatory for restaurants, shops, hospitals and long-distance trains
Italy	Green Pass	Vaccination, negative test in past three days or recovered from covid-19 in past 180 days	Required in most public venues except shops
England	NHS COVID Pass	Vaccination, positive PCR in past six months or (domestic only) a negative test in past 48 hours	International travel, some venues may ask for it
Wales	NHS COVID Pass	Vaccination	International travel
Scotland	Coronavirus vaccination status	Vaccination	International travel
Northern Ireland	Covid certificate	Vaccination	International travel
New York City	Key to NYC	At least one vaccine dose	From September, mandatory for indoor public activities such as restaurants and theatres
New York state	Excelsior Pass	Vaccination or recent negative test	Some state employees must have one, businesses can choose to require it
Israel	Green Pass	Vaccination, negative test paid for privately in the past 72 hours or recovered from covid-19	All venues except shops and malls
China	Green, yellow or red health codes indicating risk level	Based on a health survey early in the pandemic but now also takes account of vaccination or recent negative test	Not mandatory but green codes required by most workplaces, restaurants, shops, gyms and transport systems

Botany

Thieving honeybees offer a glimpse of the evolutionary origins of flowers

Richard Sima

HONEYBEES are championed as valuable pollinators, but sometimes they steal pollen without helping the plant that makes it. Now, a study of pollen theft by honeybees from a type of non-flowering plant is shedding light on why the very first flowers may have evolved.

Honeybees' reputation for diligent pollination is mostly well-deserved, but they aren't universally good for all plants. Tao Wan at the Fairy Lake Botanical Garden in Shenzhen, China, and his colleagues have discovered that, in the tropical rainforests on the Chinese island of Hainan, the Asian honeybee (*Apis cerana*) steals pollen from a plant called *Gnetum luofuense*. The bees keep all the pollen they collect from this plant for themselves, to the detriment of the plants that they take it from.

"We were totally surprised because this phenomenon has never been described before for this species," says Wan.

G. luofuense is a type of gymnosperm, a group of plants that also includes conifers, ginkgos and cycads. While gymnosperms do produce pollen, they don't make flowers or fruits, and most species are pollinated by the wind. Before this study, it wasn't known that honeybees visited *G. luofuense*.

Wan's team found that honeybees frequently visited male *G. luofuense* plants at dusk and dawn to collect pollen. But the bees avoided female plants altogether, meaning that they didn't facilitate any pollination for this species (*Ecology*, doi.org/grzr).

Bees weren't the only visitors to the *G. luofuense* flowers – the team also observed visits from *Mecodina cineracea* moths, which attended both male and female plants, serving as effective pollinators. However, when honeybees were present, the team found that these moths carried 70 per cent less pollen and the plants produced fewer seeds.

These findings provide a glimpse of the time before flowering plants, known as angiosperms, came to dominate, roughly 90 to 125 million years ago. Before angiosperms, gymnosperms were the dominant type of plant life, but only around 1500 species remain today. In comparison, there are more than 350,000 species of angiosperms.

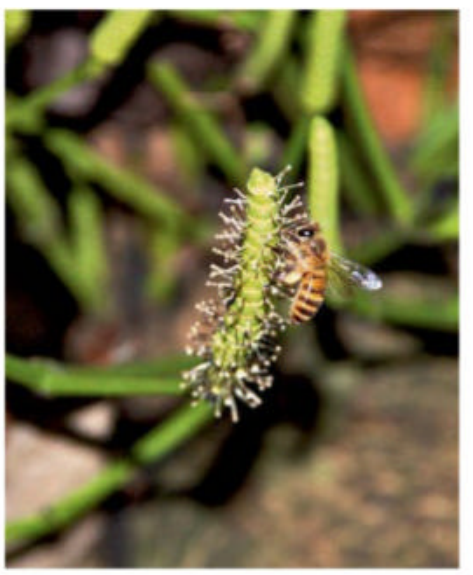
The emergence of new kinds of pollinators, such as bees around 130 million years ago, probably played a role in the origins and subsequent phenomenal success of flowering plants. Wan's team thinks that honeybees could have stolen pollen from now-extinct species of gymnosperms before flowers even existed. This could have disturbed the whole pollination systems of extinct gymnosperms, says Wan.

Although honeybees also steal angiosperm pollen, flowers may have arisen as a way to better control the behaviour of thieving bees. Showy petals and sweet nectar, for example, can help ensure that a bee will visit female, as well as male, plants.

The team's study also suggests that pollen theft may be a more common problem for the surviving gymnosperm species than previously thought. Bees have also been observed collecting pollen from wind-pollinated conifers, ginkgos and cycads, but it is unknown whether these were pollination visits or acts of larceny.

"If you ask a person in the public to name a pollinator, they will think of honeybees," says Anna Hargreaves at McGill University in Canada. "And honeybees are supercool, but they can have this really negative effect on some plants." ▮

An Asian honeybee collects pollen from *Gnetum luofuense*



PROFESSOR YAN-BING GONG

Physics

US lab reaches the cusp of ignition for nuclear fusion

A COLOSSAL laser system has created some of the most extreme conditions on Earth, bringing us one step closer to useful nuclear fusion power that would produce no hazardous waste.

Researchers at Lawrence Livermore National Laboratory's National Ignition Facility (NIF) in California have been attempting to jump-start fusion for decades.

NIF works by focusing 192 of the world's highest-energy lasers into a single powerful beam that shines on a small plastic sphere full of hydrogen. The intense heat makes the plastic explode, compressing the hydrogen inside. If the pressure is high enough, the hydrogen atoms will begin to fuse together, releasing a huge amount of energy.

On 8 August, NIF achieved its highest energy yield yet, putting out more than 1.3 megajoules of energy. That is 10 quadrillion watts of fusion power for 100 trillionths of a second. "That, in reality, is what it takes to boil a kettle," Jeremy Chittenden at Imperial College London told the New Scientist Weekly podcast. "So the amount of energy we would need to generate a power station would need to be hundreds or even thousands of times larger from every pulse."

Nevertheless, this yield is an improvement by a factor of eight over experiments conducted earlier this year, and puts NIF on the cusp of sparking fusion, the team said in a press release.

"What we're trying to achieve is a plasma state very much similar to the centre of the sun"

"It's literally held together for as long as it takes to explode," said Chittenden. "What we're trying to achieve is a plasma state very much similar to the centre of the sun... and we can't hold that pressure together for very long." The pressure of the hydrogen was orders of magnitude higher than what has previously been achieved in any lab, he said.

Not only is this a step towards clean nuclear power, it could also lead to experiments that help us understand the most extreme locations in the cosmos and the seconds after the big bang. ▮

Leah Crane

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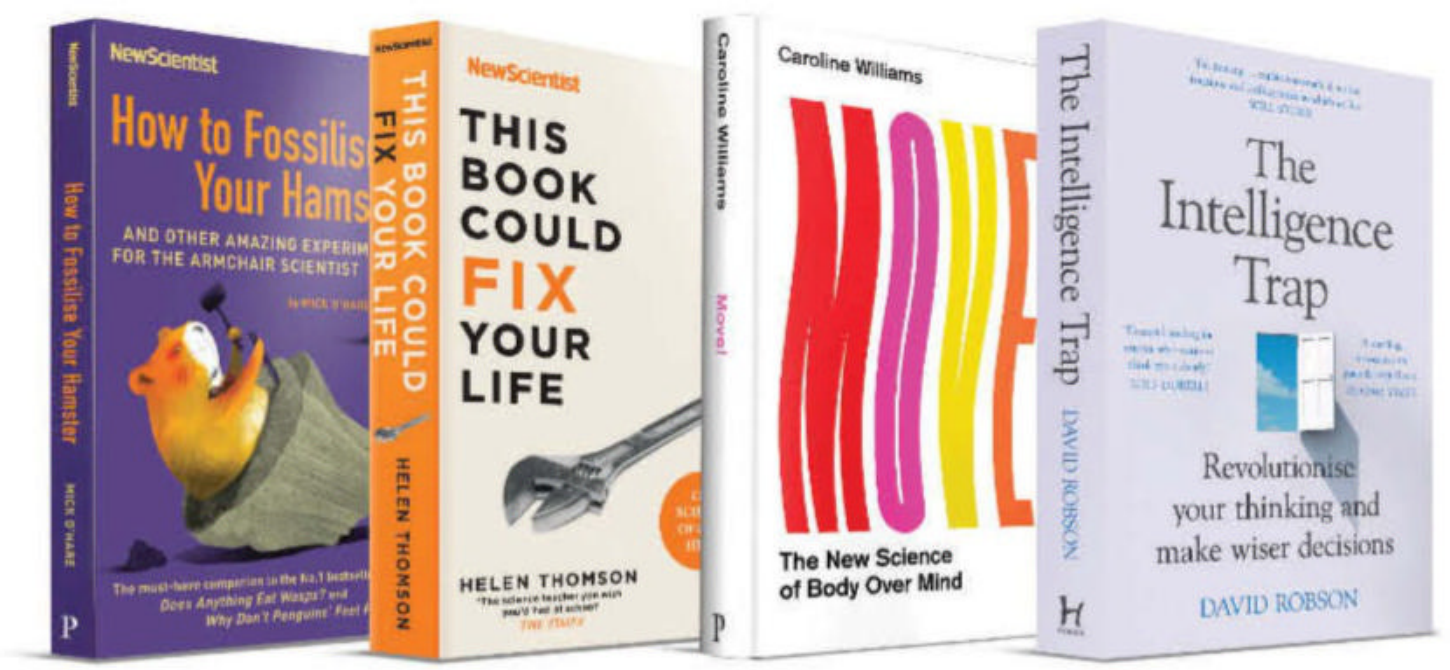

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Marine biology

Widest coral on the reef

Record-setting domed coral found in the Great Barrier Reef

Alice Klein

AN ENORMOUS coral in a remote part of Australia's Great Barrier Reef is the widest ever found there.

The dome-shaped coral was spotted off the coast of Goolboodi, or Orpheus Island, in northern Queensland in March. It was named Muga dhambi, meaning "big coral", by the Manbarra Traditional Owners group in the region.

At 10 metres across and 5 metres high, Muga dhambi is the widest and sixth-tallest coral documented in the Great Barrier Reef. It belongs to the *Porites* genus of coral. The largest known coral is thought to be another *Porites* in American Samoa. It is about 22 metres across and 8 metres high, and is estimated to be between 420 and 652 years old.

Muga dhambi is between 421 and 438 years old based on its size and growth rate, says Adam Smith at Reef Ecologic in Australia, who led a study of the coral (*Scientific Reports*, doi.org/grsw). ▮

RICHARD WOODGETT

Covid-19

How vaccines are holding up against delta

TWO doses of either the Pfizer/BioNTech or the Oxford/AstraZeneca vaccine provide good protection against symptomatic infections by the delta coronavirus variant, but both are around 15 per cent less effective against delta than the alpha variant, according to a large study in the UK.

The findings show that protection wanes over time, and imply that vaccinated people who get infected might be just as infectious as unvaccinated people. The key message is that it is important to get both vaccine doses, says study leader Sarah Walker at the University of Oxford, UK. "Two doses are always better than one."

It was previously established that vaccines provide less protection against delta than alpha, but by how much has been debated. The UK study is based on a weekly survey that started in April 2020. Since delta became dominant in the UK, the team has received results from 800,000 PCR tests done on 360,000 individuals.

Overall, after two doses, the Pfizer/BioNTech vaccine provides 84 per cent protection against symptomatic infections by delta, compared with 97 per cent for alpha, the study found. For the Oxford/AstraZeneca vaccine, it is 71 per cent compared with 87 per cent. Both vaccines are less effective in older age groups against both variants. The findings also show that the effectiveness of the Pfizer/BioNTech vaccine wanes much faster than that of the Oxford/AstraZeneca one, by around a fifth every month after the second dose.

The researchers think the protection from both vaccines will start to become similar after four or five months. That is an extrapolation, Walker cautions, as so far the team only has data going up to 80 days after two doses.

"It is important to get both vaccine doses. Two doses are always better than one"

The results of the PCR tests also suggest that individuals who get infected by delta despite being vaccinated produce just as much of the virus as people who are unvaccinated. By contrast, vaccinated individuals infected with the alpha variant usually had much lower virus levels than unvaccinated people.

The implication is that vaccinated individuals who get infected might be just as infectious as unvaccinated people. But it isn't possible to be certain about this, says team member Koen Pouwels, because the PCR tests might be detecting dead viruses rather than infectious ones, he says. ▮

Michael Le Page

Cell biology

Human proteins delivering mRNA could treat diseases

Michael Le Page

PACKAGING messenger RNA inside a human protein may make it much easier to deliver mRNA to cells in organs. This could allow mRNA to be used to treat conditions from autoimmune disorders to cancers.

The success of the coronavirus vaccines has demonstrated the potential of the mRNA approach. Instead of making proteins in factories, which is difficult and expensive, this method is based on delivering genes and letting the body do the hard work of making proteins.

The mRNAs are copies of genes that don't get integrated into cells' genomes and break down quickly, so their effect is temporary. But delivering genes to cells is tricky. One approach is to package them in the shell of a virus. But the immune system targets the shell, preventing people from being dosed repeatedly.

In the Pfizer/BioNTech and Moderna covid-19 vaccines, mRNA is instead held in oily droplets called lipid nanoparticles, injected into arm muscles. These don't provoke an immune reaction, but if lipid nanoparticles are injected into the bloodstream, they get mopped up by the liver within half an hour. This is ideal for, say, treating protein deficiencies in the liver, but not for treating brain or heart disorders.

Now, Feng Zhang, an investigator at the Howard Hughes Medical Institute who is based in Massachusetts has combined the advantages of both approaches. He and his colleagues have shown that mRNAs can be packaged in a human protein called PEG10 that forms virus-like particles (*Science*, doi.org/grtk).

Using a human protein shouldn't provoke an immune response, so people could be given repeated doses of the same treatment. By adding various targeting proteins to the outside of the particles, mRNAs can be delivered to any desired cell type. ▮

Energy

Solar panels in space could help power the UK by 2039

Adam Vaughan

SOLAR power beamed from satellites could give the UK a continuous supply of green energy as soon as 2039.

The idea of space-based solar power isn't new, but technology developments and climate change concerns have renewed interest in the concept in recent years in China, Japan, the US and, now, the UK.

A report on its economic and technological feasibility, requested by the UK Space Agency, suggests a £16.3 billion development plan could make the concept a reality, and help the UK cut its carbon emissions to meet its 2050 net-zero goal.

The authors say a network of satellites with solar panels could be launched into geostationary orbit. Each would weigh around 2000 tonnes and be about 1.7 kilometres across. The sun's energy would be converted to high frequency radio waves beamed down to a 98-square-kilometre antenna facility resembling a giant fishing net to convert it back to electricity.

Martin Soltau at Frazer-Nash, the consultancy behind the report, told a public meeting on 28 July: "Our overall finding is the technology offers new and viable options for the UK to deliver net zero." He said the benefits strongly outweigh the costs. Under his possible timeline, a small trial in low Earth orbit in the late 2020s could prove that power can be transmitted to the ground, followed by an operational power station in 2039. That facility would have a capacity of about 2 gigawatts, 27 times the biggest solar plant in the UK.

£50

Cost per megawatt-hour for electricity produced in orbit

Unlike terrestrial solar power, its space-based cousin could provide a continuous source of low-carbon power around the clock. Soltau says steady supply will be increasingly important in coming years as the UK shifts its energy supplies to more variable sources of electricity, mainly offshore wind farms.

The high price tag and the long time until investors reap rewards means public money is likely to be needed, Frazer-Nash said in its presentation. But the group says electricity beamed from orbit could be competitive with other sources of continuous low-carbon power, at about £50 per megawatt-hour.

In theory, the technology exists to make the concept work. Nonetheless, Soltau acknowledges there remain major obstacles for the UK. Those include the size of the area needed for the antenna – a challenge on a crowded island like the UK, meaning it could be sited offshore – regulatory issues over the radio frequency needed, and the need for cheap and regular rocket launches.

There is also the issue of the environmental impact of the number of rocket launches needed to establish the solar arrays. Soltau says establishing 25 solar power satellites over 10 years would require near daily launches by a rocket akin to SpaceX's Starship.

"There's no point in trying to see if it's technically achievable when the very reason you're creating the thing in the first place [net zero] is going to be null and void," says Andrew Wilson at the University of Strathclyde in the UK. He has calculated that life-cycle emissions from rocket launches and the concrete and steel involved in the antenna means space solar would have lower carbon dioxide emissions per unit of energy than coal, oil and gas, though higher than from terrestrial renewables.

Soltau notes that Wilson's study looked at 40-year-old technologies, which have seen significant developments that would cut CO_2 emissions. ▮

NASA

Solar panels in low Earth orbit would see uninterrupted sun

Climate change

Wildfires produce record CO_2

Extraordinary fires are causing the highest carbon dioxide emissions in decades

Adam Vaughan

HUGE blazes from the north-east of Russia to North America have made global carbon dioxide emissions from wildfires this year the highest in nearly two decades of modern satellite records.

"By many metrics, it has been an extraordinary fire season in the northern hemisphere," says Daniel Swain at the University of California, Los Angeles.

This year started quietly for wildfires and looked to be following the trend of recent years, which have seen a global decline in their number, driven largely by land management changes in Africa, South America and Australia.

Mid-year, all that changed. While images of an anguished woman near a fire in Greece dominated media coverage of the Intergovernmental Panel on Climate Change's latest report on 9 August, 2021's staggering wildfire CO_2 emissions (see graphic) are largely due to blazes that took hold in July across a remote part of Russia.

A heatwave has seen fires sweep across the boreal forests of Sakha in Siberia. The province's capital city, Yakutsk, has been blanketed in thick smoke. By mid-August, the CO_2 released by Sakha's fires – a good proxy for how much vegetation has been burned – was more than double the region's previous high for June to August, according to satellite data analysed by Mark Parrington at the European Centre for Medium-Range Weather Forecasts.

The band of fire in the sub-Arctic region stands in contrast to the big story of the past two years, when heatwaves led to record fires in the Arctic itself, where fuel is usually too cold to burn. "Wherever that heatwave seems to land each year, we're seeing a huge amount of fire activity," says Thomas Smith at the London School of Economics. "That's inevitably down to higher temperatures leading to the drying of fuels faster."

The overlap with striking fires and extreme heat is also playing out elsewhere, says Swain. California, Oregon, Washington, Idaho and Montana, along with British Columbia in Canada, are all seeing major wildfires in the wake of record-shattering heat. In July, Canada's national temperature record was broken by nearly 5°C. "The temperatures, and therefore how extremely dry the vegetation has become, really are the big story here," says Swain.

The recent heatwave that set the stage for this year's fires in the US and Canada would have been "virtually impossible" without climate change, according to a July study by an international team of researchers. "Climate change is making everything drier and more flammable," says Swain (see page 24 for more).

DIMITAR DILKOFF/AFP VIA GETTY IMAGES

A burned forest at Gorny Ulus in Sakha, Siberia

The Mediterranean has also had a remarkable year of fires linked to high temperatures, including a provisional European record of 48.8°C in Italy. Turkey and Greece have been hard hit. In recent weeks, there has been a big fire to the west of Madrid, and smaller ones in Portugal and Montenegro.

Figures compiled by Parrington show that wildfires this year have released a total of 4.3 gigatonnes of CO_2 up to 16 August, more than that emitted by the EU each year.

Meanwhile, smoke from fires in the western US and Canada last month not only caused local problems, but was transported as far as New York City, raising air pollution to harmful levels.

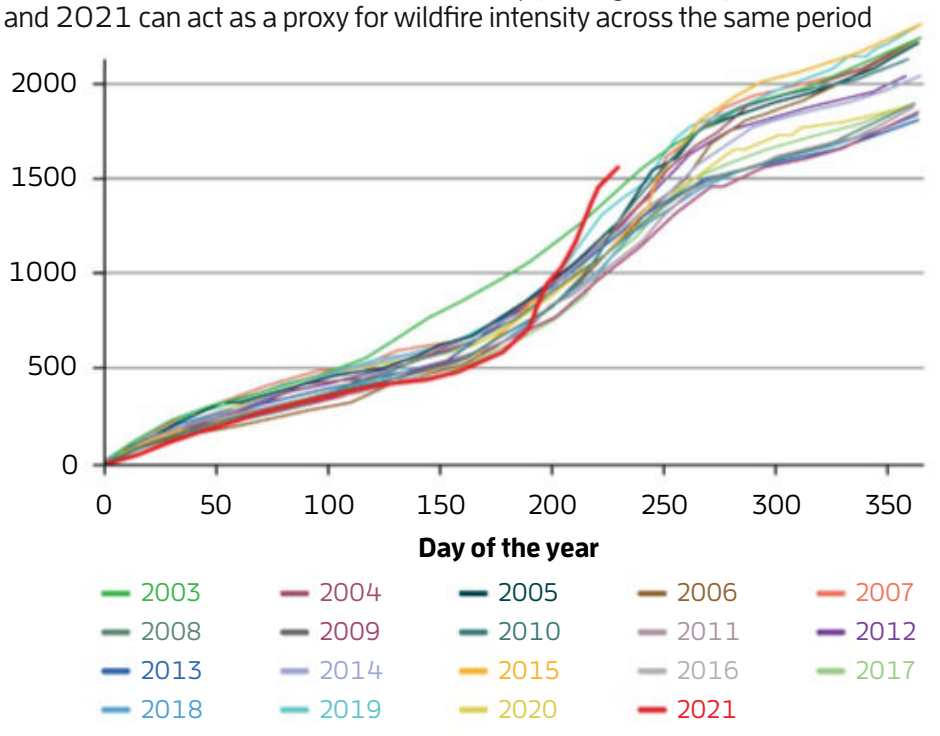
"The air quality impacts of smoke on human and animal health is really important," says Jessica McCarty at Miami University in Ohio.

In order to mitigate future fires, we will have to better manage the amount of fuel available by using controlled fires to periodically reduce vegetation, says McCarty. Education is also vital. In the US, 84 per cent of wildfires are started by people.

Exactly how bad 2021 will end up remains to be seen and will hinge on the Amazon, which saw major fires in 2019. Parrington has already detected signs of wildfires starting in the Brazilian state of Amazonas. "Given there are political difficulties in Brazil, it is unlikely it'll be a low fire year in that region," says McCarty. ▮

Global wildfires have released record CO_2 emissions so far in 2021

The amount of carbon dioxide released daily (in megatonnes) between 2003 and 2021 can act as a proxy for wildfire intensity across the same period



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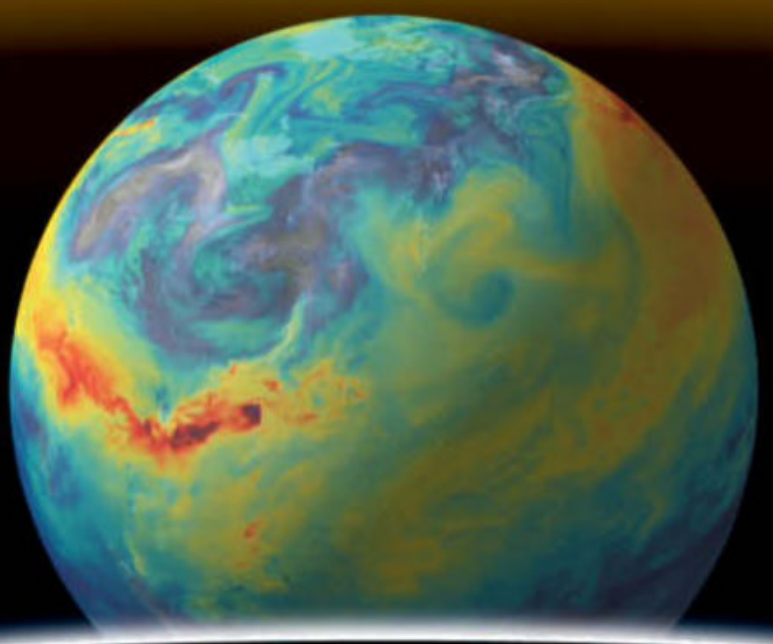

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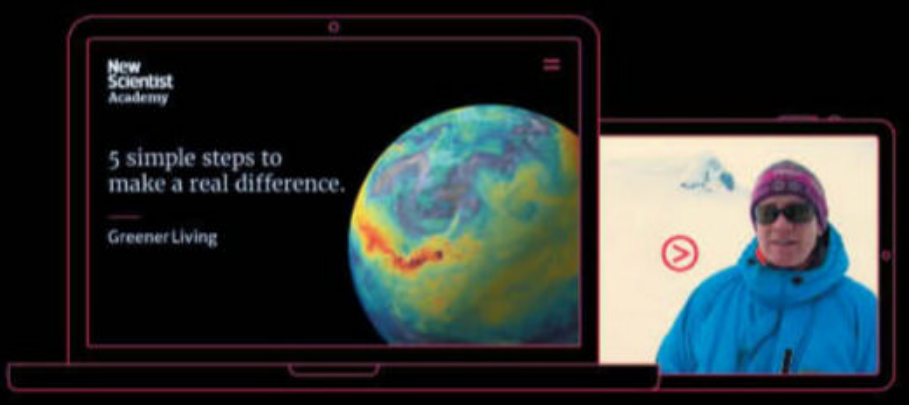
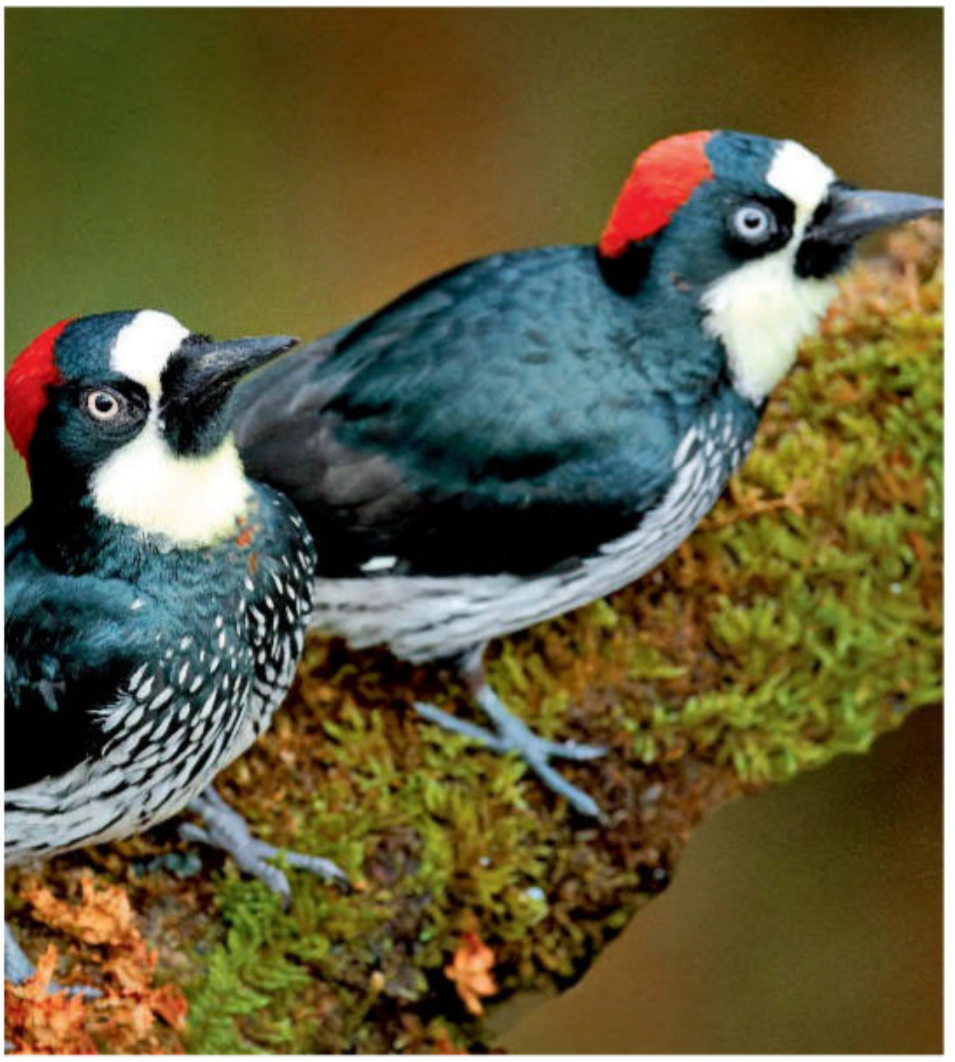


Ornithology



ONDREJ PROSICKY/SHUTTERSTOCK

Male woodpeckers live longer if they share mates...

MALE acorn woodpeckers that share mates with their brothers live longer and father more young than those that are monogamous.

Most acorn woodpeckers (pictured) form lifelong partnerships with a single mate, but about a third of females and half of males opt to breed in sibling groups, sharing one or more mates with their same-sex sibling. Scientists thought males in these groups were trading a chance of paternity for better nests, but it seems they are getting the best of both worlds, says Sahas Barve at the Smithsonian National Museum of Natural History in Washington DC.

Researchers at Hastings Natural History Reservation in California have gathered data from free-ranging acorn woodpeckers since 1968 and collected blood samples from each bird since 1984. This has let them compile genetic data on thousands of birds over dozens of generations, including many that share mates with their siblings.

Analysing this data, Barve and his colleagues found that co-breeding males fathered 50 per cent more chicks than monogamous ones (*Proceedings of the Royal Society B*, doi.org/grx6). "These cooperative breeders usually live in higher quality territories with more stored food, which may potentially increase their lifespan and thus their breeding attempts, leading to more total chicks," says Barve.

As for the females, they have about as many chicks over their lifetime whether they breed alone or in a two-sister group, says Barve. If they breed as three sisters, though, their total chick count drops. **Christa Lesté-Lasserre**

Primates

...while male chimps benefit from friends

MALE chimpanzees with more friends are more likely to father offspring – and there are at least three ways this can occur.

"Animals with more social bonds or stronger social bonds have higher reproductive success," says Joseph Feldblum at the University of Michigan. "We tried to find out how that might happen."

His team focused on chimps, which live in groups of around 25 individuals, dominated by an alpha male. The alpha sires most of the offspring, while subordinate males struggle to mate.

The team tracked 32 males and 26 females in the Kasekela chimp community in Gombe National Park, Tanzania. The animals have been studied since 1973, and the researchers had access to detailed behavioural and genetic data collected between 1986 and 2014.

They first confirmed, in line with previous studies, that males with more male friends and allies were more likely to father offspring. Then they dug into the data to figure out why.

One pattern that stood out was that males that formed close relationships with the alpha were more likely to mate, compared with those that didn't. This may be because the alpha permits them to mate with receptive females.

Independently, males that had lots of strong male friendships were more likely to rise in rank and become the alpha. Feldblum says this is more of a long-term advantage, but the reproductive pay-off of becoming alpha is huge.

Finally, males that formed a lot of strong ties with other males were more likely to sire offspring, regardless of the rank of anyone involved. This suggests there is an advantage to being part of a friendship group, even if it doesn't lead to an increase in rank (*iScience*, doi.org/grzf). **Michael Marshall**

Health

Diabetes implant restocked by pills

AN IMPLANT that releases insulin into the blood can be painlessly restocked with the hormone and wirelessly charge its battery. The team that made the device says it could revolutionise the treatment of type 1 diabetes.

The device (pictured) weighs 165 grams and is designed to be implanted inside the abdomen, on the outside of the stomach. It constantly measures levels of insulin in the blood and releases doses of the hormone via a small catheter as needed. The internal battery can be charged wirelessly by a device outside the body.

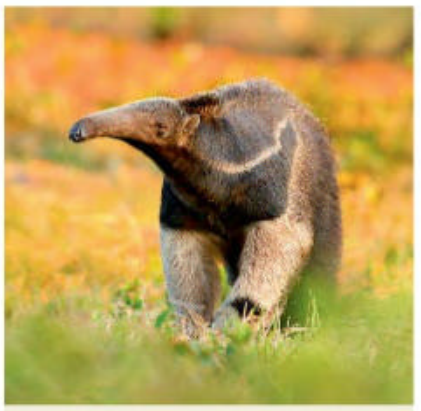
THE BIOROBOTICS INSTITUTE, SCUOLA SUPERIORE SANT'ANNA

The insulin is refilled using magnetic capsules that can be swallowed. These connect to the device from the other side of the stomach lining, where a syringe pokes through the stomach to drain them into an internal reservoir. Once empty, the capsules are released to pass naturally through the digestive system. The reservoir holds enough insulin to last the average person with diabetes a month, according to Izadyar Tamadon at Scuola Superiore Sant'Anna in Italy and his colleagues.

The team tested a prototype implant on pigs, where it effectively regulated insulin levels in the blood (*Science Robotics*, doi.org/grzc).

The researchers hope that the device will get certification for human tests. **Matthew Sparkes**

Really brief



ONDREJ PROSICKY/SHUTTERSTOCK

Anteaters must hunt for cool areas

Giant anteaters don't regulate their body temperature well due to a slow metabolism. So, the fewer cool forest patches there are where they live, the larger their home range, according to a study in which researchers tracked these animals' movements using GPS (*PLoS One*, doi.org/grzq).

Jobs linked with brain health

People with mentally demanding jobs have a slightly lower risk of developing dementia. These jobs were also linked with lower levels of three compounds that play a role in blocking the formation of new synapses, the connections between neurons (*BMJ*, doi.org/grzs).

Ancient turtles had extra-tough eggs

A rare fossil turtle egg from the Late Cretaceous period containing an embryo of an extinct land-dwelling turtle called Nanhsiungchelyidae has an exceptionally thick shell. This hints that the region it was found in, now in China, was dry, as a thick shell helps keep moisture in (*Proceedings of the Royal Society B*, doi.org/grzt).

Zoology

Rattlesnakes fool us with auditory illusion

RATTLESNAKES use sudden high-speed rattling to fool humans, and probably animals, into believing they are closer to the venomous vipers than they really are.

Rattlesnakes start their warning rattle at a slow pace that gradually rises, then switch to a constant, high-frequency rattle. This suggests contact is imminent – but in reality, they could still be a metre away, says Boris Chagnaud at the University of Graz in Austria.

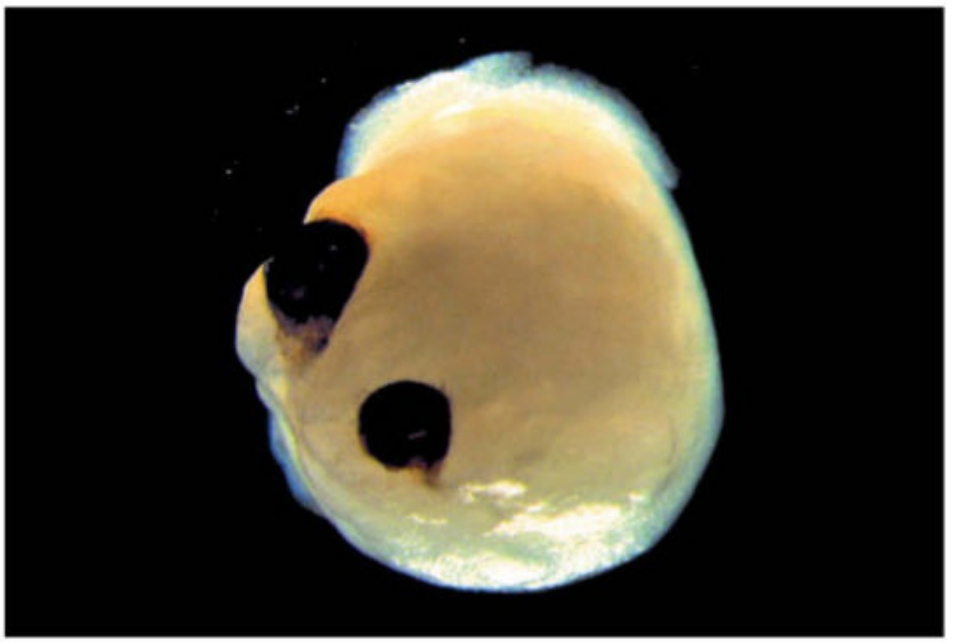
The auditory illusion probably works to stop the snake from being stepped on or wasting venom, he says. "They're not trying to save us from being bitten," he says. "They're advertising their presence to save themselves."

Chagnaud worked with a team at the Technical University of Munich in Germany to test 30 of their Western diamondback rattlesnakes as they reacted to an approaching dummy human torso set on sliding rails, and to a growing black circle made by light projections on a screen.

In both tests, the team found that the snakes' rattling frequency would gradually speed up to about 40 rattles per second, then jump to an unchanging, high-frequency rattle ranging from 60 to 100 rattles per second.

The team then ran virtual reality tests on 11 people as they moved through a virtual grass field with different sounds. The researchers asked the participants to push a button when they believed they were within reach of a sound's source and found that the listeners were easily fooled by the sudden jump in rattle speed (*Current Biology*, doi.org/grzh). **CLL**

Neuroscience



ELKE GABRIEL

Brain tissue grows eye-like structures that 'see' light

SMALL blobs of human brain grown in a dish have been coaxed into forming rudimentary eyes, which respond to light by sending signals to the rest of the brain tissue.

The pairs of eye-like structures (pictured) create tissues similar to those in real eyes, including: a round lens, which normally focuses an image; a retina, the patch of tissue at the back of the eye that senses light; and neurons that grew from the structures into the rest of the brain tissue.

Jay Gopalakrishnan at Heinrich Heine University Dusseldorf in Germany and his colleagues got brain organoids – spherical masses of brain tissue up to 3 millimetres wide – to form optic cups, an early stage of eye formation. They did this by adding retinoic acid, a vitamin A derivative involved in eye development in the embryo, 20 days into their development (*Cell Stem Cell*, doi.org/grx8).

It is unclear how similarly these tissues function to their full-grown counterparts, but when the organoids were exposed to light, electrical signals travelled along the neural pathways, suggesting that some kind of visual information is being transmitted. In a way, the brain tissue is "seeing" light, says Gopalakrishnan. Clare Wilson

Animal behaviour

Jays don't enjoy magic tricks

JAYS react with surprise when shown a cup-and-balls-style magic trick in which their favourite snack is swapped for a less appealing one. Their responses show cognitive abilities that may come into play when they pilfer food caches hidden by other birds.

Alexandra Schnell at the University of Cambridge and her colleagues showed six Eurasian jays (*Garrulus glandarius*) a version of the cups and balls magic trick, in which food was placed under one of two overturned cups.

The birds had seen a worm or cheese piece go into a cup, but in some cases the researchers swapped it for the other type of food. If the jays expected to get their favourite food and found one they liked less, they were more likely to look under the second cup, and in some cases rejected the food from the first cup. They were also slower to take food that wasn't their favourite and were more likely to repeatedly pick up the cup where they expected their favourite to be (*Royal Society Open Science*, doi.org/grzn).

The birds' reactions show an ability to imagine the immediate future, evaluate their expectations and use those to guide how they respond, says Schnell. **Sam Wong**

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Views

Comment

Data privacy in a war zone

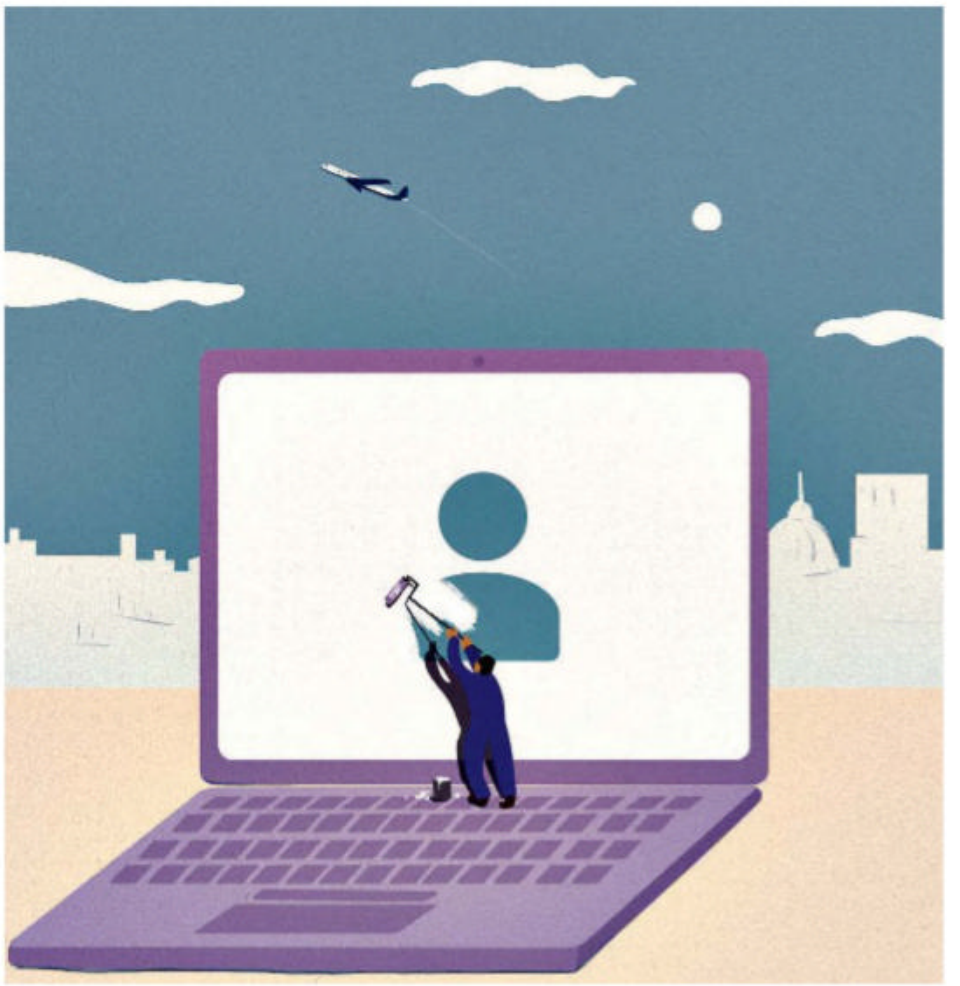
The Taliban's rise to power has left many people in Afghanistan looking to delete their digital footprint, says **Nighat Dad**

THE swift progress of the Taliban in Afghanistan has been truly shocking. It feels like only days ago that US president Joe Biden was explaining how a Taliban take over wasn't inevitable and the Pentagon was talking about how the fall of the capital, Kabul, could take up to 90 days. Now, the Taliban has control of the entire country and has held its first press conference in Kabul for local and international media. No one, I believe, had anticipated that things would escalate quite this quickly.

Though the Taliban spokesperson Zabihullah Mujahid told the press conference that it wouldn't be seeking "revenge" against people who had opposed it, many Afghan people are understandably still worried. On top of this, they – including those who worked with Western forces and international NGOs, as well as foreign journalists – have been unable to leave the country, as flight capacity has been taken over by Western countries evacuating their citizens.

As such, people have been attempting to move quickly to erase their digital footprints, built up during the 20 years of the previous US-backed governments. Some Afghan activists have been reaching out to me directly to help them put in place robust mobile security and asking how to trigger a mass deletion of their data.

The last time the Taliban was in power, social media barely existed and smartphones had yet to take off. Now, around 4 million people in Afghanistan regularly use social media. Yet, despite the huge rise of digital technologies, a comparative rise in digital security hasn't happened.



MICHELLE D'URBANO

There are few digital security resources that are suitable for people in Afghanistan to use. The leading guide on how to properly delete your digital history by Human Rights First is a brilliant place to start.

But unfortunately this is only available in English and unofficially in Farsi. There are also some other guides available in Farsi thanks to the thriving community of tech enthusiasts who have been working for human rights activists living in Iran for years.

However, many of these guides will still be unintelligible for those in Afghanistan who speak Dari or Pashto, for example. Along with other digital security trainers, I am working to make translations possible, but even this is too little, too late.

People in the global information security and digital rights community should have made more of an effort to include Afghan voices in tech spaces across the world long ago. And security forces that have been active in Afghanistan should have put more of a focus on the digital safety of locals who were part of their teams.

The US, NATO and their allies have poured billions of dollars into Afghanistan through different programmes and initiatives, so how come digital risk assessment plans weren't ready for thousands of Afghans, including activists and interpreters?

People in Afghanistan who worked with Western forces also face an impossible choice, as countries where they might seek asylum often require digital proof of their collaboration. Keep this evidence and they risk persecution from the Taliban. Delete it and they may find their only way out no longer available.

Millions of people's lives will now be vastly different due to the regime change. Digital security feels like one thing that could have been sorted out in advance. We are yet to see exactly how Taliban 2.0 will be different to that which went before. And while the so-called War on Terror appears to be over, I fear a digital terror offensive may just be beginning. ▮

Nighat Dad is a lawyer and internet activist based in Pakistan

No planet B

The dawn of the pyrocene

Directly linking wildfires to climate change is still a difficult task – but make no mistake, they are a sign of things to come, writes **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *This Book Could Save Your Life*. You can follow him @grahamlawton

IF EVERYTHING goes to plan, by the time this is published, I will be on a beach. My family and I are heading to Pelion, on the Greek mainland.

Ah, Greece… how I have missed you! I feel a bit guilty about jetting off at this difficult time, but the emissions are offset, we are all double-jabbed and will act responsibly. There's still a lot that can go wrong, of course. Positive covid-19 tests. Sudden changes to quarantine rules. A careless failure to jump through a bureaucratic hoop. And, of course, wildfires.

The village we are staying in is directly across the water from the infernos raging on the island of Evia. It looks like our destination remains untouched, but the north coast of Evia is visible from southern Pelion, and my holiday won't be sheltered from the fire.

Many people will be getting a similar sight and smell of the blazing world we have created. Wildfires have been sweeping across Greece, Italy and Turkey as southern Europe grapples with the worst heatwave for three decades. This follows devastating fire seasons in the Pacific Northwest, Amazon, Australia and even the Arctic. The world appears to be going up in flames. Some scientists have called this new normal the "pyrocene".

It now feels natural to look upon such scenes and see the infernal hand of climate change. Indeed, many newspapers illustrated their front-page stories about the recent Intergovernmental Panel on Climate Change (IPCC) report, which concluded that humans are "unequivocally" to blame for global warming, with pictures of the Evia fires.

But we should be wary about such simplistic connections. It might seem obvious that a hotter world will also be a fierier one; scientists have been sounding that alarm for years. But there is more to the pyrocene than heat, and we ignore other factors at our peril.

Last month, I attended the Ecological Society of America's annual virtual meeting, where the US National Park Service's principal climate change scientist, Patrick Gonzalez, spoke. He acknowledged that climate change has intensified the heat that drives wildfires, and that the fire season has lengthened across a quarter of vegetated land surface since 1979. However, attributing wildfires directly to climate change is rarely scientifically justified.

"Fire tornadoes are mercifully rare, but are expected to become less so as the climate really starts to bite"

Gonzalez said only three studies – all in western North America – have causally linked wildfires to human-induced warming. Recent conflagrations in the Mediterranean, Australia and Siberia can't yet be directly attributed, and in many other places, other factors are much more important. In the Congo basin, Amazon and South-East Asia – ecosystems that rarely burned in the past, but have suffered the world's most rapid increases in fire in recent decades – intentional burning to clear the land is the main driver. In Chile and south-east Australia, natural climate variation such as El Niño is still more important than anthropogenic warming. That may change once the dust has settled on the latest fires.

This isn't intended to downplay the growing contribution of human-induced warming to wildfires. In British Columbia's fire season of 2017, for example, the extent of the burn was about 10 times larger than it would have been without climate change.

The fires raging in southern Europe have yet to reach such apocalyptic proportions. They are, however, helping to fuel the narrative that climate change has arrived, and may lull us into a false sense of security that we can deal with whatever it throws at us. But be warned: the full, hellish fury of the pyrocene has yet to arrive.

To get a sense of how much worse things could get, consider the devastating Loyalton fire in California last year. On the second day of the month-long blaze, firefighters encountered a monster that had rarely been seen before in the US: a "fire tornado". Also called a pyrocumulonimbus, these occur when heat from an intense fire interacts with the atmosphere to create a flaming vortex that is a hybrid of a tornado and a wildfire.

"They create their own weather system," says bushfire expert Sarah Perkins-Kirkpatrick at the University of New South Wales in Sydney. "They burn everything, they're really intense, they spread so quickly." Fire tornadoes are mercifully rare, but are expected to become less so as climate change really starts to bite.

That is the world we are blundering into unless we get to grips with emissions quickly. But even rapid cuts can't free us from the flames. As Gonzalez said, fire begets fire: "More heat causing more wildfires, emitting more carbon, generating more heat."

When we booked to go to Pelion before the pandemic, we imagined we were planning a trip to a place where time has stood still. It now looks more likely to offer us a glimpse of a dystopian future. ▮

Graham's week

What I'm reading
Probably some dystopian fiction to match my surroundings

What I'm watching
Season 3 of Ghosts

What I'm working on
Hopefully which taverna to go to for lunch

This column appears monthly. Up next week: Annalee Newitz

Signal Boost

Welcome to our Signal Boost project – a page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from **HEART UK**

HEART UK
THE CHOLESTEROL CHARITY

Shape the future to keep families together

Familial hypercholesterolaemia (FH for short) is an inherited condition which can lead to extremely high cholesterol levels.

Without treatment, FH can lead to heart disease resulting in premature death at a very young age. For people with FH, the incidence of fatal or non-fatal myocardial infarction without treatment is about 50% by the age of 50 years in men and about 30% by the age of 60 years in women.

Once FH has been diagnosed, it can be treated with medicines and a healthy lifestyle which results in a highly significant reduction in rates of heart disease and improved life expectancy for people with FH.

About one in 250 people has FH, that's more than 265,000 people in the UK, but less than 10% of these people have been diagnosed.

At HEART UK we have ensured FH is a top health priority for prevention, and thanks to our efforts, thousands of toddlers will be screened for the FH causing gene as part of a new national pilot programme. Over the next two years, 30,000 children across England will be assessed using a heel prick blood test to identify if they have a "faulty gene" which causes FH.

We are now at the pivotal point where we can bring about a step change for thousands of people with high cholesterol in the future.

We've been innovating our support services and our work with clinicians so that they are better able to help.

Help us enable thousands more people to know their cholesterol levels and detect those with high cholesterol and FH.

With your support, we can continue to save more lives by reducing cardiovascular disease, vascular dementia and strokes caused by high cholesterol, and shape the NHS to improve early detection and treatment for those at risk.

Want to help?

Visit heartuk.org.uk/shape-the-future to find out more

Editor's pick

Political realities may rule out energy sharing future

7 August, p 34

From Roger Elwell, Colchester, Essex, UK

Your article "A new energy world" floats a potential solution to intermittent renewables: continental-wide power grids. This is a fantasy in the current and likely future world we live in.

One of the primary responsibilities of a country to its citizens is the security of power supply and this solution simply doesn't allow for that. In the recent past, we have had reports of France threatening Jersey with switching off interconnectors, and a report that the European Commission has issued similar threats to Switzerland during their trade deal negotiations.

It simply isn't feasible that countries could work together in the manner suggested whilst resisting the temptation to weaponise the grid when it suits them.

Of the four futures you describe, those where energy nationalism features heavily are the more likely outcomes for entirely practical reasons.

From Butch Dalrymple Smith, La Ciotat, France

It is a tragedy that the public won't support taxation of hydrocarbon fuels to a level that reflects the damage that vehicles and home heating systems do to the environment. It is absurd that for many trips, private cars are still more economical than trains, even when a car has no passengers.

However, there is one cheap, simple action that could be enacted tomorrow: ban all publicity for fossil fuel-powered vehicles, including hybrids, especially self-charging hybrids. While we're at it, how about decorating petrol stations with heart-wrenching pictures of scorched koalas and starving polar bears? It worked for tobacco.

From Sam Edge, Ringwood, Hampshire, UK

Capturing carbon from the air to make jet fuel isn't carbon negative. Burning the fuel will release all the carbon dioxide back into the atmosphere. It is, at best, carbon neutral, but in reality will have inefficiencies that will need to be offset by additional carbon capture and storage. We need to do this, but we also need to cut the number of air journeys taken.

Almost all air and car travel for business is unnecessary and done either to make people feel important or as a "jolly". So that could be largely avoided.

Holiday travel is more of a problem. In the UK and wider Europe, big investment in rail and bus networks and cross-border integration, along with subsidised fares, might encourage the use of these forms of transport to get to sunnier climes rather than flying or driving.

From Anne Sweeney, Maidenhead, Berkshire, UK

The graph on page 38 didn't feature renewables that were used in 1800. At that time, wind energy was used for fishing, merchant shipping, travel, food production and household tasks such as drying clothes, yet it is rated nil on the graph. Likewise, hydropower turned mill wheels and solar power was used for food preservation.

Finally, animal power in agriculture, industry, travel and heating the homes of cottagers was a substantial "renewable".

Weird new forms of matter may be among us already

14 August, p 40

From Alan Worsley, Hull, East Yorkshire, UK

After reading Jon Cartwright's article "Solid, liquid, gas... and beyond" on "bizarre new states of matter", I begin to find the apparent reports of UFOs more credible. If ETs read *New Scientist*, they should now realise we aren't as backward as they might think. They might even invite somebody to visit a UFO factory to see how they are made.

We can go in peace to settle the wider galaxy

Letters, 7 August

From Simon Shore, Swavesey, Cambridgeshire, UK

Richard Jones suggests that it would be better if we don't try to spread ourselves across the galaxy because of our tendency to greed and crime. We are, like all other life on Earth, the product of evolution and many of our more negative behaviours have helped us to survive in the past. We don't condemn the lion for its routine infanticide or the spider for its casual cannibalism.

We have developed concepts of empathy, charity and altruism – signs that our intellect is freeing us from the tyranny of the selfish gene.

From Julian Goodkin, London, UK

I was rather disturbed by the negative attitude to humanity expressed by your correspondents regarding a 500-year plan to send us into space. Of course we have given rise to Hitler, Stalin and vast mounds of plastic, but we also have the works of Shakespeare, da Vinci and Mozart and the ability to work cooperatively to avert disaster in dire circumstances.

We have our faults, but we have the ability to overcome them – that is what being human means. As far as we know, we are the only species capable of understanding such concepts. If colonising space is our salvation, we must seize the opportunity for our own good and that of the universe.

No membranes required: another origin of life story

14 August, p 19

From Frank Kolmann, Sydney, Australia

The question of what came first – cells or cell membranes – is asked yet again in your report on a method to create membranes using a set of relatively basic starting materials. Perhaps the question is redundant.

The proposal that life began in alkaline hydrothermal vents doesn't require cell membranes. The pores in the vent structures are about the size of a cell and the initial chemical reactions were driven by the proton gradient between the hot alkaline water of the vents and the cold seawater.

To this day, all life obtains energy from proton gradients. It was only after self-replicating molecules evolved in the pores of the vents that cell membranes became advantageous, as the protocells were able to sequester available resources to themselves. Eventually, protocells evolved to the point were they could exist independently of vents, thus cells were released into the oceans.

Too much chatter at sea may hamper marine life

7 August, p 15

From Michael Allen, Ottawa, Canada

Whales and dolphins already have enough difficulty communicating because of pervasive human-generated marine noise.

Now we learn that humans are going to make life more difficult for them by transmitting their clicks and whistles to hide secret underwater messages. I imagine that for cetaceans it will be akin to us trying to have a conversation with someone in the middle of a crowded, noisy cocktail party. ▮

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ANIL SETH

A NEW SCIENCE OF CONSCIOUSNESS

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In this talk, Anil Seth draws on his own research and collaborations with neuroscientists, psychiatrists, mathematicians, virtual reality specialists and more to put forward an exhilarating new answer to that question – one that will turn what you thought you knew about your self and your conscious experience on its head.

For more information and to book your place visit:

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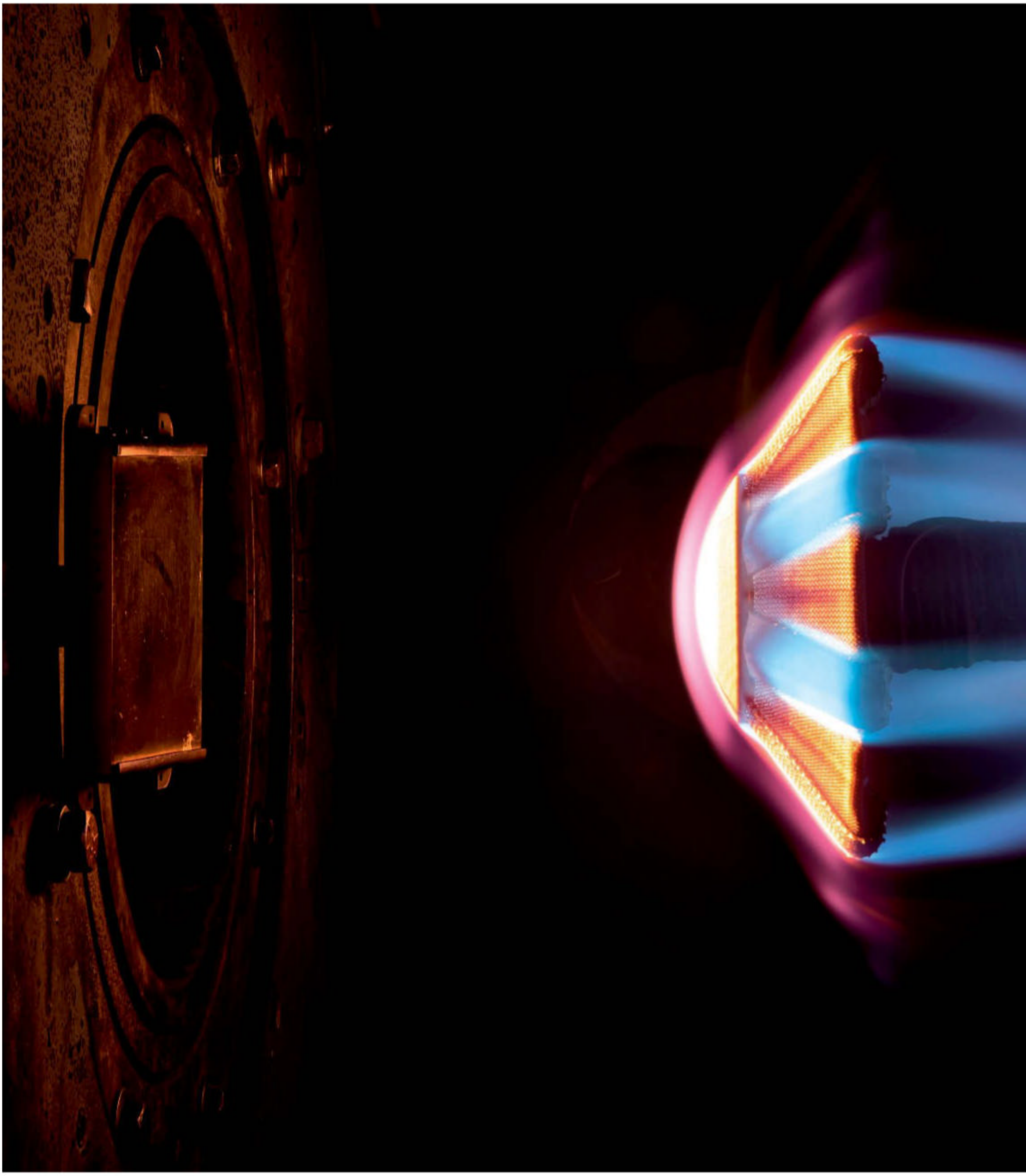
BIG THINKER SERIES
ANIL SETH



The heat is on

Photographer **Patrick Viruel/NASA**

THIS spectacle captured at NASA's Ames Research Center in Silicon Valley, California, could have important ramifications for future space missions. The material in the photo might one day allow vehicles to safely enter the atmospheres of other planets without burning up, as well as free up more room inside spacecraft.

Taken by photographer Patrick Viruel, the image shows a new type of fabric called Spiderweave being tested for NASA's Adaptable, Deployable, Entry and Placement Technology (ADEPT), an entry system it has designed for galactic missions. Because planetary atmospheres can reach scorching temperatures of several thousand degrees Celsius, ADEPT requires a heat shield made of a material that can withstand such extreme conditions without disintegrating or tearing apart.

Unlike previously tested materials that were made by stitching together individual panels, Spiderweave is continuously woven into the heat shield's fabric, making safe and efficient space travel to other planets by rovers, shuttles and other vehicles all the more likely.

The ADEPT team found that Spiderweave fared well when exposed to a temperature of 1500°C. It can also be compactly stored upon launch, which is useful for saving space for scientific payloads that researchers want to take to and from planets such as Mars.

Gege Li

Building done differently

Engineering has a diversity problem. A new podcast hopes to make the field appealing to all by celebrating a wide range of engineers, finds **Gege Li**

Podcast

Inventive Podcast

Overtone Productions

PICTURE an engineer and you may well imagine a white, university-educated man in a hard hat with a roll of blueprints under his arm.

The *Inventive Podcast* aims to flip these conceptions by highlighting inspirational and influential engineers who don't fit this constricted, outdated mould.

Host Trevor Cox, an acoustic engineer at the University of Salford, UK, chats with a different guest in each episode before asking a writer to come up with an original story inspired by those conversations. That makes the podcast itself an innovation of sorts, in that it marries fact and fiction to demonstrate there is far more to engineering than people might think.

It is a welcome addition considering the lack of diversity and uptake that still plagues engineering. In the UK, only 12 per cent of engineers are women, and 186,000 new engineers are needed each year until 2024 to make up for the country's skills shortfall in the profession.

Reassuringly, the podcast's first three episodes feature women, the first of whom is electronics engineer and activist Shrouk El-Attar. Part of her day job involves designing and developing technologies for women's health, including silent breast pumps and a pelvic floor trainer. El-Attar also performs as a belly-dancing drag king by night to challenge societal conventions and raise money for the LGBTQ+ community.

As a woman and asylum seeker from Egypt, El-Attar knows first-hand how being denied opportunities, such as going to university, can cause engineering to suffer – not only by being less diverse, but also at the expense of innovation. "How many amazing, creative technologies are we missing out on today as a society because we're telling these people with the amazing ideas that they don't belong here?" she asks.

In response to El-Attar's work and her account of being inspired into engineering by the "magic" people living inside her TV as a child, writer Tania Hershman incorporates poetry to create a thought-provoking story that reflects El-Attar's life. It uses the idea of a human being as a circuit board and emphasises the importance of language.

In the second episode, Cox meets Roma Agrawal, a structural engineer who was part of the team that designed The Shard, one of London's most iconic landmarks. Agrawal also wrote the book *Built: The hidden stories behind our structures*. She did so to encourage people to become engineers by showing that it is "so utterly an intrinsic part of humans and the way we've lived right from the beginning", she tells Cox.

The accompanying story by C. M. Taylor draws on Agrawal's self-confessed love for concrete ("I have been known to stroke concrete – I love feeling it!"),

"Shrouk El-Attar also performs as a belly-dancing drag king by night to challenge societal conventions"

as the Night Builder begins to secretly create colossal concrete structures in cities.

Cox's third guest is aerospace engineer Sophie Robinson, who works on a type of drone-inspired aircraft called eVTOL (electric vertical take-off and landing), with the idea of developing widely accessible air taxis that cut road congestion and carbon emissions.

Robinson is also an avid swimmer, having once swam across the English Channel, a fact that is at the centre of novelist Tony White's story about an engineer who grapples with the ethical dilemmas of her job while on a cold water swimming trip.

As you would expect from the experience of the personnel, the podcast is built on strong foundations. Cox asks perceptive questions that get to the heart of what it means to be an engineer, as well as helping to flesh out the details of the work itself, while each writer's take on the interviews adds an interesting and different element to the show.

The guests' enthusiasm is also infectious. "Being an engineer is my superpower," replies El-Attar, when Cox asks her which superpower she would like. "I hope people see that and that it can be your superpower too." ▮

Gege Li is a writer based in London

GETTY IMAGES/CAVAN IMAGES

Roma Agrawal worked on The Shard and appears on the *Inventive Podcast*

Under the bridge

The lowly workers of *Star Trek: Lower Decks* return for a second season and really hit their stride, finds **Swapna Krishna**

TV

Star Trek: Lower Decks
Amazon Prime Video

2021 CBS INTERACTIVE, INC

WHEN *Star Trek: Lower Decks* first premiered in the US last August, it presented a perspective we had rarely seen within the *Star Trek* universe. While we had traditionally focused on the "upstairs" bridge crew boldly going where no one had gone before, *Lower Decks* turned its sharp eye towards the "downstairs": the workers responsible for the least glamorous tasks on the ship. That it was an animated half-hour comedy further set it apart from what had come before, signalling that we should prepare ourselves for an entirely new kind of *Star Trek*.

The first season absolutely delivered on its promise, even if it was uneven in spots. In Beckett Mariner (Tawny Newsome), Brad Boimler (Jack Quaid), Samanthan Rutherford (Eugene Cordero) and D'Vana Tendi (Noël Wells), there was a relatable set of main characters who embodied the hope and promise that Starfleet has always offered, but also the realities (and drudgeries) of day-to-day life aboard a starship.

The show married the delightful absurdity of *Star Trek* to its heart, a fantastic – and often difficult – balance to strike. It is a testament to the *Lower Decks* writers, led by Mike McMahan, that they were able to pull it off so wonderfully for a season.

Happily, they have done it again with season 2. The writers excel at stories for both new viewers and diehard fans. The format of the show is much more accessible than a traditional hour-long drama. The in-jokes are fantastic and there are some deep references to past *Star Trek* canon (both popular and less so – Gary Mitchell, I'm looking at you) littered throughout the episodes, but viewers who don't pick up on them aren't missing much.

In *Star Trek: Lower Decks*, we see what life is like for low-ranking members of Starfleet

The first season of *Lower Decks* was enjoyable and approachable no matter the extent of your previous knowledge of *Star Trek*. The second season continues in that vein, delivering smart humour that never feels condescending. The show wants you to laugh with it; it isn't trying to make fun of you or point out the holes in your knowledge of *Star Trek*.

"Strange Energies", the first episode of the second season, revolves around Boimler – or more specifically (spoiler alert for season 1) the loss of Boimler, as he accepted a promotion and transferred to a different ship in the first season finale. As Mariner grapples with his decision, and the fact that he didn't tell her he was leaving, she must also contend with her new place aboard the USS Cerritos as the right hand to her mother, the captain. It is a role that anyone else would love, but Mariner prefers to operate outside the spotlight.

Mariner is arguably the main character of *Lower Decks*, and she showed considerable growth last season. During her internal reckoning, she came to terms with the fact that her desire to rebel is at odds with the part of her that genuinely wants to be a good Starfleet officer.

It is unclear where that character development will go from here, but she certainly does seem wiser and more self-aware this season. And Mariner's previous growth makes room for the rest of the characters to have their own storylines, which is always welcome. This show is at its best when it is an ensemble, and viewers are treated to plenty of that in the first half of the second season.

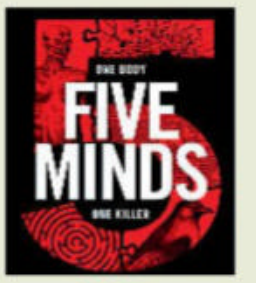
With its latest instalments, *Lower Decks* has found its groove. There are no more growing pains; it stands on its own two feet. At every turn, it is creative and thoughtful, but most importantly, it's fun. *Lower Decks* makes you want to tune in week after week, and each episode will leave you in a better mood than when you started watching. It's hard to give much higher praise than that.

Swapna Krishna is a writer who covers space, science, tech and pop culture

Don't miss

Watch

Countdown: Inspiration4 mission to space follows the first all-civilian crew of a SpaceX Dragon. Their three days in orbit later this year will raise funds for a children's research hospital. On Netflix from 6 September.



Read

Five Minds, a speculative thriller by Guy Morpuss, is set in a future where, to solve the planet's population problem, human bodies play host to multiple minds. But what if you might be sharing a body with a murderer?

Read

What's Eating the Universe? wonders physicist Paul Davies, as he contemplates the possible cause of an enormous bubble of nothing in the constellation of Eridanus, and considers 29 other mysteries of the cosmos.

TOP: JOHN KRAUS/COURTESY OF NETFLIX

The games column

Stuck in time with the ancient Romans

Time loops in video games can easily become a bit boring, but mystery adventure game *The Forgotten City* has found a nice way to bypass the problem, says **Jacob Aron**

Jacob Aron is *New Scientist*'s deputy news editor. Follow him on Twitter @jjaron

DEAR VILLAGERS

Don't break the Golden Rule otherwise statues will come after you

IF YOU could live today again, would you do anything differently? This theme has been explored in everything from films like *Edge of Tomorrow* to pretty much every sci-fi TV show of the 1990s looking to produce an episode on the cheap, but time loops are rarer in video games.

At first, that might seem strange – unlike a film, a time loop running on a computer can be instantly reset, making them easy to produce – until you realise that the best examples of the genre (*Groundhog Day*, obviously) make heavy use of cuts and rely on the viewer to fill in the repetitive details. That is harder to do in a game, where players are responsible for all of the protagonist's actions.

The Forgotten City has a neat solution to this problem, which I will get to in a moment. The game sees you thrown back 2000 years to an underground Roman settlement, where you must attempt to solve a mystery in order to free yourself from living the same day over and over. Only then can you return to your own time.

The titular city has one very simple law, the Golden Rule: if anyone commits a sin, everyone is punished. Exactly what counts as a sin is one of the themes explored in the game, as no one in the city is exactly sure. All they know is that if someone breaks this rule, the golden statues that are littered all over the place will come to life, attacking everyone they see and turning them into gold.

> **"By exploring the consequences of an all-seeing authority, the game critiques modern surveillance systems"**

Thanks to the time loop, you are able to escape this fate – and more importantly, keep any items you have picked up, along with any knowledge of what has happened before.

This makes for some fun puzzles to solve. Some are simple – can't get inside a locked door? Steal the key, reset the loop and let yourself in. Some are more complex, such as a woman who seems to have been poisoned, and is about to die, without anyone breaking the Golden Rule.

Thankfully, once you have solved a puzzle, you don't have to do it again the next loop around. The first person you meet at the start of every loop, Galerius, will happily, if slightly bewilderedly, follow your instructions to complete tasks on your behalf.

This frees you up to delve further into the plot, which had me hooked. Although set in ancient Rome, the game serves as a criticism of the panopticon concept invented by 18th-century philosopher Jeremy Bentham, who designed a prison in which everyone could be watched from one location, with the intention being they would be on their best behaviour. By exploring the consequences of an all-seeing authority, it also critiques modern surveillance systems.

One slight disappointment is that the time loop in the game is a bit of a cheat – certain events trigger not at particular times each day, but when you approach a specific location – but I can forgive that.

These days, most video games are created by vast armies of developers operating in teams around the globe, so I was impressed to learn that *The Forgotten City* was mainly the work of just three people. They have cleverly worked within those limitations – the city you explore is more of a large town, and only hosts a couple of dozen people, while the time loop allows for scenes to be reused without feeling cheap – to create something that really shines. ▮

Game
The Forgotten City
Modern Storyteller
Multiple consoles

Jacob also recommends...

Games
The Legend of Zelda: Majora's Mask
Nintendo
The definitive time-loop video game, in which hero Link has just three days to prevent the moon (which has an evil-looking face!) crashing into the planet.

The Sexy Brutale
Cavalier Game Studios
Another time-loop mystery, set in an Agatha Christie-like mansion whose inhabitants are all murdered over a 12-hour period.

AN IMPORTANT MESSAGE FROM PROFESSOR NICK LEMOINE MD PHD FMEDSCI, CHAIR OF THE MEDICAL RESEARCH FOUNDATION

Gifts in Wills could be the key to protecting the future of human health

Our experience of COVID-19 shows how suddenly a global health challenge can appear. As someone interested in science, you will understand that while nobody can predict what we will face next, we can be certain that the future will bring many more threats to human health.

As Chair of the Medical Research Foundation – the charitable arm of the Medical Research Council – I have seen the incredible impact that individuals who remember the Foundation in their Wills can have on the future of our health and wellbeing here in the UK. These gifts fund research and researchers which can have far-reaching implications for human health.

With a gift in your Will you can play a key role in providing the science that will protect the health of future generations.

Right now, the Foundation is funding research to tackle antimicrobial resistance, and investing in researchers like Dr Myrsini Kaforou – who will make the fight against antimicrobial resistance her life's work.

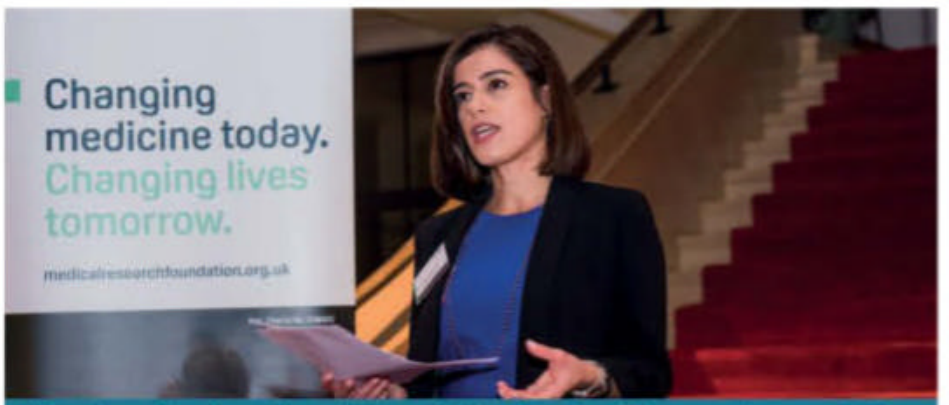
Without support at the crucial early stages, researchers like Dr Kaforou can be forced to abandon their passion and leave science altogether, with an immeasurable loss to future human health. Gifts in Wills provide the long term funding and security that allows the Foundation to invest in projects like Dr Kaforou's and lay the foundations for quality research in years to come.

"As scientists, our duty is to secure the future of research for the generations that follow."

Professor Fiona Watt, President of the Medical Research Foundation and Executive Chair of the Medical Research Council.

Your Will can fund the rational response to health challenges that medical science provides.

While we don't know what the future holds for human health in the UK, we do know that research, and the brilliant scientists driving that research forward, are the key to meeting those challenges for years to come.



"The funding I received through the Medical Research Foundation will be transformative for my research." Dr Myrsini Kaforou

But many of these scientists rely on the generosity and foresight of fellow members of the public – people like you, who understand the power of science and are willing to leave a gift to medical research in their Wills. At the Medical Research Foundation, over 90% of our voluntary income comes from individuals who choose to include a gift in their Will – they are crucial in the Foundation's ability to fund research that will enable the next generation of scientists to make real world discoveries in the future.

I firmly believe that a gift in your Will to the Medical Research Foundation is an excellent investment and will have a lasting impact on science and on the future of human health in the UK.

Please consider this very special gift today.

Professor Nick Lemoine MD PhD FMedSci
Chair of the Medical Research Foundation

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Quantum frontiers

Particles in many places at once, spooky influences over vast distances, cats in boxes that are dead and alive at the same time – the quantum world is notoriously weird.

Things get most baffling with the questions quantum theory raises about the nature of reality. These are frontiers of our understanding, beyond which lies a wilderness of interpretation where physics begins to blend into philosophy.

Over the next 10 pages, we explore this – rather fuzzy – cutting edge and look at the new insights and experiments both deepening and challenging our understanding. We kick off with the question that lies at the heart of all the rest...

WHAT MAKES QUANTUM THEORY SO STRANGE?

THE pleasure and pain of quantum theory began when an "or" became an"and". Are the fundamental components of material reality – the things that make up light, matter, heat and so on – particles or waves? The answer came back from quantum theory loud and clear: both. At the same time.

Max Planck started the rot back in 1900, when he assumed, purely to make the maths work, that the electromagnetic radiation emitted by a perfectly absorbing "black body" comes in the form of discrete packets of energy, or quanta. In 1905, Albert Einstein took that idea and ran with it. In his Nobel-prizewinning work on the photoelectric effect, he assumed that quanta were real, and all electromagnetic waves, light included, also act like discrete particle-like entities called photons. Work in the 1920s then reversed the logic. Discrete, point-like particles such as electrons also come with a wavelength, and sometimes act like waves.

Physicist Richard Feynman called this "wave-particle duality" the "only mystery" of quantum physics – the one from which all the others flow. You can't explain it in the sense of saying how it works, he wrote; you can only say how it appears to work.

How it appears to work is often illustrated by the classic double-slit experiment. You fire a stream of single photons (or electrons, or any object obeying quantum rules) at two narrow slits close together. Place a measuring device at either of the two slits and you will see blips of individual photons with distinct positions passing through. But place a screen behind the slits and, over time, you will see a pattern of light and dark stripes build up, as if each photon were a wave that passed through both slits, diffracted and interfered with itself like ripples encountering an obstacle on a pond.

Mathematically, these sorts of imponderables are described using entities known as wave functions. These depict quantum objects as existing simultaneously in superpositions ›

SKIZZOMAT

of all possible states, not just of position, but momentum, energy or any other property you might measure. Each possible state comes with a probability attached reflecting how often you would see it if you made the same measurement many times over – but you will never know for certain what you will get from any one measurement. Complicating things still further is the uncertainty principle, which says that there are pairs of quantum properties, such as position and momentum, that you can never measure together to an arbitrarily high accuracy.

Layers of weirdness

Then comes the phenomenon of entanglement. Einstein introduced this in a paper he co-authored in 1935 in the spirit of pointing out it couldn't be true. It says that if you prepare two quantum particles in the same state and separate them, measurements on the one influence the outcome of measurements on the other. This "spooky action at a distance", in Einstein's phrase, has been demonstrated in countless experiments, and is now the basis of emerging technologies such as quantum computing (see "Will we ever have a useful quantum computer?", page 42).

Further iterations of the double-slit experiment build new layers of weirdness on top of all this. For instance, you can show that the apparent guise a quantum object takes depends on how you choose to measure it – even if you only make that choice after it has passed through the slits.

For all these reasons, the only mystery has come to be expressed as the "measurement problem", the centre of a huge, unresolved debate about the nature of quantum reality and our role in it. Erwin Schrödinger formulated it best with his notorious thought experiment about a cat in a box that is apparently dead and alive until you decide which one it is (see "Who or what collapses the wave function?", right).

The measurement problem has sucked physicists down many curious wormholes of metaphysical interpretation. But as we will see, no one has yet come up with a particularly convincing explanation of it, or at least one all can agree on. Most probably, the answer to quantum theory's only mystery is something no one has thought of yet – not an "or" or an "and", but a "nor". **Richard Webb**

"There is a huge, unresolved debate about our role in making reality"

WHO OR WHAT COLLAPSES THE WAVE FUNCTION?

QUANTUM stuff, whether single atoms, electrons or photons of light, is notorious for seeming to be here, there and everywhere – and indeed everything – all at once (see "What makes quantum theory so strange?", page 35). It exists as clouds of possibilities, manifested in a beast you can't get around when contemplating quantum mysteries: the wave function.

On one level, the wave function is just a mathematical expression that lets you calculate the probability a particle will manifest in a particular location, say. The mystery is the way the maths says that, once you look at it, the wave function "collapses" to leave something definite we can all agree on. This creates the picture of the world that our classically trained eyes see. But how does the mathematics relate to the reality before the measurement – and what exactly, if anything, does the act of measurement change?

Erwin Schrödinger expressed the unease we might feel about apparently "making" reality when he mused about a cat inside a box that might or might not have been killed by a random quantum process inside it. Before you look, he asked, is the cat dead and alive at the same time?

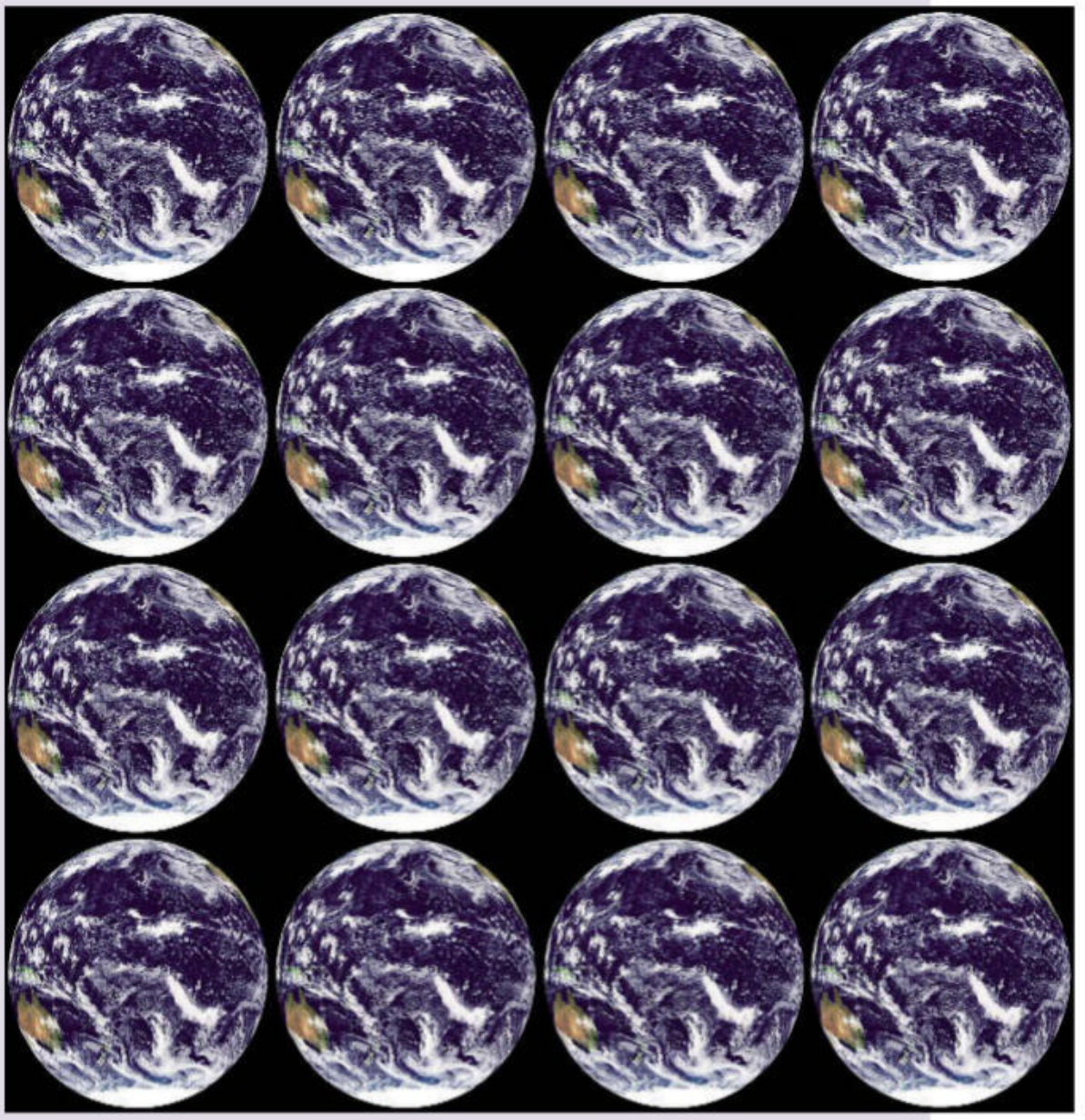
The orthodox take on quantum theory, known as the Copenhagen interpretation, says yes: the maths adds up, so just shut up and calculate. "From a practical point of view, it works perfectly," says Angelo Bassi, a theoretical physicist at the University of Trieste in Italy. "But from a fundamental point of view, why should the wave function collapse?"

Some physicists argue that it all makes complete sense if you think of the wave function as a way to predict what might happen. It changes with time, just like a weather forecast. "The universe is not made of wave functions, just as it is not made of weather forecasts," says Christopher Fuchs at the University of Massachusetts, a leading advocate for an interpretation of quantum theory known as quantum Bayesianism, or QBism.

For QBists like Fuchs, quantum theory is a tool for us to better navigate the world, not a description of the world as it exists independent of our presence. So of course the wave function collapses – and how could it be anything other than us doing the collapsing?

Or you can go to the opposite extreme and say that the wave function doesn't collapse at all. In the many worlds interpretation, every possible outcome of a measurement encoded in the wave function happens in different universes. No one collapses anything at the point of measurement – the world just splits, carrying us with it into one particular branch.

If you prefer an answer that gives us a hope of understanding physical reality, and doesn't invoke a multiverse that we can never hope to observe, there is yet another option: that wave functions collapse spontaneously, without the influence of observers. This "objective collapse" was first proposed in the 1970s, but has enjoyed a revival in recent years largely because it promises to submit to empirical testing. "The other interpretations simply aim at



NASA

The existence of many parallel worlds is one consequence of quantum theory – possibly

reinterpreting the wave function," says Bassi, who is a proponent.

In this picture, the chances of an atom's wave function collapsing on its own is so small that you might have to wait billions of years to see it. Group enough of them together, however, and it rises dramatically. The cumulative effect would be a kind of faint background "noise" of collapsing wave functions that a sensitive enough detector might pick up.

"Testing the large-scale limit of quantum mechanics", or TEQ, is a project that aims to do just that, and perhaps write the observer out of quantum theory for good. Designed specifically to look for collapse noise, the project involves levitating a bead of glass a few nanometres wide using electric fields, watching its motion closely. The latest version was delayed, but Hendrik Ulbricht at the University of Southampton, UK, who is leading the experiment, expects results within a year. "We are all very excited," he says.

Looking for noise isn't something physicists typically do. "Usually, we suppress the noise as much as possible, because the physics is in the signal," says Ulbricht. But there is an interesting precedent. When astronomers Robert Wilson and Arno Penzias first detected an all-pervasive background radio signal in 1964, they thought it might be coming from New York City, from other galaxies or even from nearby pigeons. Finally, they realised they had discovered the cosmic microwave background, relic radiation left over from the big bang. "There could be a similar story with these collapse models," says Ulbricht. Abigail Beall

For a quick-fire guide to quantum interpretations, see page 40

WHY AREN'T BIG THINGS QUANTUM?

IT IS often said that the very small is governed by quantum physics, and the large by classical physics. There seems to be one set of rules for fundamental particles and another for us. But everything, including us, is made of particles. So why can't we too be in superpositions or show wave-like interference when we pass through a doorway, as a photon or electron does when it passes through narrow slits? Ditto any large, inanimate object?

To cut to the chase: we don't know the answer. One of the most intriguing ideas now being tested, however, is that classical reality might emerge through a process analogous to evolution by natural selection.

That notion has its origins in the 1970s, when physicists first came to realise that a particle's quantum behaviours of superposition, entanglement and suchlike leak out into its environment, disappearing as a result of interactions with other particles – a process called decoherence. "The coupling to the macroscopic environment spoils the quantum coherences so fast that they are unobservable," says Jean-Michel Raimond at the Sorbonne University in Paris, France. Experiments have demonstrated that decoherence is a real, physical process, albeit one that happens in the blink of an eye.

What it can't tell us, however, is why various definite properties, such as position or velocity, emerge for us to observe. Why do these properties survive the transition from quantum to classical, while some other quantum features don't?

To Wojciech Zurek at the Los Alamos National Laboratory in New Mexico, it looked a lot like there was some sort of selective filtering going on. That filtering, he realised, is caused by decoherence itself: it turns out that it destroys some states, like superpositions, but leaves others unchanged.

Zurek also noticed that to measure those robust states, what we really do is look at the imprints they leave on the environment. For example, the position of an object is imprinted on the photons of light that bounce off it, so we can deduce the position by looking at the reflected light. Intriguingly, it turns out that those states selected by their robustness to decoherence are precisely the ones that are also good at making ›

many imprints – copies, you might say – of themselves in the environment.

This survival of states by virtue of their ability to make copies reminded Zurek of evolution by natural selection, so he called the idea quantum Darwinism. "Quantum Darwinism says that the preferred [observable] states are those that disseminate copies of themselves in the environment so as to more easily allow a set of independent observers to reach a consensus about the result of the measurement," says Raimond.

In recent years, Zurek and others have begun to put the idea to the test. They realised that if there is some form of natural selection going on at the quantum-classical transition, you should see a clear signature of it as a quantum object interacts with its environment. Specifically, quantum Darwinism predicts that most of the information we can gather about the object will appear within the first few copies it imprints on the surroundings, with subsequent copies adding very little that is new. In other words, the information transferred from the object to its environment "saturates" rapidly.

With that in mind, three teams have looked at quantum systems that could be described precisely enough for this signature to be clearly observable. All of them have found exactly the kind of information saturation predicted. As Raimond points out, however, these experiments involved simplified systems. "I do not think there is yet a general result that states that [this theory of] decoherence should work for all systems," he says.

And one question remains: why do we only see one of all the possible values a particular property could have when measured? A superposition of two positions for a particle can't survive the quantum Darwinian filter, but both classical positions can – so what happens to the one not observed? "Decoherence predicts that the measuring device is in a statistical mixture of all the possible states," says Raimond. "So how is it that just a single result emerges? This problem is not at all addressed by the decoherence mechanism." **Philip Ball**

WHERE DOES QUANTUM WEIRDNESS END?

AN APPLE never appears to be in many places at one. That statement hardly seems surprising – until you start burrowing into the depths of quantum weirdness, and realise there's no fundamental reason why that shouldn't be so.

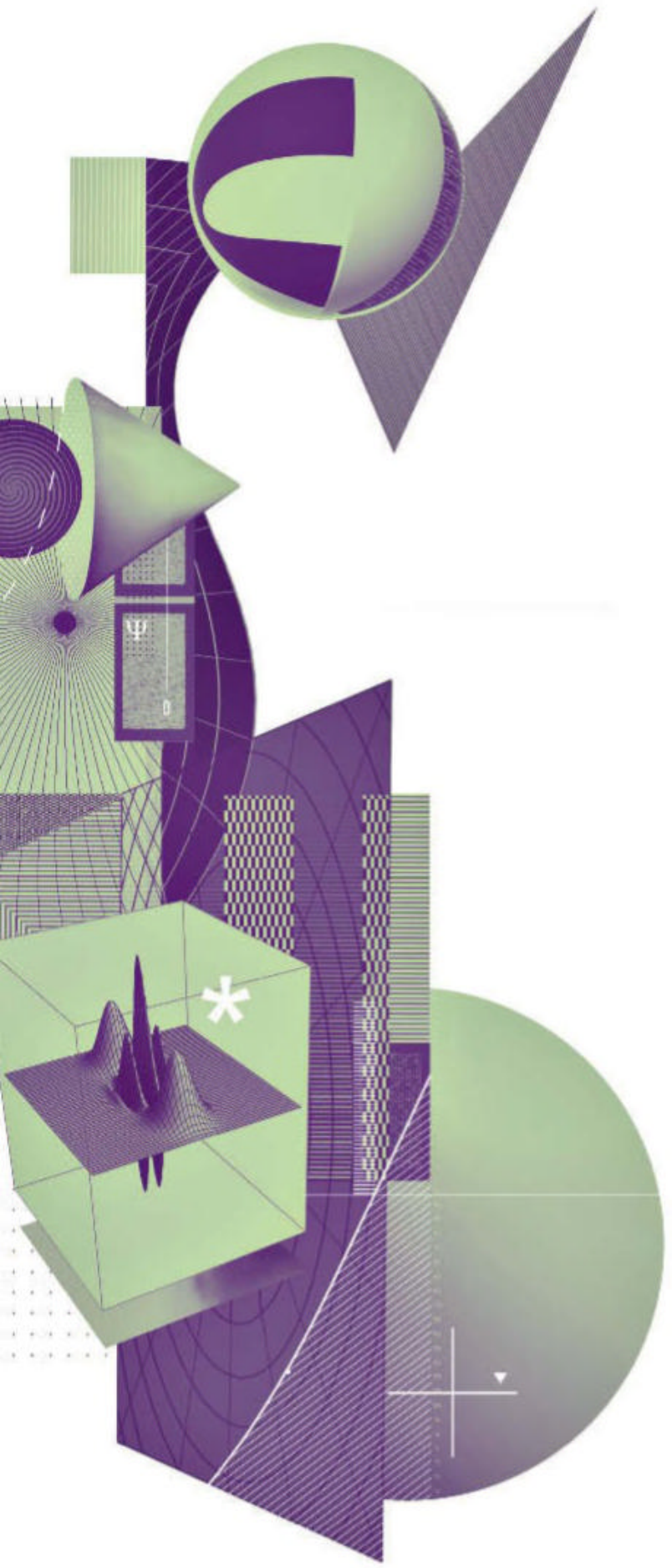
The theory of decoherence implies that the reason quantumness vanishes is because the more particles there are in an object, the harder it is to sustain quantum properties like a superposition of locations as it interacts with its environment (see "Why aren't big things quantum?", page 37). Yet in theory, if those interactions can be restricted by isolating the quantum system, there should be no limit on the size for which an object can keep displaying such quantum behaviour.

Can that really be true? With the right set-up, could we quantumly entangle a pair of Braeburns so that it becomes impossible to say which of them is ripe until we bite one? In recent years, Anton Zeilinger and Markus Arndt at the University of Vienna, Austria, and their colleagues, among others, have been doing their best to find out by attempting to get objects of ever-increasing size to remain quantum – and so perhaps find out where they stop being so.

In the 1990s, the cutting edge in their experiments was beams of large molecules a whole nanometre across, plenty big enough to see in an electron microscope. Arndt and his colleagues subsequently went larger, reporting interference for carbon-based molecules each containing 430 atoms. These were 6 nanometres across, the size of small proteins. They have now reached the scale of 2000-atom molecules, which, says Arndt, "still behave perfectly quantum-mechanically". Other researchers are preparing to put nanoparticles with millions of atoms into quantum superpositions.

At this point, the obstacles to Big Quantum seem to be merely technical. Oriol Romero-Isart at the University of Innsbruck in Austria has proposed that it should be possible, with sufficient control over decoherence, to put a biological particle like a virus or a bacterium into a superposition state – or even to do so with a microscopic creature like a tardigrade. "I don't think there is any roadblock to doing these experiments with microorganisms, provided they can withstand a high vacuum," he says.

As we place larger and larger things in quantum states, however, there is a chance we could discover something new about the process by which quantum becomes classical. Some researchers suspect there might be more to it than decoherence alone. Notably, Roger Penrose at the University of Oxford reckons



that gravity, which is a negligible force for atoms but ever more significant as objects get larger, could trigger a switch to classical behaviour, perhaps via an as-yet unobserved physical process that collapses the quantum wave function. If so, efforts to put even nanoparticles into superpositions should fail.

In any case, Romero-Isart says we shouldn't take it for granted that quantum mechanics will still hold at large scales. "There are extremely exciting questions about the interplay of quantum mechanics and gravity that could perhaps be addressed in the future," he says. **Philip Ball**

IS THE QUANTUM WORLD REALLY RANDOM?

THE quantum realm of atoms and particles has randomness at its core. At least that's what the maths of probabilistic quantum wave functions implies (see "What makes quantum theory so strange?", page 35). Our knowledge of the quantum world is rather like a die throw – in the air it takes many values at once, before landing on one. Until then, the result is unknowable. Or is it?

Quantum randomness is "just odd", says Sabine Hossenfelder, a theorist at the Frankfurt Institute for Advanced Studies in Germany, contradicting our intuitive understanding of cause and effect. Unlike most of her peers, she's not convinced the quantum world is an incorrigible gambler. "I don't think one should give up trying to find an explanation," she says.

She favours an idea known as superdeterminism, that what we ultimately see on measuring a quantum object is somehow predetermined by factors we can't observe. The idea has been around for a while, but has remained pretty unloved, partly because it seems to undermine the notion of scientific experiment: if undetectable initial conditions somehow predetermine outcomes so that experimenters cannot use their free will, how can we trust science? Many also argue that superdeterminism is "fine-tuned" to an absurd extent: to make any sense of the data we collect in the physical world, we need to know about the initial conditions from which the world arose.

Hossenfelder recently published a paper stating the first problem need not be an issue, because it wouldn't apply to humans or macroscopic apparatuses – these still follow the predictable rules of classical physics. Regarding the second argument, she reckons that you can actually calculate how a certain quantum system behaves deterministically without taking into account everything that has ever happened.

She hasn't convinced many of her colleagues, but that hasn't stopped her drawing up plans to put the basic idea to the test. If you measure the position, say, of a quantum object in short enough time intervals, with minimal noise, enough times, you might see that particles starting out in a similar state end up in a similar state, contrary to what quantum theory predicts. The randomness might appear, says Hossenfelder, because this underlying determinism gets lost in the noise and long measurement intervals.

Or it might be because the present and the future can influence the past. This is admittedly "a very strange idea", says Matthew Pusey at the University of York, UK. But he has shown that backwards causation is, at the smallest scales at least, a necessary consequence of the fact that the equations of quantum mechanics work just as well both forward and backwards in time.

And it sounds "less crazy", says Pusey, when you consider that time in general relativity is just another dimension alongside the three spatial ones. This gives rise to a four-dimensional "block universe" – mapping all locations at all times – with past, present and future being equally real, and the "now" losing its special status. Advocates for retrocausality, then, just like superdeterminists, believe that randomness is an illusion caused by our partial, naive view of the world – in this case, our misconceived idea of how time works.

Think back to the die throw, they might say. Dice can be loaded, and throws masterfully controlled. Ultimately, even specks of dust or fluctuations in air temperature can influence the result. We only think of it as random because it is so hard to work out these details. Is the same true for the quantum world? You wouldn't want to bet on it either way. Miriam Frankel

DOES LIFE USE QUANTUM EFFECTS?

ONE response to the question "does life use quantum effects?" comes in the form of another question: "why wouldn't it?". All life has evolved to make use of the world we happen to find ourselves in, so why should the magic of quantum effects remain off limits? After all, phenomena such as the telepathic connections implied by entanglement or "quantum tunnelling", in which quantum objects pass effortlessly through energy barriers that on the face of it they shouldn't be able to surmount, look like useful survival tools.

The counterargument is that, as any biologist will tell you, living organisms are wet, warm and very, very noisy: their molecules jiggle and their fluids flow, creating an environment where the phenomenon of decoherence would overpower any quantum effects (see "Why aren't big things quantum?", page 37). In recent years, though, we have been able to map out the delicate connections between atoms and molecules inside cells – and found some tantalising hints that life might indeed exploit quantum weirdness.

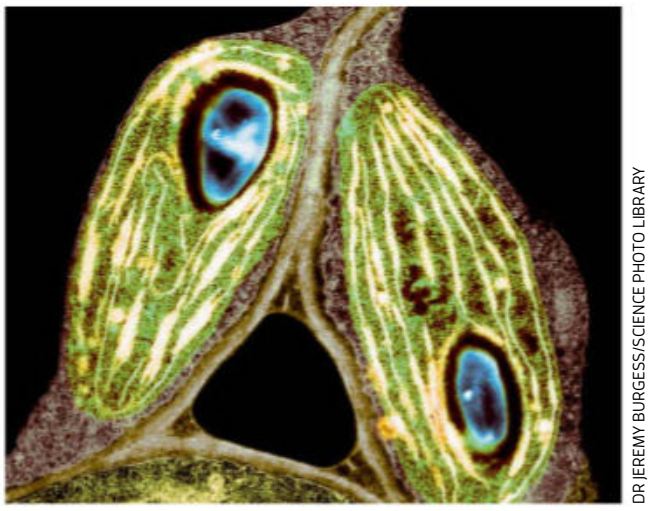
Take one of the most important innovations in the history of life: photosynthesis, the process by which plants and some bacteria convert sunlight to chemical energy. The reaction starts with photons of light exciting electrons in chlorophyll molecules to generate quasiparticles – packets of energy that move around as if they are particles – called excitons. These are shuttled around until they find "reaction centres" where their energy can be captured and stored. But excitons lose energy as they go, so researchers wondered if they might be able to use quantum effects to simultaneously try out all routes and take only the most efficient one.

Subtle effects

Sure enough, this phenomenon of quantum coherence has been observed in chlorophyll molecules from green sulphur bacteria and marine algae at physiological temperatures. But just because a quantum effect is detected in a living thing doesn't mean it offers an evolutionary advantage. Indeed, the importance of coherence in photosynthesis is "more subtle than originally thought", says Gregory Scholes at Princeton University, who led some of the initial experiments. What we need, he says, is a less ambiguous example.

That might come from migratory bird species, whose extraordinary navigational prowess is key to their survival. One explanation for how they might do it points to quantum-entangled particles in proteins called cryptochromes, found in some species' eyes. The idea is that during flight, tiny changes in Earth's magnetic field are registered by these entangled states and relayed to a bird's brain.

There is some evidence for this: cryptochrome sensitivity is known to increase when birds are migrating, and these proteins are conspicuously absent in chickens, which barely fly and so wouldn't need this ability. In June, Jingjing Xu at the University of Oldenburg in Germany and her colleagues demonstrated that cryptochromes in the eyes of European robins are magnetically sensitive. That is highly suggestive, but the experiments were done on proteins suspended in liquid in test tubes, and it is possible they respond differently inside the eyes of the birds. For the moment, then, we are still searching for a clear-cut example of quantum mechanics offering plants or animals an evolutionary upper hand. **Thomas Lewton**



DR JEREMY BURGESS/SCIENCE PHOTO LIBRARY

Chloroplasts in plant cells are centres of photosynthesis – and quantum weirdness, too?

YOUR QUICK-FIRE GUIDE TO WHAT QUANTUM THEORY MEANS

The peerlessly accurate quantum description of the subatomic world has inspired many different interpretations with their own advantages and disadvantages. Which one do you prefer?

	> What is the nature of quantum reality?	> What collapses the wave function?	> What problems does it solve?
Copenhagen interpretation	Pass. Quantum theory is merely a tool for making predictions; the quantum world is in essence unknowable	Pass. We can only predict what happens when we make a measurement, nothing more	It sweeps the big questions about meaning under the rug, not least what is a measurement?
Many worlds interpretation	The wave function is objectively real; each measurement splits the universe into many copies of itself	It doesn't collapse; all the possibilities it encodes manifest in separate universes	If the wave function doesn't collapse, the mystery of what does the collapsing vanishes
Quantum Bayesianism	Pass. Quantum theory is a way to represent our subjective knowledge of reality	You. Collapse is just the process by which each observation updates what we know	It gives a clear answer to the knotty question of what a quantum measurement entails
Objective collapse theory	Objectively real. The quantum state describes the world as it exists apart from and regardless of us	Collapse happens spontaneously, without observers, perhaps as a result of gravity	It writes the observer out of quantum theory, so explains how reality was made before consciousness
De Broglie-Bohm theory, aka the pilot wave theory	Objectively real and deterministic: the outcomes of measurements aren't random	It doesn't collapse. "Pilot waves" guide the evolution of quantum states on a hitherto unseen layer of reality	It rids quantum theory of its observer problem and its randomness; it can explain quantum entanglement

IS CONSCIOUSNESS QUANTUM?

IF IT is a controversial idea that warm, wet life might exploit quantum magic (see "Does life use quantum effects?", left), that's nothing compared with certain researchers' convictions that quantum phenomena might help explain human consciousness.

Orchestrated objective reduction theory (Orch OR), originally proposed by physicist Roger Penrose and anaesthesiologist Stuart Hameroff in the 1990s, seeks to bridge the gulf between physical matter and felt experience. The idea is that consciousness arises when gravitational instabilities in the fundamental structure of space-time collapse quantum wave functions in tiny proteins called microtubules, which are found inside neurons. It is heady stuff, but if pulling together quantum mechanics, gravity and consciousness in one fell swoop sounds too good to be true, it might be. Orch OR's critics argue that any quantum coherence inside microtubules would fall apart in the warm and noisy environs of grey matter long before it could have any effect on the workings of neurons.

Yet in one tantalising experiment last year, as-yet unpublished, Jack Tuszynski at the University of Alberta in Canada and Aristide Dogariu at the University of Central Florida found that light shone on microtubules was very slowly re-emitted over several minutes – a hallmark of quantum goings-on. "This is crazy," says Tuszynski, who set about building a theoretical microtubule model to describe what he was seeing.

Gregory Scholes, a biochemist at Princeton University, is studying microtubules for signs of similar quantum effects. Initial experiments point to long-lived, long-range collective behaviour among molecules in the structures. Both groups plan to test whether anaesthetics, which switch consciousness on and off, have any impact on microtubules. "There is amazing structure and synchrony in biological systems," says Scholes. "We just need to do experiments that are quite different from anything we've done before."

Anaesthesiologist George Mashour at the University of Michigan is in favour of such ventures. But he cautions that "you can't make any jump to consciousness". There are many more steps before these sorts of experiments begin to replicate the conditions inside a brain, he points out. Ultimately, says Mashour, if anaesthetics do switch off long-lived quantum states in microtubules, this would amount to a "proof of principle that would at least take Orch OR out of the realm of total fringe". There may be life in the idea of the quantum brain yet. Thomas Lewton

> What problems does it create?	> Unofficial slogan
It leaves various mysteries outstanding, refusing to engage with what quantum theory means	"Shut up and calculate"
The idea of infinite parallel universes we can never access, making it impossible to put to the test	"Everything happens across infinite worlds"
The idea that reality doesn't exist without conscious observers	"Quantum fuzziness is all in your mind"
It can't say precisely what physical process collapses the wave function	"Reality is real, no observers necessary"
It invokes "hidden variables" and says reality is non-local such that everything in the universe is connected	"Everything is interconnected, if you look closely"

IS GRAVITY A QUANTUM FORCE?

WHEN the two most important figures in your life don't get along, there will always be trouble. Just ask physicists: the two most totemic theories in their field are fundamentally incompatible, and generations of researchers have failed to reconcile them.

Quantum theory describes matter at its smallest scales, tracing three of the four basic forces of nature – the electromagnetic force and the strong and weak nuclear forces – to the subatomic particles that carry them. Einstein's general relativity, meanwhile, makes sense of the cosmos at its grandest scales, revealing the force of gravity as the product of matter warping space-time.

Perhaps the biggest hint that they should be unified is that when you try to apply general relativity to the extreme conditions at the centre of a black hole, say, its equations go haywire. "That is the theory itself saying that we are stretching it beyond its regime of validity," says Astrid Eichhorn at the University of Southern Denmark.

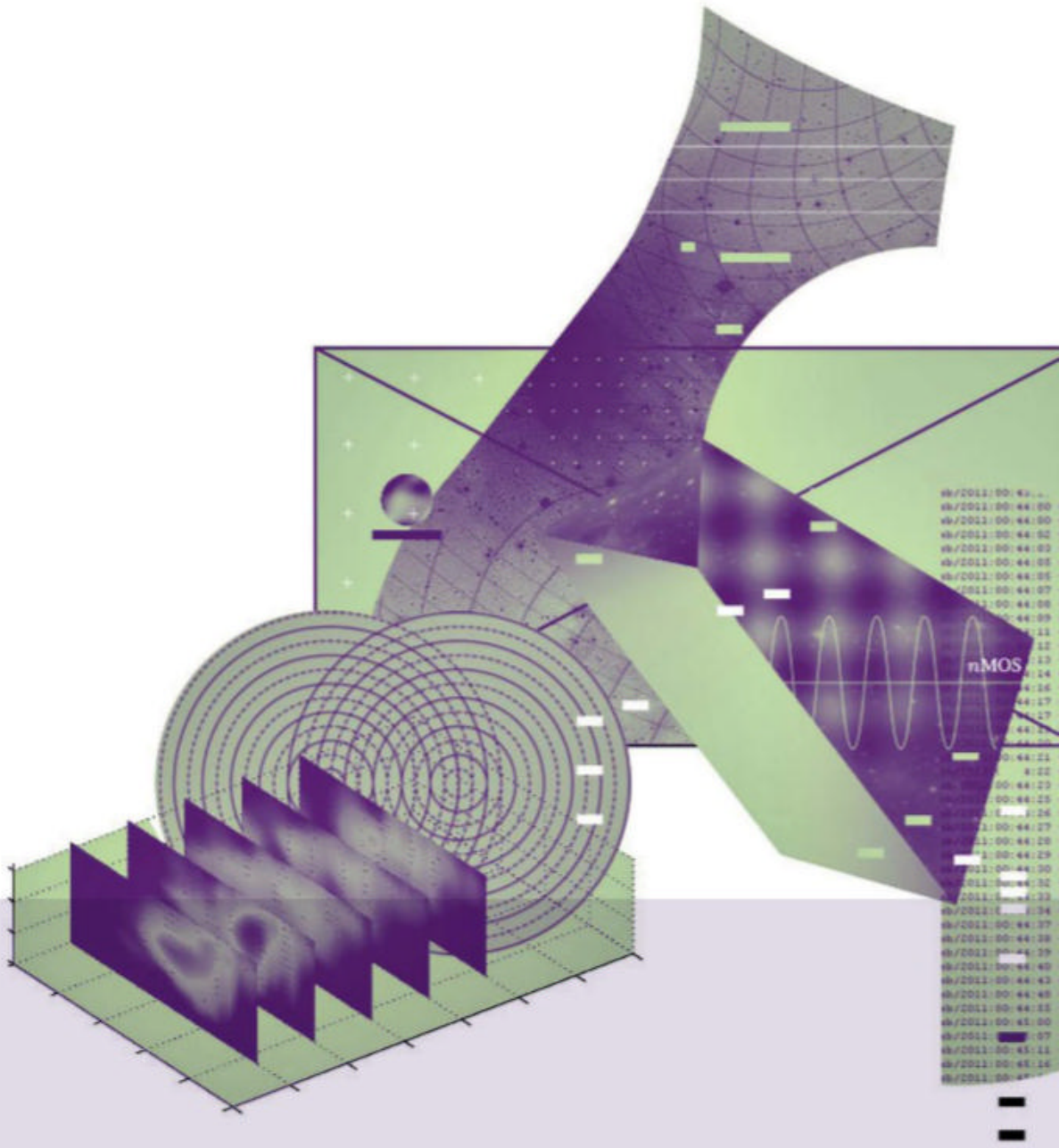
It makes sense to think that a more fundamental theory of gravity should emerge from quantum mechanics, because quantum mechanics best describes the world at the tiny scales and high energies where general relativity breaks down. But what that quantum theory of gravity looks like has proved a uniquely devilish question to answer.

One knotty problem arises from the way we calculate observable properties of subatomic particles with quantum theory. When you try to calculate an electron's mass, say, the number of terms in the equations explode to infinities. This "non-renormalisability" has long been an insurmountable barrier, but just recently an idea called scale symmetry has suggested that, once you reach sufficiently high energies, things become more tractable again. The effect really kicks in at energies too high to probe with experiments, but it leaves an imprint at scales we can observe, meaning we can look at how a given idea works at low energies to see what happens at the highest energies, where gravity would be a quantum force.

Mikhail Shaposhnikov at the Swiss Federal Institute of Technology in Lausanne and Christof Wetterich at Heidelberg University in Germany have already used this approach to predict the masses of particles, including the Higgs boson and the top quark. Eichhorn and her colleagues are also using it to predict ›

other particle properties, including interaction strength, and they are finding promising matches with existing measurements.

But what if they are barking up the wrong tree? While the overwhelming majority of physicists assume gravity is a quantum force, there is actually zero evidence to back that up. Sougato Bose at University College London has an idea of how to change that. He has proposed an experiment to probe if the quantum-mechanical spins within two microscopic diamonds can become quantum entangled with one another through gravitational interaction, something that would happen only if gravity is a quantum force. "These will be groundbreaking experiments," says Bose – but it's too early to tell which way they will fall. **Anna Demming**



WILL WE EVER HAVE A USEFUL QUANTUM COMPUTER?

IT IS 40 years since physicist Richard Feynman pointed out that quantum systems should be able to carry out an entirely new form of computation that outperforms even the most powerful conventional computers. "Feynman argued that quantum computing should offer an exponential speed-up for many classical computations," says Cristian Calude at the University of Auckland in New Zealand. And with a slew of breakthroughs, quantum computers look like they might now be hitting the big time. Perhaps.

Because they have properties that just don't exist in the classical world, quantum entities such as atoms, photons, electrons and the like have access to a different set of routines for information processing if used to make quantum bits, or qubits – a potentially much more powerful set.

Part of that is down to quantum superposition, which means a qubit can be used to represent a complex combination of the 0 and 1 binary states used in normal computing. That doesn't mean it is 0 and 1 at the same time. A better way to put it is that might turn out to be 0 or 1.

Quantum algorithms use a process called "interference" to skew these undefined properties and bias the interactions of multiple qubits in a way that increases the likelihood they will arrive at a final state that contains a solution to the problem they are trying to solve.

That's where entanglement comes into the mix. The spooky connections between qubits it generates somehow allow for a pattern of interference where the paths leading to each wrong answer destroy one another and cancel out, while the paths leading to the right answer are reinforced.

The power has long been proven. In 2019, Google's quantum computing team announced it had achieved "quantum supremacy" – when a quantum processor can do things that a classical computer can't. Its 54-qubit Sycamore processor took just 3 minutes and 20 seconds to solve a problem that would take 10,000 years to crack on the world's most powerful classical computer, the researchers said.

Which isn't to say that Google's quantum computer, or any that has reached quantum supremacy since, is close to doing anything useful. The problem Google cracked was highly esoteric. In May, Isaac Chuang at Massachusetts Institute of Technology, one of the world's leading authorities on quantum computing, spelled out the current state of the technology in stark terms: "Quantum computing today is actually, from a practical standpoint, quite useless, other than for generating publicity."

Trial and error

That brings us to the long journey ahead to a practical machine. The inconvenient truth is that, in quantum computing, size matters. Data-holding qubits must maintain their delicate quantum states for a long time, and not succumb to environmental influences such as heat and vibration that can cause them to decohere, creating errors in the computation.

This is a problem that can only be overcome by scaling up. Current estimates suggest that in large, programmable quantum computers, most qubits – perhaps as many as 5 in 6 – will be doing error correction, not computation. That means we are going to need as many as a million qubits before we can do anything truly useful. Keeping so many qubits sufficiently cold or maintaining all their quantum states long enough to do a computation is a monumental engineering challenge.

It could take decades to get there, but the big players are at least making steps in the right direction. IBM is aiming to build a 1121-qubit machine by 2023, and the company has envisaged a colossal helium-cooled refrigerator to contain it. Others, including Winfried Hensinger at the University of Sussex, UK, want to avoid the complications involved with cooling: they are scaling up operations with

trapped ion qubits that shuttle around a large circuit to perform computations. Still others are performing computations by sending photon qubits around a silicon nitride chip that can be manufactured at scale using processes already proven in the semiconductor industry.

So do we have a "yes"? Not so fast. Gil Kalai, a mathematician at Israel's Hebrew University of Jerusalem, has argued that the base level of noise in a quantum computer will always be too high, no matter how many qubits are available. "My analysis asserts that quality error correction won't be possible," he says.

Sabrina Maniscalco at the University of Helsinki in Finland is similarly sceptical. "Finding a remedy to the effect of noise induced by the environment is not just, in my opinion, a technological issue, but more of a conceptual and foundational one," she says. "I would say that I am hopeful, rather than confident." Michael Brooks

IS QUANTUM THEORY THE FINAL ANSWER?

QUANTUM theory earned its exalted status by providing peerlessly accurate predictions of the behaviour of atoms and molecules, revealing the world of the very small in all its glorious strangeness. But it doesn't actually make sense of the universe.

For starters, we still don't understand key tenets of quantum weirdness. Take entanglement: the existence of a telepathic link between spatially separated particles runs counter to all our ideas about how the universe works. Nor do we have a grip on what distils the objective, classical reality we see from the myriad possibilities for what a quantum object might be when it is measured (see "Who or what collapses the wave function?", page 36). That's a big omission.

It gets worse. Zoom out a tiny bit and you realise that you can't get the rules of chemistry – how atoms and molecules combine, and the properties of those combinations – from quantum theory. "This has prompted some philosophers to argue against the fundamentality of quantum mechanics," says Vanessa Seifert at the University of Bristol, UK. Zoom out a lot and it becomes more troubling still, because of the incompatibility of quantum mechanics and general relativity (see "Is gravity a quantum force?", page 41).

All in all, it is clear we need to do better. The hunch is that just as classical physics emerges from quantum physics, there might be a deeper theory from which quantum physics arises. But what would it look like? Ciarán Lee and John Selby, who work at the Perimeter Institute in Ontario, Canada, have suggested that we will have to lose at least one, and possibly two, cherished notions in physics: causality and the idea that information is always conserved. A deeper theory without these can, in the right circumstances, be translated into the quantum theory we know. Alternatively, we could choose to ditch Einstein's conception of space-time or the notion of human free will. "There are multiple ways quantum theory could be modified and only experiment can decide what is correct," says Magdalena Zych at the University of Queensland in Australia.

Some researchers hoped, for instance, to see a revealing deviation from the predictions of quantum theory when a third slit was added to the classic double-slit experiment that reveals the wave-particle duality of quantum objects (see "What makes quantum theory so strange?", page 35). They hoped in vain.

Or perhaps we need a new version of the Schrödinger's cat thought experiment to stimulate further progress? Renato Renner and Daniela Frauchinger at the Swiss Federal Institute of Technology in Zurich recently provided just such a thing. In it, a couple of extra observers watch the original experiment observing a potentially dead-and-alive cat. That creates a complicated quantum scenario where no one can agree on the state of the cat, potentially exposing a hidden flaw in quantum theory – although no one can agree what.

Chiara Marletto at the University of Oxford hopes that quantum theory's problems might force us to approach physics differently altogether. The traditional way of formulating laws of physics says that laws of motion or change, together with some initial conditions, are all that's available to make sense of the universe. "We are reaching a bottleneck," she says. "This approach cannot grasp everything when it comes to the physics of information, the physics of life and thermodynamics," she says. Her new angle of attack, called constructor theory, seeks to reformulate laws of physics in terms of "counterfactual" laws about what can and can't happen.

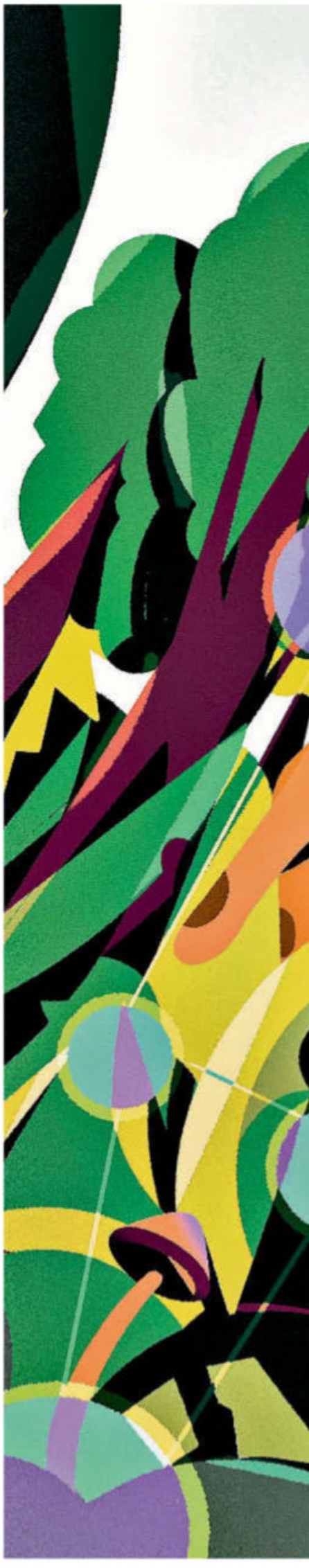
"There is no guarantee any theory can completely describe the universe"

For his part, Carlo Rovelli at the University of Aix-Marseille in France argues that no deeper theory will free us from the weirdness of quantum theory. "We might find something that goes behind quantum theory; nothing is definitive and final," he says. "But I expect that if we do, it will be even more strange to us than quantum theory."

The other possibility, of course, is that such a deeper theory doesn't exist. "There is simply no guarantee that any mathematical theory can faithfully and completely represent the universe," says Zych. **Michael Brooks** ▮

At one with nature?

Richard Webb finds out whether technology can connect us more deeply to the natural world



FABRIZIO LENCI

I AM not an appy person. Technology generally makes me glum. I was the last person I know to get a smartphone. I shop in real shops, and like to read on thinly sliced tree. I was on social media for all of six months before I found the angst, bile and FOMO outweighed the LOLZ.

Call me a stick-in-the-mud. In fact do, because instead of head stuck in screen, I would far rather be out getting my legs dirty somewhere glorious and green. And pardon me if you disagree, but I'm right and you're wrong. We can leave the debate about whether screen time is of itself good, bad or indifferent for our psyches to another time. We do know that time spent outdoors in natural spaces is phenomenally beneficial, not just for our physical health, but for our mental well-being, too – and that our modern, indoor, sedentary, tech-led lives are increasingly lacking it.

Tech itself seems to be trying to ride to the rescue. Countless smartphone apps now aim to increase our appreciation of the great outdoors, from route planners and fitness apps to plant identifiers and birdsong recorders, via any manner of mindfulness widgets.

To my mind, that's like fighting fire with fire. But hey, we like evidence around here. So I fired up my phone, loaded it with apps and headed for the great green yonder to find out whether tech could increase my connection with nature – and through that, perhaps understand a little more about why it's so darn good for us.

1 May 5.20am @51.270:0.532

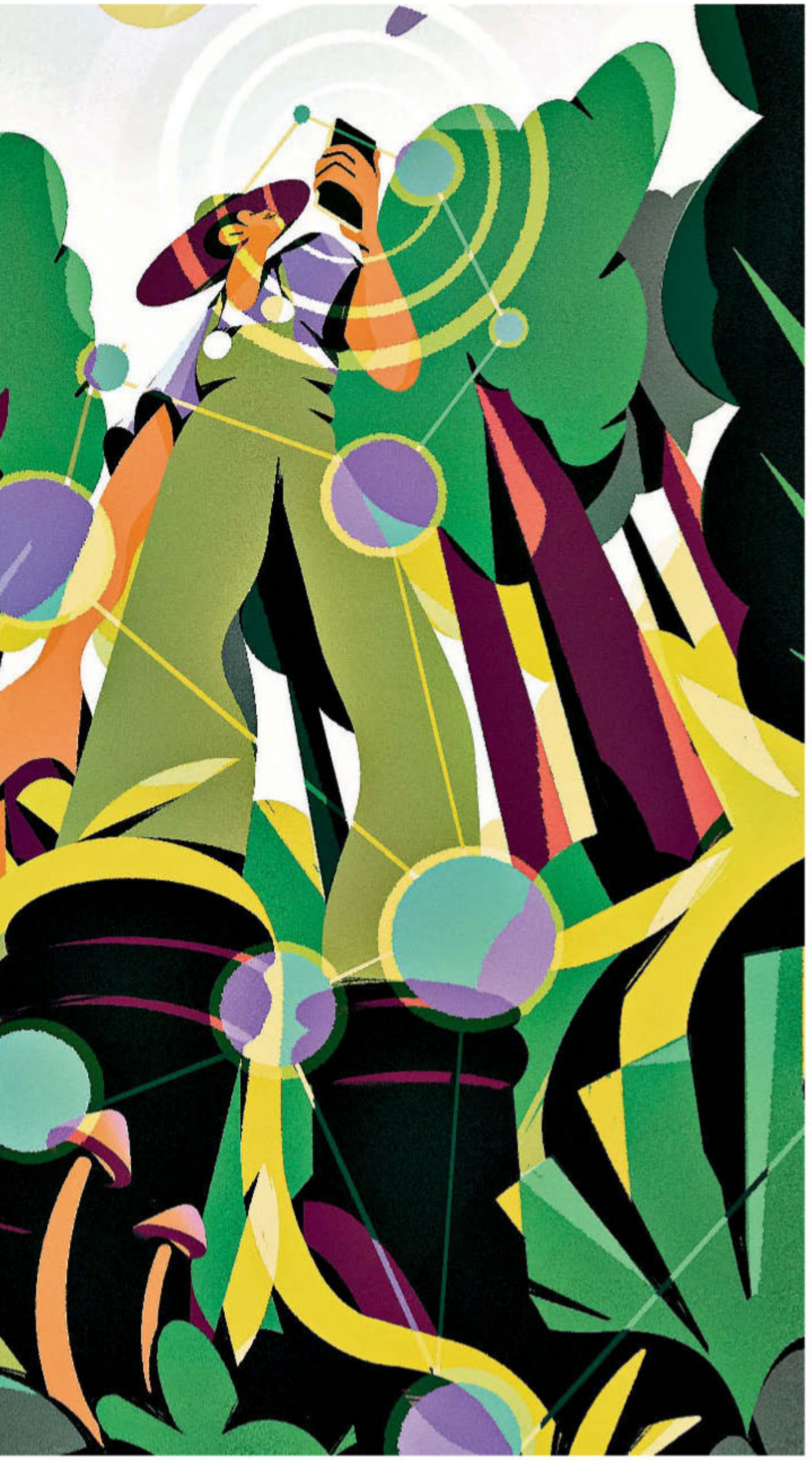
A waning supermoon is visible as I peer through the curtains, woken by bright sunshine and an infernal racket of sparrows directly outside. I open a birdsong app and wave my phone bleary eyed out of the window in the direction of the commotion.

Yep, definitely sparrows. I remember it's Saturday and go back to bed. Sleep is important for mental health, too.

"Outdoorsy technophobe – I can certainly relate to that," says Mathew White, when I explain my project to him. An environmental psychologist at the University of Vienna in Austria, he seeks to tease out the connections between nature exposure and mental well-being in his research.

"The effects are relatively small compared to other things that are important for our mental health: our relationships, our employment status, yadda yadda yadda," he says. "But there's a consistent positive relationship that we know of through every conceivable type of research." The benefits come in the form of boosted happiness, social drive, creativity and cognitive function, as well as reduced susceptibility to negative states of mind from anxiety to depression.

It is a feeling many of us have perhaps experienced, without quite knowing where it comes from. "I got into this area when I was 17," says environmental psychologist Melissa



Marselle at the University of Surrey, UK. "I found that the stress of being a teenager, all of that 'who likes me, who doesn't like me' and whatnot – just being in the woods made all those problems seem really small."

But if nature is free medicine, few of us are taking it as advised. Research by White and his colleagues suggests 2 to 3 hours of "nature time" per week provides an optimal mental boost. In England, research from government agency Natural England indicates that barely 40 per cent of people spend time outdoors away from their home more than once a week. For a quarter of children, it is less than once a month. By far the most often cited reason is lack of time.

1 May 6.45 am @51.267:0.516

Mist is rising from the river as I pedal along the bank in bright early sunshine, cold penetrating through my gloves. There's an overwhelming feeling of peace. Seeking a more expansive view, I consult the map on my phone and turn left across the bridge and up a steep hill onto higher ground.

I was a bit disingenuous about my distaste for tech. Two years ago, a present bought "for a friend" just happened to land me with Great Britain's entire Ordnance Survey maps on my phone, too. Then, as a way of staying connected during the long months of remote working, colleagues started a club on Strava, an app that allows you to track and share runs, walks and bike rides. That unleashed a beast I didn't know lurked inside me. The ability to track, compare, share – and maybe compete – became an additional source of motivation to get out when the spirit was otherwise unwilling and I "lacked time".

Getting people to do things they know are good for them is a huge issue generally in psychology, says Marselle. Nature also doesn't generally come to you. "For nature and biodiversity to have an impact on your mental health, you need to have exposure to it," she says. "These apps you're using are a really interesting behavioural intervention."

We get more out of nature when we seek it out. In April, White and his colleagues published a study of more than 16,000 people across 14 European countries plus California, Canada, Hong Kong and Queensland, Australia. It showed that recreational visits to nature are better correlated with good mental health than just living in rural areas or "blue" spaces around sea or inland water. In Natural England's research, meanwhile, people ›

“To me, it seems there is an intrinsic tension between nature connectedness and using tech”

report a mental boost with any trip to a local park or recreation ground, but the effects are greater with visits to (presumably more distant) hills and mountains, blue spaces or even farmland.

Where I live in the south of England, such environments are rarely that far away, just a short hop on a bicycle, bus or train even for a non-driver like me. If you can overcome the lack of motivation, though, orientation can become the next stumbling block. Google or Apple maps don’t quite cut it when it comes to finding the often heavily disguised Great British Footpath.

A wealth of trail-finding apps have sprung up to fill the gap, allowing you to follow routes mapped out by others aided by GPS location on your phone. I’m sniffy. Getting lost is half the charm, after all.

Recommended apps

Motivation

Plenty of apps exist for tracking and sharing physical activity outdoors. Strava is one of the biggest, and provides maps of routes taken, plus analysis of speed and altitude, based on your phone’s location data. The basic version also allows you to share photos and comment on friends’ runs – with all the plusses and minuses of social media interaction.

Trailfinding

I use a paid-for app, Memory-Map, for access to Ordnance Survey maps of Great Britain, and you will have difficulty finding those for free. But there are plenty of free alternatives that provide mapping and access to pre-packaged trail descriptions across the world, with AllTrails and Komoot among the most popular. For those venturing solo into wilder territory, Cairn allows you to crowdsource phone reception hotspots and send updates to named contacts should you get into difficulties.

Species ID

Seek is a sleek general species identification app produced by *National Geographic* and the California Academy of Sciences. It allows you to point your phone’s camera at a plant, bird, insect or whatever else, connecting you with its databanks to identify the species in real time (data connection permitting). It sets you challenges, rewards you with badges and allows you to climb up levels according to how many species you record. Like many others, it has an (optional) social aspect to it, allowing you to see and like other people’s photographs.

Birdsong

A greater appreciation of nature’s acoustic backdrop has been a big change for me in testing out these apps. My favoured app, BirdNET, comes with the academic imprimatur of the ornithology lab at Cornell University in New York. It is basic and currently only covers common European and North American species, but allows you to record birdsong and either analyse it then and there, or save it for identification when you have connectivity.

Basic versions of these apps are all available for free on Google Play or Apple’s App Store, unless otherwise noted.

7 May 7.50 am @51.211:-4.102

I’m lost. Against my better judgement, I’m using a trail app to guide me on a run along the north Devon coast that probably should have been against my better judgement, too. This is supposed to be a holiday.

This gorse thicket came as a surprise. According to my plant identification app, there have been various campions – sea, red and bladder – all the way up the hill. And goldfinches, says the birdsong app. I can’t help thinking that the multiple distractions is why my phone now seems to know where I am, but I don’t.

Using “technology” to guide visits to natural spaces is nothing new. “In the old days, of course, you’d use books, maps and the odd birdsong record,” says White. “In theory, apps are not so different” – more immediate and perhaps more accurate, he says.

It’s a polite way of calling me a digital snob, but I’m increasingly thinking a lack of immediacy might be half the point.

Equally, I have been assuming so far that being in nature equates to reaping its benefits. That’s a presumption a lot of early research was prone to, as well, says Miles Richardson at the University of Derby, UK. “It’s easy to do science by measuring visits and time,” he says, “but your relationship with nature matters more than time and visits.”

Studies on people in urban green spaces of varying biodiversity, for example, have shown that those who really take in the setting reported better well-being and a greater restorative effect than those who were reading, talking or otherwise socialising. In 2019, Richardson and his colleagues prompted participants in Sheffield, UK – via a smartphone app, as it goes – to record the nature they saw around them and their reactions to it in words and photographs. A follow-up study showed that participants, including those with mental health difficulties, reported sustained benefits to their well-being even one month after the trial. “Noticing nature is the route to nature connectedness and mental health,” says Richardson.

Marselle describes it as “absorption”: the more connected you are to the natural experience with all five senses, the greater the benefit you seem to get. One explanation is simply that humans are attuned to natural environments, as this is where we have spent most of our evolutionary history. “Our brains have less work to do to keep us safe,” she says. “Modern environments are stressful for us. They’re loud, they’re noisy, they’re fast-paced,”

says White. "The philosophy is that nature brings us back down to a homoeostatic state for which we're most adapted."

Attention restoration theory, meanwhile, focuses on the way modern urban life requires us to be constantly redirecting our attention, whether at the screen in front of us or on traffic, people and other obstacles on a busy street. By holding our attention with less effort – but still providing a breadth and depth of experience to engage our senses – calmer, greener spaces allow us to restore drained cognitive reserves.

Lots of apps aim to tap into these ideas, explicitly or otherwise. Richardson's app, for example, has morphed into a Nature Notes function on the iPhone version of Go Jauntly, a trail app. Many general mindfulness apps include soothing nature images and soundtracks, feeding off a finding that "indirect" experience of nature can still provide some mental-health benefits.

I did try. I loaded one mindfulness app onto my phone, but deleted it within 24 hours as its constant push notifications suggesting I check my stress levels were stressing me out. Just not my Thermos of tea, you might say.

ELVA ETIENNE/GETTY IMAGES

Identification apps can enrich our experience of nature

12 May 7.33 am @51.295:0.586

I'm running on the hills near home when I see a sea of cowslips on an escarpment meadow. At least I think they are cowslips. Frustratingly, my plant app can't be any more precise than Order: Ericales ("Heathers, Balsams, Primroses, And Allies").

I'm not sure what a primrose ally is when it's at home. I lean too far over to get a better angle with my phone's camera, and my foot slips on the steeply banked grass, planting me firmly on my back several metres downhill. No harm done, and staring rather damply up at a bright blue sky from a downland meadow, my annoyance gives way to a smile. That's nature connectedness for you.

To me, it seems there's an intrinsic tension between nature connectedness and use of tech: if it's all about mindfulness in the moment, fiddling about with your phone is the last thing you should be doing. "You can be in nature, but not necessarily connected, because essentially, you're connected somewhere else," says White.

Sadly, it seems little research has been done to confirm my prejudices. A 2018 study by Richardson and his colleagues did find that "problematic smartphone use", amounting to a compulsive inclination to check your phone, was correlated with low nature connectedness. The same study found that such connectedness also decreases with time spent on your phone each day and the number of selfies a person takes per week.

Independent research from Natural England shows that a sense of nature connectedness is high among young children, falls off a cliff around puberty and doesn't regain its former levels until we are into our 30s. Other research indicates that use of technology is correlated with increased sedentary time during childhood.

None of this indicates any causation, however. Perhaps unsurprisingly, in Richardson's 2018 study, nature connectedness was also positively correlated with the number of nature photos taken a week. "For some people, that's going to be the way back to a closer relationship with nature," he says.

Many apps specifically focus on observing and recording nature, whether birdsong, plants, bug life or fungi. I have found them quite compulsive. It may be that I have a high "need for cognition", White speculates: knowing and being able to classify what I see is rewarding in itself, potentially increasing my nature connectedness. "If an app helps enrich your experience and connects you more by improving your understanding, that's a good thing," he says.

Perhaps, but don't those moments of frustration when the tech doesn't work take me out of the moment and destroy it? Marselle thinks not. Attention restoration theory suggests four conditions need to be present for us to find a natural environment restorative: it gives us a sense of being away from stressful everyday environments; it provides fascination; it is compatible with what we want to do, be that a run, a wander or a picnic in the park; and it is "coherent", somehow making sense to us. "Irrespective of if you bring your app out on occasions, you're still getting that experience," she says.

I might have to think longer-term, too, says White. "One question is, OK, your initial experience may have been undermined, but are all your subsequent experiences enriched?" he says.

Richardson suggests the effect of such interactions may build up over time. As you find yourself capable of identifying more off your own bat, that increases a sense of wonder at the beauty and variety of nature. "Even though you're delivering knowledge, you're delivering it in a way that taps into emotions," he says. "Emotions are what forms that close relationship with nature." ›

SKAMAN306/GETTY IMAGES

Apps that allow us to track and share our outdoor physical activities can be very motivating

1 June 6:36 am @51.256:0.567

Running on a path across a cornfield on one of my semi-regular early morning routes, I stop and walk. Last time I was here, I became aware of something I had never consciously noticed before – a complex, endlessly varied river of music bubbling up from the corn itself. It's here again now. I wait a while, and my patience is rewarded. A skylark ascends. Something within me does, too.

"Transcendence" is a word that is often bandied around in discussions of nature's effects. We know that even mundane natural sights and sounds can inspire experiences such as humility, awe and self-reflection. We know that such transcendent experiences are associated with more positive moods and emotions. What we don't know, because nobody's studied it directly yet, is whether that is the pathway by which nature weaves its mental magic. "Biodiversity and health is a new emerging research area," says Marselle. "We're just at that first baseline of 'x correlates with y'."

"Identity" is another important word. We form emotional attachments with biodiverse environments we are familiar with, which in turn strengthens a psychological anchor of feeling we belong somewhere. One recurring theme is that perception of richness of tree cover, abundance of birds, butterflies and plants and a mosaic of habitats is as important as actual species biodiversity in making us feel good. That's perhaps especially important in somewhere like the UK, where the "natural" landscape is largely a cultural one, shaped by human hand and husbandry over millennia. "We humans generally dislike uncertainty," says White. "Uncertainty really raises dissonance." Familiarity, in other words, breeds content.

After a month or so using nature identification apps, this is something I am beginning to understand. There's a charm to those first moments of recognition: seeing a skylark; the reminder that that flower is called the yellow archangel, and realising why; the great warbling from a bed of reeds in Essex that the app told me was coming from a great reed warbler. But those interactions also build up over time into a soul-warming sense of familiarity: recognising the complex call of the wren, so surprisingly loud for such a tiny bird; knowing the scent of wild garlic on the air and following it to its source.

It is changing something about how I interact with nature. My jaunts into the green, which previously I thought of mainly in terms of wholesome concepts like fresh air and physical exercise, have become about much more. I stop far more, and bathe all my senses in the beauty, and awe, in the unnoticed and mundane.

8 July 7.04 am @51.258:0.560

Another month has passed. I'm on the footpath skirting the cornfield before the one where I first noticed the skylark, when I stop again. I'm arrested this time not by the acoustic backdrop, but by a new addition to the landscape: a row of flags with the insignia of a housing developer. The skylark field will presumably be next to go.

Healthy, biodiverse ecosystems are important for far more than our mental health. They provide us with food, regulate weather and climate, nourish soils and purify water and air – benefits worth trillions each year, provided by nature for free.

A greater sense of connection to ecosystems is demonstrably good for us. Another hope is that it might be good for nature, too, boosting our motivation to preserve what we have and to strike a better balance between our immediate material needs and the kind of world that can sustain them.

We are still far from understanding what that means. My homeland might regard itself as a nature-loving nation, but White's 18-country study shows it ranks towards the bottom of the league on green-space visits. Meanwhile, Natural England's research reveals that, despite widespread concern about biodiversity loss and environmental degradation, the proportion of people willing to accept changes to their lifestyle to protect the environment is low – just 1 in 6 – and has hardly budged in the decade the agency has been asking the question.

When I get home, I do something that fewer than 1 in 20 of my fellow citizens do, according to that same research, and contact a local conservation group. It isn't necessarily where I expected this project to lead me, but it is a kind of answer all the same. I admit it's a surprise that tech helped me to slow down and deepen my appreciation of the natural world. And whether I will continue to be an appier person, I don't know – but happier? I think so, yes. ▮

Richard Webb is *New Scientist*'s executive editor

Fellowships for Postdoctoral Scholars

AT WOODS HOLE OCEANOGRAPHIC INSTITUTION

Scholarships designed to extend the education and training of the applicants and to advance their research careers are available to new or recent doctoral graduates in diverse areas of research.

Applications will be accepted from doctoral recipients with research interests associated with the following Departments:

- **APPLIED OCEAN PHYSICS & ENGINEERING**
- **MARINE CHEMISTRY AND GEOCHEMISTRY**
- **PHYSICAL OCEANOGRAPHY**
- **GEOLOGY & GEOPHYSICS**
- **BIOLOGY**

Interdepartmental research, including with the Marine Policy Center, is also encouraged.

Applications will also be accepted from those with research interests on the following:

- **USGS/WHOI** - areas of common interest between USGS and WHOI Scientific Staff. The individual will interact with both USGS and WHOI based advisors on their research.
- **THE OCEAN BOTTOM SEISMIC INSTRUMENT CENTER (OBSIC)** - the earth's internal structure and earthquake processes using seafloor seismic measurements.
- **THE OCEAN TWILIGHT ZONE (OTZ)** - twilight zone (100-1000 m) ecosystems and processes, including biomass, biodiversity, life histories and behavior, trophic interactions, links to the global carbon cycle, and ways to engage scientists with stakeholders.

Criteria for awards include demonstrated research independence, productivity and novelty, and community service including contributions to making ocean sciences and engineering more diverse, equitable and welcoming. Scholarships are awarded for 18-month appointments ($63,300 stipend per year; health and welfare allowance; and a modest research budget). Recipients are encouraged to pursue their own research interest mentored by resident staff. Communication with potential WHOI advisors prior to submitting an application is encouraged. **COMPLETED APPLICATIONS MUST BE RECEIVED BY OCTOBER 15, 2021**, to start any time after January 1, 2022 and before December 1, 2022. Awards will be announced in December.

Further information about the Scholarships and application forms as well as links to the individual Departments and their research themes may be obtained at:

https://go.whoi.edu/pdscholarship

A goal of the Postdoctoral Scholar Program is the long-term broadening of participation in ocean science and engineering; women, minorities, veterans, those with disabilities, and other underrepresented groups are encouraged to apply.

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The back pages

The science of cooking

How to make juicy jam

We all love home-made jam, but getting it right means grappling with the chemistry of pectin, says **Sam Wong**

Sam Wong is social media editor and self-appointed chief gourmand at *New Scientist*. Follow him @samwong1

What you need

1 kilogram of fruit such as strawberries, blackberries or raspberries
1 kg sugar
Pectin (or use jam sugar, or add an apple to the fruit)

MAKING jam is a great way to enjoy a glut of summer fruit. Sugar preserves work rather like a salt cure, with the high concentration of sugar drawing water out of microbial cells. Because sugar molecules are heavier than sodium and chloride ions, you need a lot more sugar to do the job. That is why jams are often made with a roughly equal weight of sugar to fruit.

The moist yet solid consistency of jams and jellies comes from the physical structure of a gel, a sponge-like network that traps water molecules in separate pockets. The network is made from pectin, a polymer made of long chains of sugar molecules, found in plant cell walls.

Fruits such as quinces, apples and citrus fruits are high in pectin. For other fruits, you can add pectin to ensure that the jam sets – there is even a special jam sugar containing pectin for this purpose, though adding an apple to a batch of low-pectin fruit also works.

To make the jam, start by heating the fruit gently with a little water to soften it. As it is heated, the pectin chains come loose from the cell walls and dissolve in the fluid released. In water, pectin molecules become negatively charged and repel each other, so they need help to join together into a gel network. Adding sugar when the fruit is cooked aids this: it helps the gel to form by attracting water molecules to itself, so the pectin molecules are more exposed to each other.

KAJAKIKI/GETTY IMAGES

Acid released when the fruit is heated neutralises the negative charges, allowing the pectin chains to bond. Bringing the mixture to the boil to evaporate water also helps bring the pectin molecules closer together. Some recipes call for lemon juice to be added at this stage, which provides additional pectin and acidity.

The most challenging part of jam-making is knowing when to stop cooking the mixture and pour it into jars. Too early and the mixture won't have "reduced" enough for the jam to set; boil it for too long and the pectin breaks up too much, stopping it from becoming jam.

One way to tell is to use a thermometer: the more water that is evaporated, the hotter the mixture gets. When it reaches 105°C, this indicates a sugar concentration of about 65 per cent, normally about right for the pectin molecules to join together (though that does depend on acidity and other factors). Another way is to chill a saucer in the freezer, then place a blob of jam on it. If the surface of the jam mixture "wrinkles" when you poke it with your finger, the jam will set and you should stop cooking.

If it fails to set, it may be because there wasn't enough good-quality pectin in it, or that the pectin was damaged by prolonged heating. Or perhaps the mixture lacked enough acid. Reboiling it and adding liquid pectin or more acid may help. ▮

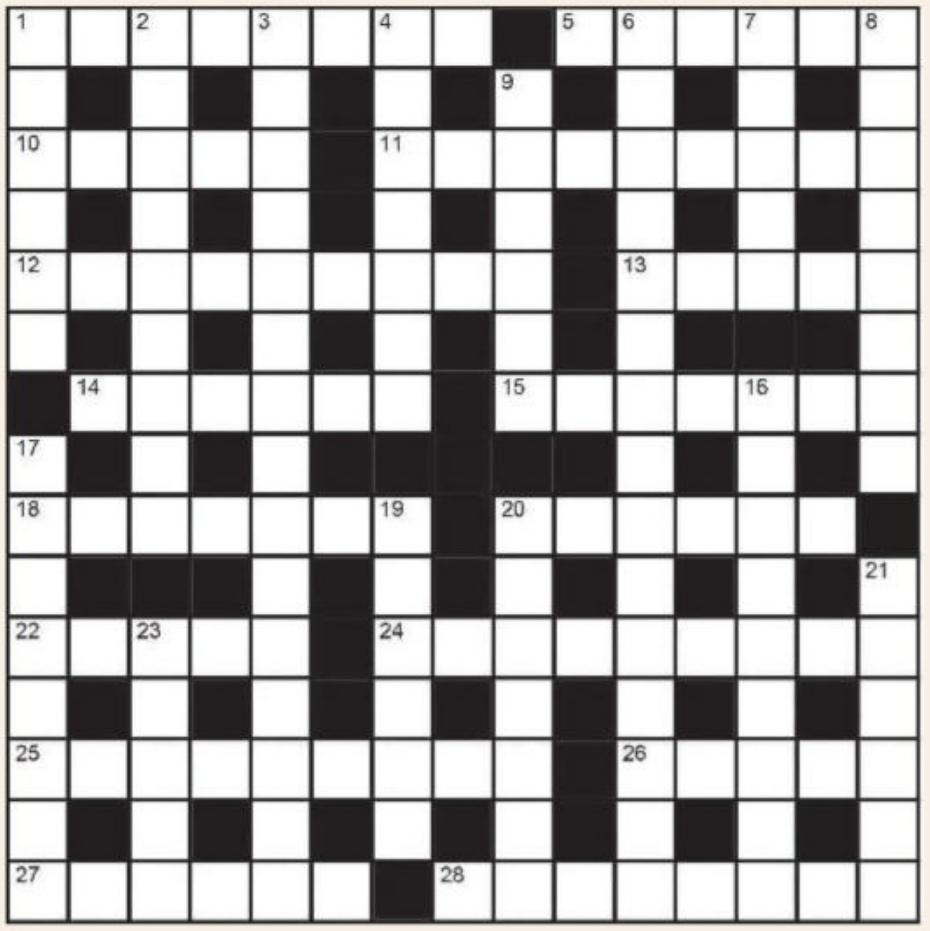
The science of cooking appears every four weeks

These articles are posted each week at newscientist.com/maker

Next week

Stargazing at home

Quick crossword #90 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Theoretical technology on the scale of trillionths of a metre (8)
5 Counting frame (6)
10 Rapid transit railway (5)
11/27 Wind or solar, say (9,6)
12 Set the position or values of an instrument (9)
13 Unit of heat energy (5)
14 Run of good fortune (6)
15 External parasite (7)
18 Methanol or ethanol, perhaps (7)
20 Memory trace (6)
22 Area of a planet differentiated by colour (5)
24 Rusting (9)
25 The theory of evolution by natural selection (9)
26 ð (5)
27 See 11
28 Curved elastic supports (1-7)

DOWN

1 Low-density volcanic rock (6)
2 ___ converter, exhaust emission control device (9)
3 Problem-solving (15)
4 Place where motor vehicles may be left (3,4)
6 Alternative term for a tied-arch bridge (9,6)
7 Assembly of wires; flex; hawser (5)
8 Polyamine found in all eukaryotic cells (8)
9 Sternutation (6)
16 Antibiotic patented in 1960 (9)
17 Manhattan Project development site in Tennessee (3,5)
19 Meteor that seems to originate in the constellation Leo (6)
20 Puzzles (7)
21 Sequences of items from a text sample (1-5)
23 Prickly shrub in the genus *Ulex* (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #116

1 How many baobab species are found in the *Adansonia* genus?

2 Who first described the behaviour of chromosomes in the cell nucleus during mitosis?

3 In what year was the electric chair first used to execute someone?

4 What name is given to the central shaft of a bird's feather?

5 Quasars and Seyfert galaxies are part of what class of astronomical objects?

Answers on page 55

Puzzle

set by Colin Beveridge

#128 Tournament headache

Four hungover footballing mathematicians groaned in unison. "Anyone remember who won yesterday's tournament between our four teams?" asked Ranko, the Red Star Belgradient goalkeeper. Ignacio, the Integer Milan striker, raised his hand feebly. "I remember that we each played each other once. Three points for a win. One for a draw. And all of the scorelines were different."

Tom, the Tottingup Hotspur defender, opened one eye. "Are 1-0 and 0-1 different or the same?" "They're the same, obviously!" said Patrick, of PSV Eigenvector, adding: "I remember that every team scored a different number of goals in each of their games."

"But never more than two!" said Ranko. "And I know my team didn't concede a goal." Patrick pulled a silver medal out of his pocket. "And we must have finished second," he deduced.

"I know which game ended 2-2!" said all four at once.

Which was it?

Solution next week

Photon speed

How does a photon "know" to travel at the speed of light?

Elaine Patrick
Cyffylliog, Denbighshire, UK
I don't know, ask Erwin Schrödinger. He was a relative of mine on my mother's side. He told her mum, but she couldn't understand it either. We've been in the dark ever since.

Yang Guijen
Balik Pulau, Penang, Malaysia
The laws of the universe require that all the energy and matter particles occupying its space must abide by its rules – so as to maintain a viable home and playground for all. One of these rules is that if you are a massless particle of electromagnetic origin, and you want to play in vacuum space, then you must move at the speed of light, 299,792,458 metres per second, consistently.

If you are a particle with mass, however, then there are other rules that you can follow.

"Does time actually exist as anything or is it just a convenient invention to allow us to talk about how things are moving?"

@kbachmann, via Twitter
Wouldn't any speed travelled by photons be, by definition, the speed of light?

Ian Glendinning
Vienna, Austria
All massless particles always travel at a speed represented by the letter *c*, whereas massive particles can travel at any speed between zero and *c*. Since photons are massless, they travel at *c*, which is called the speed of light because the photon was the first known example of a massless particle.

So the short answer to the question is that a photon knows to travel at the speed of light because it is massless.

Ken Appleby
Ledbury, Herefordshire, UK
What we call photons are actually interactions of electromagnetic fields. Between interactions, photons don't exist. You can't watch a photon in transit, only detect an excitation of the electromagnetic field when it happens.

Photons don't exist as particles. There are no particles, just interactions of quantum fields. Maxwell's equations embody and explain in elegant mathematics the empirical results of Faraday's experiments into electrostatic and magnetic fields – fields being a novel concept of Faraday's invention. The equations reveal the existence of electromagnetic waves, which are always observed to travel at the constant speed *c*, regardless of the motion of emitter, receiver or observer. It was this apparent paradox that Einstein's special relativity paper resolved, by dispensing with the notions of simultaneity, absolute space and time.

So at root, the answer to your question is just simply that that is reality. That is what we observe. The reasons are illuminated by the equations of electrodynamics, but ultimately it is an empirical observation. At least, so far.

James Bailey
Southampton, Hampshire, UK
This question is the wrong way round. A photon is a packet of electromagnetic radiation. A very small part of the spectrum of that radiation (wavelengths of around 400 to 750 nanometres)

IULIIA VERSTA/ALAMY

This week's new questions

Baking boundaries **Scientifically speaking, what is the difference between a cake, a biscuit and a sponge?** **Dee Muggle**, *UK*

Absolute heat **If absolute zero is the lowest possible temperature for matter, is there an upper limit or highest possible temperature?** ***Chris Tatler***, *Hamilton, New Zealand*

What makes a cake a cake and a biscuit a biscuit?

is detectable with our eyes and we call this light. It is like asking why light takes 1/299,792,458 of a second to travel 1 metre, when in fact we just find it more convenient to define it as that, rather than use the old definition of a metre as a ten-millionth of the distance from the equator to the North Pole.

The really interesting question for me is why does electromagnetic radiation travel at 300,000 kilometres per second, and that brings us back to the question of time that has been raised before. Does light travel through time? If so, what exactly is it that it is travelling through? Or does time itself do the moving and is constantly sweeping past us like the wind while everything else stands still?

Does time actually exist as anything or is it just a convenient invention to allow us to talk about how things are moving?

Grinning mammals

Grinning or baring the teeth is usually a sign of aggression in animals, so at what point did it become advantageous for humans to use this to signal friendship or mirth?

Garry Trethewey
Cherryville, South Australia
Frightened babies expose their teeth; happy babies stretch their lips without extreme tooth exposure. Other primates expose their teeth with open mouth when threatened or with the mouth nearly closed in submission.

Psychologists and animal behaviourists have invoked the notion of "primary process" – a sort of primitive signalling. It lacks details like negatives, tenses etc. Thus a dog can't tell another dog: "I will not bite you." Instead, it has to initiate biting, and then stop, which in itself signals: "I will not bite." Similarly, perhaps, a human

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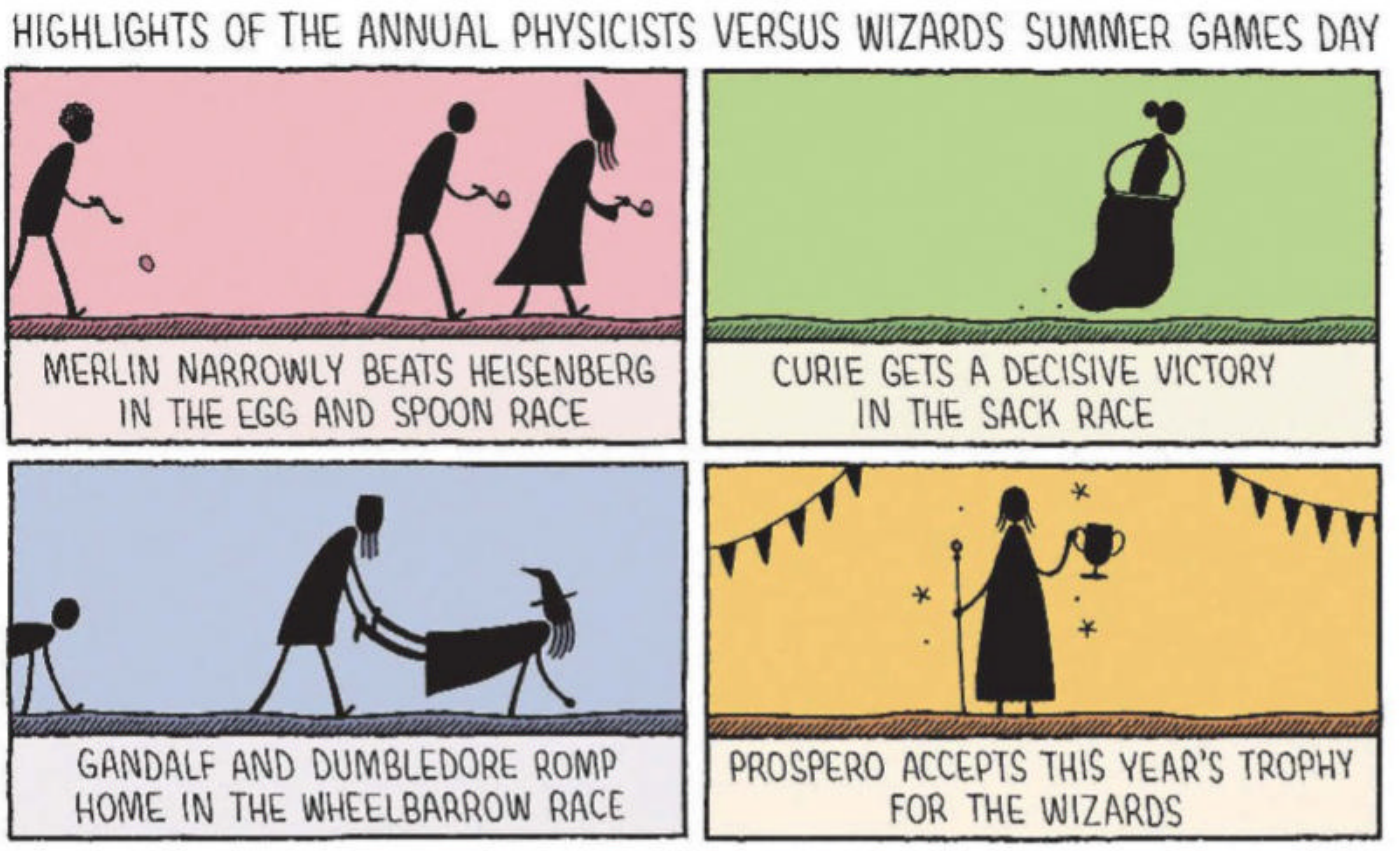
Tom Gauld
for New Scientist



baring of teeth without a follow-up assault indicates friendship. Perhaps doing this smile-like, with a nearly closed mouth, indicates submission, necessary for friendship. This may be analogous to the handshake, thought to be a voluntary act of submitting to another's control.

The meaning of a smile varies by culture. Many readers of this column might regard a smile as a positive signal, but in some cultures it can be viewed with distrust or suspicion, or as a signal of embarrassment or guilt.

Bernard Harper
Liverpool, UK
Primates flash their impressive canine teeth often and for many reasons we do not. Typically, they do so to show gender, rank, dominance and aggression. But sometimes it is just human-like yawning or mirth. These signals can be seen at great distance and allow groups to display their strength without getting dangerously close.

Humans, however, are very

"Many readers might regard a smile as a positive signal, but in some cultures it can be viewed with distrust or as a signal of guilt"

different because our canines are small remnants. In contrast to almost all other primates, our teeth and bodies have lower sexual dimorphism too. Human smiles tend to attract unthreatening attention, unlike in apes.

We augment smiles with a vast array of micro-expressions best read at close range. Our complex facial expressions function as a visual language of great subtlety. Together with other facial features, they strongly suggest human evolution was different to that of other primates. Cooperation and signalling complex information and empathy at close range seem to have been more adaptive to us than to any known primate.

Violence and aggressive posturing may have had a lower adaptive value for us because our ancestors had far lower physical differences between genders or between adults. A diet without any need for prominent canines would also make such teeth a liability.

So we can now smile safe in the knowledge that this is relatively unlikely to be interpreted as meaning anything else.

Martin van Raay
Culemborg, the Netherlands
Grinning or baring our teeth can still be a sign of aggression, even though we don't realise it.

It is a reaction to anything unexpected (and therefore threatening): "Watch out, I can defend myself by biting you!" As this display makes the threat go away, it gives us a feeling of relief, which may be why laughing makes us feel good. And making another person feel good strengthens friendship.

But being in company isn't necessary for mirth – I sometimes laugh at silly things popping up in my own head. ▮

Answers

Quick quiz #116 *Answers*

1 Eight
2 Walther Flemming
3 1890
4 The rachis
5 Active galactic nuclei

Cryptic crossword #64 *Answers*

ACROSS 1 JPEG, **3** Probably, **9** Upstart, **10** Order, **11** Demagnetised, **13** Capita, **15** Peddle, **17** Pumpkin seeds, **20** Tempi, **21** Notable, **22** Watchmen, **23** Trap

DOWN 1 Jaundice, **2** Epsom, **4** Ratter, **5** Biodiversity, **6** Bedhead, **7** Yard, **8** Caught up with, **12** REM sleep, **14** Plummet, **16** Fiancé, **18** Ember, **19** Stow

#127 Brahms and Liszt *Solution*

It is possible to construct jigsaw-like pieces for the conditions and then see the possible ways they can fit together. The notion that only one item is correctly positioned gives the following unique solution:

	First name	Surname	Composer
1	Claudio	Grump	Liszt
2	Agnes	Iddyhat	Khachaturian
3	Edgar	Hobble	Mozart
4	Dolores	Jabber	Schubert
5	Bjorn	Flop	Prokofiev

Solar system agronomy

Could we grow endangered plants on other planets? We pause and consider this question. No.

Still, since this query is the subject line of a PR email from an online flower-delivery service, handed to us by a colleague with a pair of tongs and a disparaging look, we find it worthy of further consideration. Even more so since we are promised conclusions reached "using research and working with a designer".

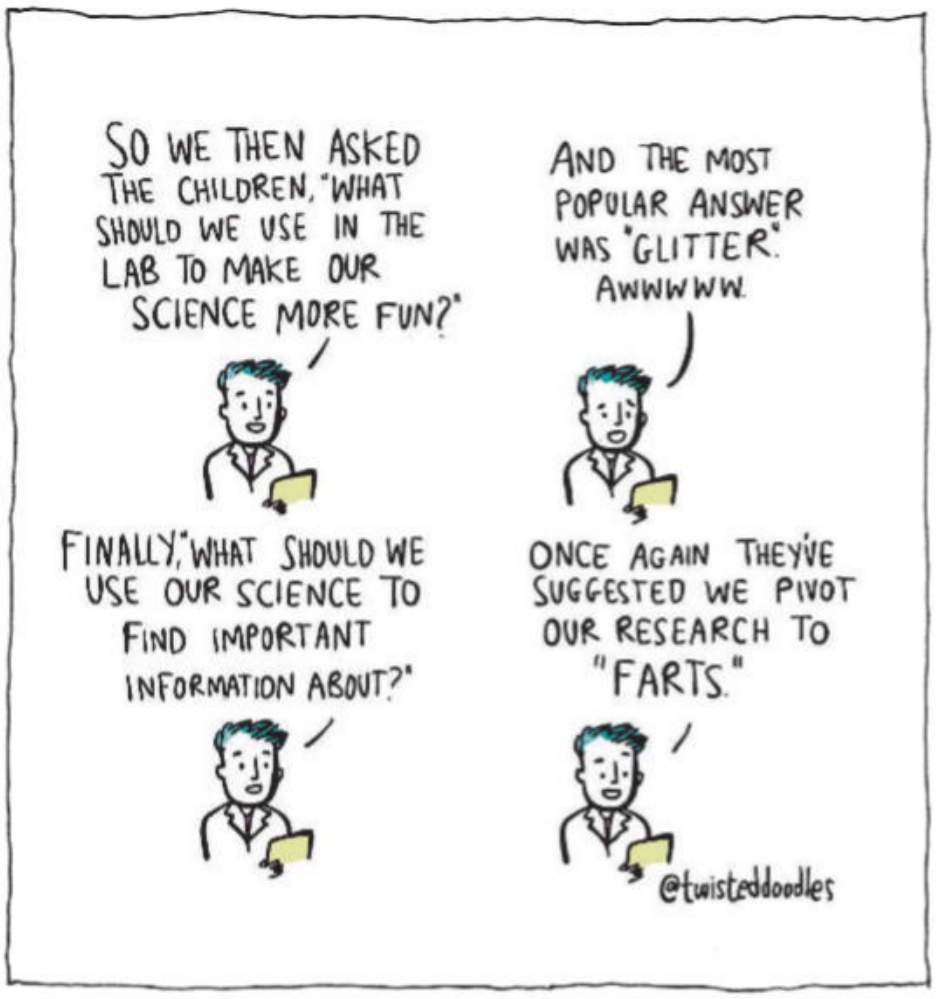
"Today, nearly 40% of the world's plants are endangered, according to a report from the Royal Botanic Gardens, Kew," we read. Sad, sad science fact. But never fear, once we have destroyed Earth's ecosystems, a bright, green future exists elsewhere in the solar system, at least in the world of whirly-eyed PR.

"As the soil on Mars has double the amount of iron than soil on planet earth, leafy green vegetables and microgreens would easily thrive there," we learn. Dandelions, too, apparently – a species far from endangered on Feedback's small patch of terra firma. "Hops vine [sic], trees, shrubs and poison ivy might be able to survive the challenging temperatures on this moon", it opines of Jupiter's satellite Europa, where days struggle to rise above -135°C and surface radiation levels are around 2000 times those on Earth. "One of the only things that can kill poison ivy is boiling water – so the cold and wet conditions on Europa seem to be the ideal environment for this plant."

The outlook is even rosier on Titan, the Saturnian moon where water ice at around -180°C fulfils the function of bedrock, and great surface lakes are filled with liquid natural gas. "Titan's surface is sculpted by methane and ethane, which only one other planet in the solar system has: Earth. Therefore, tobacco plants should grow on this moon too", our correspondent concludes, non-sequentially.

"Please let me know if you have any questions", the email ends. So, so many, including where we get some of the wacky Europa baccy too. Optimism is a fine, fine thing, but as far as the future of life on Earth is concerned, we fear the rationalist's counterstatement applies: *il faut cultiver notre jardin*.

Twisteddoodles *for New Scientist*



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Bog standards

"We are all in the gutter, but some of us are looking at the stars", as one of the usual suspects once wrote. Or we are all in the gutter, sending in responses to our recent item on peculiar toilet signage (31 July).

"Toilets and viewing area" was an unfortunate juxtaposition that confronted Richard Ellam at an Aberdeen Science Festival some years back, while Chris Evans relays that "A lay-by eatery near where I live (on the A59 between Skipton and Clitheroe) for some years displayed a sign reading 'Sit-in or take-away toilet' " – neither of which seems particularly practicable or desirable.

Hazardous fore play

Our item on the newly introduced crocodile hazard at the Royal Port Moresby Golf Club in Papua New Guinea (14 August) reminds Stuart Reeves in Wake Forest, North Carolina, of playing at the Skukuza Golf Club in Kruger National Park in South Africa – a sentence that exhausts us even typing it.

Its "local rules" include such gems as "Burrowing animals – Rough/ Fairway drop without penalty from holes made by burrowing animals and termites, NOT HOOF MARKS. Burrowing animals include warthogs, moles and termites".

Other rules ("formal and informal") that Stuart has encountered on his travels include "Give way to a herdsman and his cows crossing the fairway; free drop from a hippopotamus footprint; free drop about 3 club lengths if the ball lands in the coils of a snake (no need to be precise); if a monkey steals your ball it is a lost ball". Strong stuff – and further congratulations on your self-confessed status as a "recovering golfer".

Transcendental number

Mentions in *Almost* the last word (14 August) of "interesting numbers, numbers with their own Wiki page and the fine-structure constant (approximately 1/137) prompted me to recheck the Wiki page for 137", writes Mike Sargent, displaying the talent for the tangent that we so admire among Feedback readers. "It has for several years now informed us that 'Wolfgang Pauli, a pioneer of quantum physics, died in a hospital room numbered 137, a coincidence that disturbed him'."

"It is difficult to know which is more surprising, that Pauli's consciousness transcended death, or that he then contrived to communicate his feelings on his demise to a Wiki page editor," he continues. We don't wish to sound too woo, but it is a fundamental tenet of quantum mechanics that information cannot be destroyed, and "Physics might create a backdoor to an afterlife – but don't bank on it" is the headline of an article we see in our webspace starting from that basis. We would say that's living proof, but that's possibly not quite right.

Last laugh

Casting our all-seeing eye over our shoulder, we see that our neighbours and friends in *Almost* the last word (backwards readers: you'll find it towards the front) are discussing how a photon "knows" to travel at the speed of light.

With the privilege of having the actual last word, we must give the obvious missing answer: because it is very bright.

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