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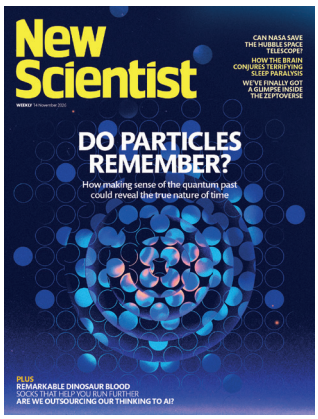
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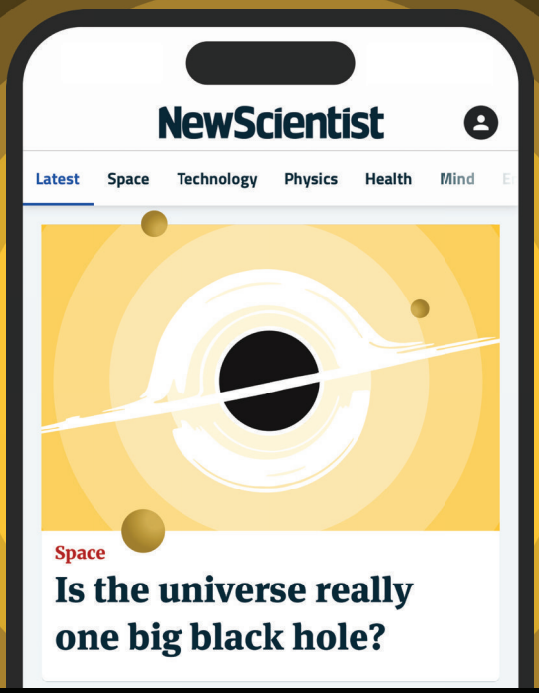
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Space history's dark ages

We must preserve space age artefacts for future generations – but who will foot the bill?

AROUND 40,000 years from now, the Voyager 1 probe will pass within astronomical spitting distance of the star Gliese 445. From there, it will continue drifting through the universe on an endless journey that marks humanity's first attempt to reach the stars.

Voyager 1 – which on 18 November will have travelled one light day from Earth – began its odyssey almost 50 years ago, meaning it has been operating for the majority of the space age (see page 39). That makes it a rarity: most of our iconic spacecraft ended their lives burned up in Earth's atmosphere or in bits at the bottom of the ocean. Two of the most important missions still flying today, the Hubble Space Telescope and the International Space Station, look set to share the same fate in the near future, even as scientists call for Hubble to be preserved (see page 4).

While some craft like the space shuttles are on display in museums, our present space history is, essentially, in its dark ages, with little thought currently given to preserving spacecraft in situ, where our space-travelling descendants may wish to marvel at them. Even the Apollo hardware left behind on the moon has almost no protection in international law.

"It would be a shame to be unable to look back at how humanity took its place among the stars"

Perhaps we need an organisation like the UNESCO World Heritage Committee to designate important space artefacts for preservation, and encourage funding from cultural and heritage budgets, not scientific ones, to do this. Of course, with such budgets often under threat and the US set to leave UNESCO at the end of this year, this could introduce new problems.

Private philanthropy is another option. If humanity is to one day take its place among the stars, a fantasy that fuels many a tech billionaire, it would be a great shame to not be able to look back at how we got there. Just as we remember 19th-century captains of industry like Andrew Carnegie and J. P. Morgan for funding great cultural institutions, perhaps we should be lobbying for the creation of a Musk Space Museum or Bezos Orbital Institute. ▮

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Space

The race to save Hubble

NASA is turning to the private sector for solutions to keep the Hubble Space Telescope from its impending fiery and fatal fall back to Earth, reports **Matthew Sparkes**

THE Hubble Space Telescope is slowly falling out of the sky, and it could burn up in Earth's atmosphere as soon as 2032. Researchers are urging NASA to rescue it, arguing that the ageing instrument is still vital for science and will leave a stark capability gap if lost.

Hubble was launched in 1990 and has provided a wealth of new science in the decades since. NASA claims that more than 23,000 peer-reviewed scientific papers have emerged from its images.

But the space-based telescope requires periodic servicing and raising of its orbit, as atmospheric drag causes it to slowly lose altitude. Hubble has gyroscopes that allow it to shift position to image different parts of the sky, but no propulsion of its own.

The last time that Hubble was lifted to a higher orbit was in 2002, when the space shuttle Columbia visited – one of five shuttle missions to the telescope. Since then, NASA has retired the shuttle fleet and no longer has any spacecraft with the capability to carry out the task. NASA estimates that Hubble has a 10 per cent probability of re-entry by September 2032, and a 50 per cent probability by December 2033.

The space agency has put out a call for ideas from the commercial sector, giving companies until 30 November to submit plans for either raising the orbit of Hubble to at least 600 kilometres or safely de-orbiting it and letting it crash into the ocean. The telescope has parts of sufficient density that they would probably survive atmospheric re-entry.

Alise Fisher at NASA says the agency is open to ideas from inside or outside the organisation, and isn't taking anything off the table. "It wouldn't be appropriate for the agency to speculate about specific potential responses, so we don't inadvertently limit them, but NASA is looking to explore a range of technologies and approaches, including those the agency may not have considered previously."

NASA



Hubble has been taking extraordinary snaps of the cosmos since 1990

NASA's call-out explains that a private company would need to supply everything for the mission: the launch vehicle, the spacecraft and, if applicable, the crew.

Thomas Haworth at Queen Mary University of London is part of a panel of scientists advising NASA on what direction to take with Hubble. He went into discussions with colleagues expecting the focus to be on how NASA could be advised to extract the most science from Hubble before the end of its life, but found that re-boosting its orbit was actually higher on the agenda, he says.

"It's within the realms of possibility," says Haworth. "The overall document that we're coming up with, which still isn't submitted yet, is going to try and strongly make that recommendation. There is quite a lot of effort to argue for a boost."

NASA is likely to make a decision quickly once that recommendation is in, because planning a boost mission will take years, says Haworth. "You need to decide now."

"Attempting to repair Hubble maintains key skills that will be essential for future space exploration"

Stephen Wilkins at the University of Sussex, UK, says Hubble has unique abilities unmatched by any other instrument.

Hubble can do high-resolution ultraviolet imaging better than anything currently available. NASA aims to launch the Ultraviolet Explorer in 2030, which will cover the same part of the spectrum but with a tenth of the resolution, and the Habitable Worlds Observatory (HWO) may launch in the 2040s and match Hubble's ability. But if Hubble is allowed to burn up in 2032, this could leave a decade or more of lost science, and if the HWO is cancelled, then that could be a virtually permanent setback.

Launching a mission to physically grapple with the telescope, which is 13 metres long and weighs over 12,000 kilograms, will be no easy task. But it could also bring intangible benefits besides lengthening Hubble's lifespan, says Wilkins.

"While repair is more complex now that we don't have the space shuttle, attempting to repair Hubble helps maintain key skills that will be essential for future space exploration or exploitation," he says.

Hubble was always designed to be serviced, says Mark Norris at the University of Lancashire, UK, so it is fitted with grapple points for robotic arms to grab hold of. But raising its orbit wouldn't be a permanent solution and it has begun to show its age.

"The instruments are gradually degrading through exposure to the space environment," he says. "It's a bit of a miracle it's still going, but they over-engineer these things and they did service it so many times – they made sure that when the last service was done, everything was left working. It's still doing really great science."

NASA administrators will need to make difficult decisions about costs, as ongoing servicing and ground support will be needed on top of any mission to boost Hubble's orbit.

"If they can save it, it makes sense, but it depends how much [it costs] and what gets axed in order to save it," says Haworth. ∎

Neuroscience

Parkinson's may be driven by 'vicious cycle' that disrupts brain cleaning

Carissa Wong

INFLAMMATION of lymphatic vessels, which drain brain waste, may be involved in the onset of Parkinson's disease. The condition is associated with the build-up of a misfolded protein called alpha-synuclein, which may not be efficiently removed from the brain if the lymphatic vessels are impaired. But the accumulation of alpha-synuclein seems to further damage these vessels, creating a self-reinforcing chain of events where each problem worsens the other.

"It is a vicious cycle," says Justin Rustenhoven at the University of Auckland in New Zealand. This may also help explain why Parkinson's disease is a progressive condition that worsens over time, he says.

Parkinson's disease, which affects more than 10 million people worldwide, is characterised by a loss of neurons in brain regions that control movement. This causes symptoms such as tremors. The condition is thought to be caused by alpha-synuclein, which occurs naturally in the brain, misfolding and forming clumps that damage neurons.

In 2021, researchers showed that accumulation of alpha-synuclein in Parkinson's disease may partly result from impaired drainage of brain waste via meningeal lymphatic vessels. These are found in the outermost layer of three membranes, called meninges, surrounding the brain. The vessels receive waste from a network of channels surrounding the brain's blood vessels, called the glymphatic system, before transporting it to other parts of the body for disposal.

But what causes the lymphatic impairment in Parkinson's disease was unknown. Rustenhoven and his colleagues wondered whether it may result from alpha-synuclein clogging up the meninges.

The team analysed post-mortem samples of the meninges from seven people who'd had severe Parkinson's disease and seven people without the condition. Only the Parkinson's samples had alpha-synuclein clumps. "For the first time, we showed that these aggregates accumulate at the brain's borders in people with Parkinson's," says Rustenhoven.

> "This may help explain why Parkinson's disease is a progressive condition that worsens over time"

To determine whether such protein accumulation impairs clearance of brain waste, the researchers injected mice with a virus that infected cells called fibroblasts in the meninges. This caused them to continually produce alpha-synuclein at elevated levels, similar to those seen in people with Parkinson's disease. At such high levels, alpha-synuclein misfolded and formed toxic clumps that spread across cells in lymphatic vessels in the meninges, but not inside the brain.

Two months later, brain imaging revealed that meningeal lymphatic vessels in these mice drained waste fluid half as rapidly as those of control mice, which were injected with a virus encoding an inert protein. What's more, in the first group of mice, immune cells called macrophages had engulfed the alpha-synuclein clumps at the brain's borders. This caused the macrophages to double in number and produce about triple the amount of TNF-alpha, an inflammatory molecule.

Next, the team exposed sheets of human cells found in meningeal lymphatic vessels to either alpha-synuclein or TNF-alpha. Both molecules caused gaps to form between the lymphatic cells, making them leaky, says Rustenhoven (*Journal of Experimental Medicine*, doi.org/rww9).

"The accumulation of alpha-synuclein in the brain borders basically drives an immune response that pokes holes in those lymphatic vessels, making them ineffective at draining," he says. "We already know from other studies that those lymphatics are important for draining alpha-synuclein, so impaired lymphatic drainage [due to alpha-synuclein] means even more of the protein is going to build up."

Breaking the cycle

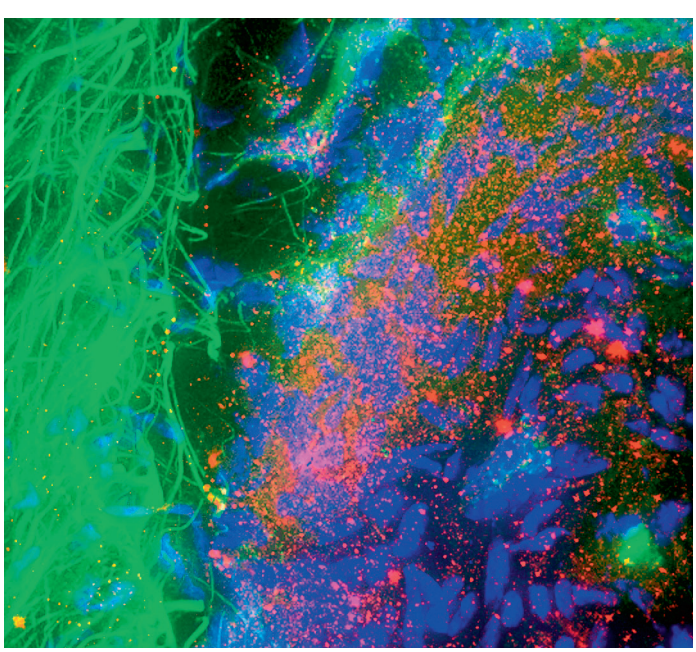
This feedback loop keeps reinforcing itself, which may cause the worsening of brain damage and symptoms associated with Parkinson's, says Rustenhoven.

The same mechanism probably applies to other neurodegenerative conditions where proteins accumulate, such as Alzheimer's disease, says Camille Carroll at Newcastle University in the UK.

Understanding this creates new treatment opportunities. "Therapies that dampen or modulate that immune response could prevent lymphatic dysfunction to treat Parkinson's," says Rustenhoven.

The team now plans to carry out similar experiments where mice are studied after they develop Parkinson's-like symptoms, not just its associated brain changes.

"Their mouse model was appropriate for the question they were asking, which was looking specifically at the effects of alpha-synuclein at the brain border on lymphatics," says Carroll. "But linking their findings to symptoms will be important."



MYA C. SCHIESS, ROGER BICK, UT MEDICAL SCHOOL/SCIENCE PHOTO LIBRARY

Parkinson's is thought to be caused by clumps of the protein alpha-synuclein (red) damaging neurons (nuclei of neurons shown in blue)

Neuroscience

Vibrations may boost brain drainage

Gently shaking the body seems to help flush out a protein linked to Alzheimer's disease

Carissa Wong

LYING on a vibrating mattress while taking nitric oxide pills has shown promise for boosting the brain's waste-disposal system. It caused the brain's blood vessels to swell and constrict more strongly, which enhanced the glymphatic system's clearance of a protein that accumulates during Alzheimer's disease.

Other experiments into boosting the glymphatic system have involved ultrasound, pink noise and even intermittently inhaling high doses of carbon dioxide. But risky experimental approaches like taking nitric oxide and inhaling CO_2 shouldn't be tried at home, says Vesa Kiviniemi at the University of Oulu in Finland.

Prior studies in mice have shown that vibrating the body activates a motion-sensitive protein called Piezo1, which is found in muscle cells in the walls of the brain's blood vessels. This causes the vessels to dilate and constrict more strongly, which helps push waste fluid from brain cells through the glymphatic system, a network of channels that surrounds blood vessels in the brain and transports waste for disposal elsewhere in the body.

> "The treatment seemed to enhance the ability to clear beta-amyloid from the brain to the blood"

Other research has shown that nitric oxide, which is naturally produced in the brain, also dilates its blood vessels. This seems to make the surrounding glymphatic channels narrower, putting more pressure on the waste fluid so it exits the brain more quickly, says Kiviniemi.

Combining these approaches, Kiviniemi and his colleagues recruited 29 adults who hadn't been diagnosed with Alzheimer's disease or any other cognitive issues. The participants took a pill that dissolves when under the tongue, releasing nitric oxide. They then lay on a mattress that caused their bodies to gently vibrate for 40 minutes, taking another pill halfway through.

Blood samples revealed that their levels of a type of protein called beta-amyloid 42 increased by 35 per cent, on average, after the intervention (*Nature Communications*, doi.org/rwxf). This protein, which usually helps neurons signal and connect to each other, misfolds and forms clumps in Alzheimer's disease. "The treatment seemed to enhance the glymphatic system's ability to clear beta-amyloid from the brain to the blood," says Kiviniemi.

"A 35 per cent increase in circulating beta-amyloid 42 is a substantial and very interesting acute effect," says Tuomas Lilius at the University of Helsinki, who wasn't involved in the work. "It is certainly possible it could become biologically, and eventually clinically, relevant."

Side effects were mild and minimal, with six people experiencing issues such as nausea and headache.

Brain scans suggest the treatment enhanced the flow of fluid along glymphatic channels, probably by widening the brain's blood vessels and making them pump more strongly, says Kiviniemi.

But other mechanisms could also be at play, says Christopher Brown at the University of Southampton, UK. For instance, this intervention may slow the breakdown of beta-amyloid 42 by the liver, leading to higher amounts in the blood, he says. ▮

Archaeology

Stunning ancient engravings found in Spanish cave

A GALLERY of hundreds of engraved motifs and dozens of prehistoric animal images has been found in a cave in Spain, where they had gone unnoticed despite the cave being a popular tourist attraction.

Josep Maria Vergès at the Catalan Institute of Human Paleoecology and Social Evolution stumbled on the rock art at Cova de la Font Major, west of Barcelona. So far, 280 motifs have been discovered, including 55 animal figures, making the cave one of the richest and most important archaeological finds along the Iberian coast.

While it is extremely difficult to date the engravings themselves, human occupation in the cave has been dated to between 26,000 and 41,000 years ago and, based on the style, the art is likely to be over 19,000 years old (*Antiquity*, doi.org/rwxd).

Team member Míriam Salas-Altès, also at the Catalan Institute of Human Paleoecology and Social Evolution, says one of the most outstanding figures is a hind, or adult female deer, depicted with its head lowered, its muzzle extending across a natural fissure.



JOSEP MARIA VERGÈS BOSCH & MÍRIAM SALAS-ALTÈS

The cave contains dozens of animal depictions, including this image of a horse

The crack appears to have been deliberately incorporated into the composition as the surface of a body of water from which the hind is drinking. "If this hypothesis is correct, the scene would constitute one of the earliest known representations of water in human artistic expression," she says.

Paul Taçon at Griffith University in Australia says the discovery fills a large gap in our knowledge of the distribution of Palaeolithic art in western Europe. "It is exciting that new discoveries at long-visited sites are revealing ancient evidence of a very early painting tradition." ▮

James Woodford

Quantum physics

First look at ‘ultraquantum’ turbulence

Karmela Padavic-Callaghan

A TYPE of turbulence that only exists in the quantum realm has been directly observed for the first time. This ultraquantum turbulence may be representative of what happens in many exotic settings, from liquid helium to neutron stars.

Turbulence refers to chaotic and irregular currents in a liquid or gas that is perturbed, like unruly versions of whirlpools you create by stirring a cup of tea. Many fluids we encounter daily behave this way, but liquids and gases in the quantum realm follow completely different rules. When made turbulent, they remain largely still, but become pocked with thin, tangled, string-like whirlpools before quieting down into equilibrium.

To get a look at this ultraquantum turbulence, Sebastian Morris at the University of Cambridge and his colleagues started with thousands of potassium atoms that they had cooled very close to absolute zero – the coldest temperature possible – with lasers and electromagnetic fields. This made the atoms behave like a very dilute quantum gas.

The researchers then corralled the atoms into a cylindrical shape a few dozen micrometres in size. By controlling the atoms’ interactions with each other and their energies, they could also create a disturbance that would engender turbulence and vortices.

Imaging the whole cylinder would have hidden the tangles, so Morris and his colleagues used a sheet of laser light to isolate and image just one slice of it.

“As soon as I got the first pictures, I felt like, this is the one,” he says. “You can see these holes, these imprints of the vortex lines as they wind in and out of this imaged cross-sectional slice.”

The researchers took many images and studied the distribution of vortices as they tangled, fell apart, connected into rings or moved to the cylinder’s edge, tracing how the quantum fluid became less and less turbulent and disordered. Intriguingly, they found this process to be very similar to what had previously been observed in liquid helium, which is also a quantum fluid, but one that is a lot denser and whose atoms interact more strongly (*Physical Review Letters*, doi.org/rxgq).

The way order forms is similar for the two systems, but nothing else is, says team member Christoph Eigen at the University of Cambridge. This exemplifies a universal behaviour for a whole class of quantum systems, one that ought to show up in other, even more dissimilar settings, says Zoran Hadzibabic, who is also at the University of Cambridge and worked on the experiment.

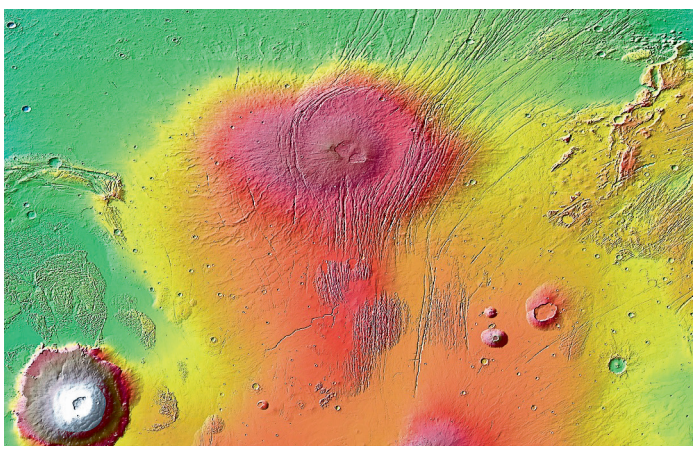
Mathematical models for ultraquantum turbulence have existed for decades, but it is usually hard to image vortices, especially in a three-dimensional collection of atoms, says Thomas Gasenzer at Heidelberg University in Germany. The new work supports the models with precise and sophisticated experimental evidence, he says.

Because of the universality of the process, future experiments could also shed light on ultraquantum turbulence far away from the lab, says Gasenzer. “The same kind of [turbulence] dynamics has been proposed to happen, for example, in the dark matter halo of a neutron star.” ▮

Solar system

Mars may be volcanically active

Matthew Sparkes



NASA/JPL-CALTECH/ARIZONA STATE UNIVERSITY

Signs of volcanic gases have been seen at this volcano (centre, red)

SIGNS of fresh fissures and gases often produced by magma suggest the Red Planet could be volcanically active. This may be good news in the hunt for life, as a continuous heat source would be needed to keep microorganisms safe from frigid temperatures on the surface.

Scientists have seen evidence of volcanoes on Mars in the past few million years, but no evidence of lava flows or current eruptions had previously been found.

In 2019, the ExoMars Trace Gas Orbiter detected evidence of hydrogen chloride (HCl) in Mars’s atmosphere. That gas is commonly associated with magmatic vents on Earth, and researchers wondered if the same were true on Mars.

Now, Daniel Mège at the Polish Academy of Sciences and his colleagues have looked at the little data available – just 15 recorded instances of the gas – alongside new photographs of the surface. They were able to link recent, narrow fissures in Mars’s Alba Mons region to the HCl emissions, providing strong evidence of underground lava flow (*Science Advances*, doi.org/hcq7kx).

To assess whether the HCl could have come from the fissures, the team modelled the wind direction at the time the measurements were taken.

“We have 2 kilometres of wind between them, and in this season, there are a lot of dust devils. So, the atmosphere is turbulent. It’s an enormous mess,” says Mège.

Nicolas Thomas at the University of Bern, Switzerland, another team member, says that until the area is investigated up close, there will always be doubt about the source of the gas. But, he argues, this finding makes the case for further surface exploration of Mars.

Thomas thinks the finding makes the prospects for life on Mars more likely. “We know that Mars, even at the equator, can be –70°C, –80°C at night. It’s a very harsh environment,” he says. “If this thermal source were constant and continuous, then you have to admit it’s improving the situation [in terms of the hunt for life].”

“This is definitely a highly interesting finding,” says Lena Noack at the Free University of Berlin. “Many scientists working on Mars will not be too surprised, as the picture of a ‘dead’ Mars was inconsistent with many recent research findings.” ▮

Climate change

What causes mega heatwaves?

An unexpected feedback loop that is currently not included in climate models helps to explain why the world is experiencing record-shattering heatwaves, finds **Madeleine Cuff**

MID-LATITUDE regions such as Europe are set to suffer more intense heatwaves than previously thought, according to new research that has uncovered a three-way feedback loop that amplifies extreme heat conditions.

Heatwaves across the world have shocked scientists with their scale and severity in recent years, with heat extremes dramatically outstripping both historical records and the predictions of climate models. For example, in the UK in 2022, temperatures exceeded 40°C (104°F) for the first time in history, despite predictions that such a milestone was probably still years away.

10%
The temperature increase of mega heatwaves from the feedback loop

Researchers have been scrambling to understand why very extreme heat is occurring more frequently, and with greater intensity, than expected at this level of warming.

Scientists already knew that high-pressure systems allow more solar radiation to reach Earth's surface, heating up the land. They also knew that higher temperatures dry soils more quickly, removing the cooling effect provided by evaporation, thereby further amplifying heatwaves.

Now, it seems that when temperatures climb high enough, dry soil, high pressure and extreme heat can amplify each other further, with dry soil helping to sustain high-pressure systems in the atmosphere.

"Basically, the soils that are affected by circulation pattern also start to affect back on the circulation pattern itself," says Kai Kornhuber at the International Institute for Applied Systems Analysis in Austria.



ANDREW WADDISON/WILD KEN HILL/BAV MEDIA/SHUTTERSTOCK

Destructive fires broke out during the scorching 2022 UK heatwave

This three-way feedback effect makes extreme heatwaves 10 per cent hotter than they would otherwise be, according to the research by Kornhuber and his colleagues – a factor not fully accounted for in climate model projections (*Science Advances*, doi.org/rxcj).

This will have serious consequences for our ability to cope with future extreme heat. "Ten per cent hotter or colder can really make a difference between a heatwave and a record-shattering heatwave," says Kornhuber. "We're facing so many critical thresholds in social and biophysical systems that an extra 10 per cent can really lead to temperatures that are then quite damaging."

This may include serious public health consequences, a breakdown of vital infrastructure such as transport links and energy grids, crop failures and the collapse of ecosystems.

As the world warms due to climate change, regions including Europe, Russia, North America, parts of South America and Australia will hit thresholds where this feedback effect is triggered increasingly often. Kornhuber says work is now needed to ensure climate models are properly including this feedback effect when projecting future extremes.

Dim Coumou at the Free University of Amsterdam says the work helps to solve "part of the puzzle" of why heatwaves are outstripping model projections in their severity. "It shows that climate models are not doing a good job in reproducing this feedback mechanism, and that is a concern," he says. ▮

CO_2 is seeping out of Antarctica's permafrost

Gaps in existing climate models go beyond extreme heatwaves (see main story). Indeed, greenhouse gases may be escaping from thawing permafrost in Antarctica – a potentially significant emission source we haven't accounted for.

Over a series of three field campaigns in 2020, 2023 and 2025, Livio Ruggiero from Italy's National Research Council and his colleagues collected hundreds of measurements across Taylor valley – a freezing desert on the edge of Antarctica. The scientists drove a small canister into the ground at each selected site and monitored the gases that percolated up into the device to determine how fast carbon dioxide seeped through the frozen soils.

In 2020, the measurements showed an average of roughly 1.7 grams of CO_2 creeping through 1 square metre of soil every day. By 2025, that rate had grown five-and-a-half fold to 9.5 grams per day (*Global Biogeochemical Cycles*, doi.org/rxcg). "The increase was amazing," says Ruggiero, and entirely unexpected.

Ruggiero and his colleagues speculate that subglacial lakes in Antarctica's interior that have accumulated salt and CO_2 over aeons could be discharging their brines with quickening pace as the continent's glaciers melt, and this salt water may be thawing the permafrost from the bottom up, allowing subterranean stores of CO_2 to escape.

The researchers argue that climate scientists must begin to account for these processes in their carbon budgets for the southern hemisphere.

Syris Valentine

Physics

Particle smasher gets first glimpse into the smallest realm ever explored

Karmela Padavic-Callaghan

WELCOME to the zeptoverse, the world of the unprecedentedly small. A new analysis of data from the Large Hadron Collider has uncovered an extraordinarily rare particle decay that opens the door to this realm and its secrets.

The standard model of particle physics tabulates all known particles and how they interact, but it cannot explain dark matter and dark energy, which fill most of our universe. Consequently, researchers test its predictions in particle collider experiments, searching for signs of new particles and forces.

Now, Paula Collins and her colleagues at the Large Hadron Collider beauty (LHCb) experiment at the CERN particle physics laboratory near Geneva in Switzerland have found the first evidence of a rare decay involving the "beauty quark" particle, which opens a whole new world for these searches (arXiv, doi.org/hcq9zj).

"People have been searching for it for more than 40 years," she says. "Everyone's just over the moon."

Beauty particles are often produced in the LHC's particle smashes, but the researchers focused on a specific process where a beauty quark gets annihilated by an antiquark – its antimatter cousin – and their annihilation produces another particle and antiparticle pair, the electron-like muon and antimuon, which can be detected. This process is exceedingly rare and has eluded experiments for decades.

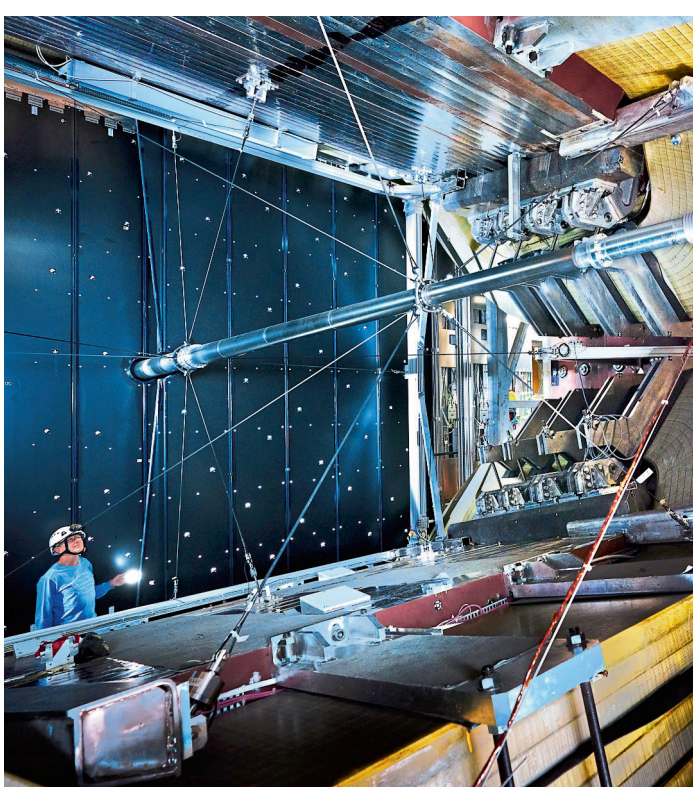
"These very, very rare decays, they're almost impossible according to the current laws of physics," says team member Harry Cliff at the University of Cambridge. "This happens only for 1 in 10 billion beauty particles."

The finding is still preliminary, with relatively large uncertainties and a significance level of 3.2 sigma, while the gold standard for a discovery is 5 sigma. This means the chance that the signal in the experiment occurred randomly instead of being meaningful is about 0.3 per cent.

Exotic particles

Cliff says future experiments ought to lower this uncertainty, but the data already reveals that we have reached the zeptoverse, a world at scales as small as sextillionths of a metre – the smallest ever explored. Undiscovered denizens of this world could influence the beauty particle decay process and because the process is so rare, researchers would immediately spot that change, says Collins. In this way, measuring this process is like surveying the zeptoverse, which could hide exotic particles similar to the Higgs boson.

"It was really a surprise that the team would be able to see this very rare event," says Jure Zupan at the University of Cincinnati in Ohio. He says this was made possible by technical upgrades that the LHCb team has made in recent years. According to Collins, LHCb can currently process about 40 million particle events every second and the amount of raw data it reads out is roughly equivalent to 2 per cent of the global internet bandwidth. The researchers used machine learning techniques to process and analyse this tremendous amount of particle data.



BRICE, MAXIMILIEN/CERN

The Large Hadron Collider beauty experiment at CERN spied the decay

"It's like a very powerful microscope where now you're able to see much shorter distances because you don't have a fog in front of your eyes," says Zupan.

LHCb can now access effects that it otherwise could not see without increasing the energy of its particle smashes, which would require big technological changes, says Zoltan Ligeti at the Lawrence Berkeley National Laboratory in California. "There is a widening observation window. It's absolutely exciting," he says.

This process is not only ultra-rare, but mathematical theories predict it very well, so investigating it makes for a particularly important test of the standard model, says Cristina Lazzeroni at the University of Birmingham in the UK.

Although the new measurement is consistent with the standard model, Ligeti says this doesn't mean that all possible new particles have been ruled out. In his view, the new measurement implies that the effects of such particles must be small but not necessarily negligible and LHCb could quantify this further going forward. "What they measured is very interesting, but I think even more interesting is the promise [of future experiments]," says Zupan.

"These very rare decays, they're almost impossible according to the current laws of physics"

Cliff, however, is worried about the future of the team's research because last year the UK government withdrew funding from a planned LHCb upgrade. "We are now really scrambling to figure out will we be able to continue doing this sort of research," he says. ▮

Ancient humans

Early Neanderthals may have made huge knives as a flex

Christa Lesté-Lasserre

MORE than 300,000 years ago, hominins in Britain were crafting huge, skilfully shaped handaxes whose primary purpose may have been for showing off.

"It seems they're [the giant flint axes] meant to visually stand out and be appreciable to other group members as something unusual and interesting to look at," says Malaika Standley Barrow at University College London. "So there's definitely some prowess or something."

Ficrons are Stone Age handaxes carved from flint with curved sides, rounded bases and remarkably pointed tips. Most ficrons are similar in size to other handaxes from this period, measuring about 8 to 15 centimetres long, and probably worked as cutting or butchering knives. But a few stand-out ficrons exceed two or even three times the usual length and 10 times the weight.

To find out what purpose they might have served, Standley Barrow and her colleagues examined 817 ficrons and other handaxes from seven archaeological sites across southern Britain. Among those tools were seven giant ficrons measuring at least 22 cm long.

3D scans and measurements revealed that six of the seven giant ficrons had extremely exaggerated proportions compared with smaller handaxes from the same sites. The giant handaxes also tended to be more symmetrical and have straighter edges than smaller versions, suggesting they were crafted with more skill and precision. This means these larger axes weren't simply scaled-up versions of standard ficrons, but probably deliberately crafted to be visually distinct, says Standley Barrow.

The researchers then commissioned experienced flintknappers to make 10 giant and 10 normal-sized replica ficrons from British flint. Next, they had 20 students use the replicas to cut through 10 pieces of rope, first with a normal-sized ficron, then with a giant one.

> "They're meant to be appreciable to other group members as something unusual"

Knappers like James Dilley at Ancient Craft in Norfolk, UK, found the giant ficrons especially challenging to make, particularly the fine tip. "You need a lot more skill and experience to make one of these." On average, knapping a giant ficron took about 45 minutes, compared with about 20 to 30 minutes for smaller ficrons, he says.

Yet there seemed to be no practical benefits for this extra work: on average, the students took 22 per cent more time cutting the rope with giant ficrons, often resorting to using two hands to manoeuvre a heavy knife (*Journal of Archaeological Science: Reports*, doi.org/rxg7). For butchering or digging, pressure on the blade would probably break the tip quite easily, Standley Barrow adds.

Even so, it is possible the blade could have been used both ceremoniously and practically for delivering a killing blow to a wounded prey, she and her colleagues argue.

Luke Dale at Durham University, UK, finds that concept particularly compelling. The giant ficrons could have had limited practical use in a culturally important role and hold a prominent social function, he says.

The age of the tools suggests they were probably made by early Neanderthals. ▮



BRITISH MUSEUM AND THE SEASIDE MUSEUM, HERNE BAY

Giant ficrons require a lot of skill and experience to make

Physics

Tiny magnet could be fastest spinning visible object

Karmela Padavic-Callaghan

A MINUSCULE magnet that levitates within a superconductor trap may be the fastest spinning object visible to the naked eye, and one of the fastest spinning objects ever made.

Superconductive materials conduct electricity with perfect efficiency and expel any magnetic field that tries to permeate them. Because of this, a magnet placed above a superconductor experiences repulsive magnetic forces and starts to levitate. Tao Wang at the Agency for Science Technology and Research in Singapore and his colleagues have now set one such levitating magnet spinning at an unprecedentedly fast rate.

The researchers used a spherical magnet made from neodymium, iron and boron that was about 30 micrometres wide, similar to the width of a fine human hair. They placed it in a cylindrical container made from lead, then enclosed that container in a vacuum chamber.

Next, they used liquid helium to cool the set-up to around -269°C. In these extreme circumstances, lead behaved as a superconductor and the lack of air meant that the magnet could levitate without bumping into any particles. A magnetic coil spun the magnet, pushing this tiny rotor to 138 million revolutions per minute (*Science Advances*, doi.org/rxg5).

"This, so far, is the fastest magnetically levitated rotor," says Wang. The fastest rotating human-made object was also a levitated sphere, but that one was nano-sized, so invisible to the naked eye, and levitated by laser beams.

As the rotor experiences basically no friction, and it is magnetic and cold, its behaviour is very sensitive to its environment, which makes it a promising sensor. The team has successfully tested it as a gauge of vacuum at very low temperatures. Wang says this may be useful for builders of quantum computers. ▮

Technology

The deadly return of landmines

3D printing and drones have helped mines become a key weapon in the Russia-Ukraine war

David Hambling

ANTIPERSONNEL (AP) mines seemed to be on the way out in 1997, when 122 countries signed the Ottawa Treaty to ban them. But now such mines are making a comeback on both sides of the Russia-Ukraine war.

"These things are both cheap to produce and offer a level of sophistication that actors couldn't hope to reproduce for a hundred times the price only a few years ago," says Seán Moorhouse, an explosive ordnance disposal consultant.

AP mines come in two forms. Blast mines are typically scattered by aircraft. Activated by pressure, they are designed to maim. Larger fragmentation mines, laid by combat engineers, have tripwires and spray lethal fragments in all directions.

Three technologies have enabled the resurgence of AP mines in Ukraine, says Moorhouse: 3D printing, microcontrollers and drone delivery.



SERGEY BOBOK/AFP VIA GETTY IMAGES

A deminer in Kharkiv, a region of Ukraine that is now littered with mines

3D printing enables any frontline unit to produce its own mines. Different shapes, sizes and colours proliferate, making mines harder to spot.

Fragmentation mines can be triggered by microcontrollers connected to sensors rather than tripwires. In Ukraine, the most common type is magnetic and sensitive enough to be set off by a rifle carried nearby. Doppler microwave sensors detect movement; others sense body heat or vibration. A new variety is triggered by the approach of any Bluetooth device.

Drone delivery of both blast and fragmentation types has been transformational. Drones slip far behind the lines to place mines precisely on tracks and paths, or around trenches, giving a greater chance of finding a victim than random scattering.

The combination of these technologies makes mines both deadlier and more accessible. "The triad of drone delivery, 3D printing and microcontrollers will proliferate worldwide," predicts Moorhouse. Networks of soldiers and volunteer groups produce mines in garage workshops in Ukraine and Russia. The technology is easy to replicate.

"These simple devices can be rapidly produced by any group with access to explosives, enabling a significant expansion of mine warfare," says Roy Gardiner at the non-profit group Defense Tech for Ukraine.

AP mines threaten civilians for decades after a conflict. When the Ottawa Treaty was signed, this lasting danger outweighed any military value. The calculus seems to have changed. Ukraine suspended its implementation of the treaty, and others – Poland, Finland, Latvia, Lithuania and Estonia – have withdrawn. Russia never signed the treaty.

He says demining agencies need to act urgently to adapt to the challenges of new AP mines and update their training programmes. Technology may mitigate the problem, with AI-enabled drones beginning to play a role in mine detection and disposal. But Moorhouse warns the risk from AP mines is growing rather than shrinking. ▮

Health

Electricity-emitting toothbrush may help fight plaque

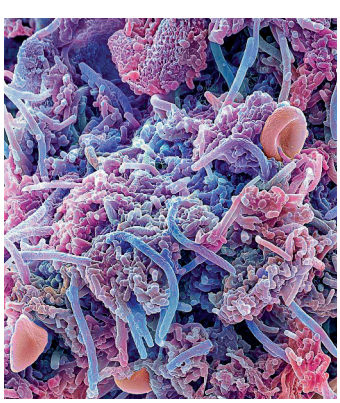
A TOOTHBRUSH that generates electricity may more effectively fight harmful bacteria, while removing plaque, than existing products.

Brushing regularly can help remove plaque, a sticky layer of bacteria that forms on teeth. These bacteria can produce acids that cause cavities and irritate gums, sometimes leading to tooth loss. But even thorough brushing can leave behind bacteria, allowing colonies to grow back within hours.

Previous research has shown that so-called piezoelectric materials, which generate electric charges under pressure, fight bacteria in infected wounds and medical implants. This inspired Yanhui Lu at Peking University in China and her colleagues to develop toothbrush bristles made from piezoelectric plastic.

The idea is that, as the bristles bend, they generate electricity, triggering chemical reactions that produce molecules called reactive-oxygen species that damage bacteria, while the bristles physically remove plaque.

The researchers made two sets of bristles of different thicknesses. Tests confirmed the bristles generated electricity under pressure, particularly the thicker ones. The team also detected reactive-oxygen species on the brushes.



STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY/ALAMY

Plaque-forming bacteria often get left behind after tooth brushing

Next, the researchers exposed two common oral bacteria to their bristles and nylon ones, which are used in standard toothbrushes. The thicker piezoelectric bristles were particularly effective, killing about 53 per cent of *Streptococcus mutans*, which causes cavities, and 78 per cent of *Porphyromonas gingivalis*, which contributes to gum disease. This compared with just 9 and 8 per cent, respectively, for nylon bristles (*Science Advances*, doi.org/hcq9j3).

"The concept is great," says Nicholas Jakubovics at Newcastle University in the UK. "Anything that even slightly improves the way dental care works could have a benefit, because oral disease is just so widespread." ▮

CL-L

Health

Covid vaccines had big return on investment

Shosha Adie



XINHUA/SHUTTERSTOCK

The covid-19 vaccines protected public health and the economy

THE covid-19 vaccines may have provided health and economic benefits worth up to $64.3 trillion in the first year alone – almost double an earlier estimate. Previously, researchers calculated that the $79.4 billion invested in developing covid-19 vaccines saw a return of between $4.8 trillion and $37.9 trillion globally in the first 12 months after their rollout. But now, a reanalysis of the data suggests it is actually between $6.43 trillion and $64.3 trillion.

The $6.43 trillion figure is based on a cost-effectiveness analysis that is generally used in the health sector and factors in quality of life, while the $64.3 trillion figure is based on a cost-benefit analysis used in the public sector (*PLOS Medicine*, doi.org/hcq9z8).

Both include data from 173 countries on lives saved, averted hospitalisations and productivity. For instance, one estimate Hallie Benjamin at the London School of Hygiene & Tropical Medicine and her colleagues used came from modelling that suggested the vaccines prevented 14 million to 20 million deaths in their first year.

The initial $4.8 trillion and $37.9 trillion figures were released when the research was in a preprint stage, before it had been peer-reviewed. Changes made during the peer-review processes "strengthened the quality of our findings", says Benjamin.

The researchers originally used the Value of Statistical Life Years, which considers how many years a person would be likely to live because of the vaccine, a figure that would be lower if someone was older. As part of the peer-review process, they were advised to instead use the Value of Statistical Life. Team member Mark Jit at New York University says this treats life spans more equally and is aligned with recommendations for valuing mortality-risk reductions.The cost-benefit analysis figure also increased significantly due to a change from calculating the economic value of avoiding a death, says Jit.

Richard Carpiano at the University of California, Riverside, says we already knew the covid-19 vaccines were a "life-saving success", but this study reinforces that "protecting the public's health is protecting the economy". ▮

Mind

Zapping brain temporarily helps you think harder

Michael Le Page

STIMULATING the part of the brain linked to our motivation to make a mental effort may help us excel at a difficult task. But there is a catch: you could become more mentally fatigued afterwards.

Hongmei Xia at the University of Munich and her colleagues put electrodes on the heads of 31 volunteers with no known health conditions. During a half-hour session in an MRI scanner, the participants spent 20 minutes doing the 3-back memory test, where you have to remember and identify the third item back as an ongoing sequence is presented to you – a very demanding mental task. They were then offered €1 for doing an easy test or €2 for a harder one.

During the 3-back memory test, the electrodes delivered transcranial direct current stimulation (tDCS) to a region of the brain called the dorsolateral prefrontal cortex to randomly chosen volunteers, who were unaware they were receiving it.

Other studies have shown the dorsolateral prefrontal cortex is involved in controlling the cognitive effort we make.

The volunteers who had tDCS reacted faster and more accurately than those who didn't receive this stimulation. For instance, their average reaction time was 0.98 seconds, compared with 1.12 seconds with sham stimulation.

"Volunteers who had brain stimulation reacted faster and more accurately"

"Their performance is much better; however, this good performance comes with lower motivation in the end," says Xia.

Xia thinks stimulating the dorsolateral prefrontal cortex will boost brain performance generally. "I can imagine any cognitive task will be better, but afterwards you will feel more fatigued," she says.

After the tests, the volunteers who got tDCS had higher levels of the neurotransmitter glutamate in their dorsolateral prefrontal cortex, according to a non-invasive technique called magnetic resonance spectroscopy. The higher their glutamate levels, the more likely they were to choose the €1 task over the €2 one (*PNAS*, doi.org/hcq4bk).

Some researchers think mental fatigue is a result of the buildup of glutamate, which can harm cells at high levels. Xia thinks her team's findings are the strongest evidence of this yet. The findings suggest it is important to take a break when you feel mentally tired, she says.

"I think the claim that the stimulation made people 'work harder' is well substantiated," says neuroscientist Emile Radyte at Samphire Neuroscience, a UK-based company exploring the use of tDCS to treat conditions such as premenstrual syndrome. But the study doesn't prove that higher glutamate levels were the cause of the greater mental fatigue, she says.

It is a good study, says Nilli Lavie at University College London, but the greater mental fatigue could be a result of using more neural energy, rather than the buildup of glutamate. It's also hard to precisely target the dorsolateral prefrontal cortex with tDCS without an MRI scanner to guide you, says Lavie. "Drink coffee instead," she says. ▮

Archaeology

Iron Age 'king' was probably a woman

Historians assumed that Verica, a British ruler who prompted the Roman invasion in AD 43, was a man, but there are clues suggesting they got it wrong, finds **Michael Marshall**

KING Verica is one of the central figures in early British history. Verica convinced the Roman emperor Claudius to launch an invasion, setting in motion the Roman Empire's conquest of Britain. Except a new analysis suggests we have long misread Verica's gender and she was actually female.

Our knowledge of Verica comes from two main sources. The first is Iron Age coins from England, which bear the name "Verica". The other is the Roman historian Cassius Dio, who in the early 200s AD wrote a history of Rome. Cassius Dio records that a Briton called Berikos fled the island following an uprising and went to the Emperor Claudius to ask for help. Most historians agree that this was Verica and that Cassius Dio slightly mangled the name.

Britain became a Roman province for several centuries following Claudius's successful invasion of Britain in AD 43.



CHRIS RUDD LTD.

Coins found in southern England show Verica on horseback

In his forthcoming book *Caratacus: Great king of Britain*, and in a summary article published in *Current Archaeology*, Miles Russell at Bournemouth University in the UK presents several lines of argument that Verica was a woman.

The first point is Verica's name. In Iron Age Britain, names that end with "a" are usually female, like Boudica of the Iceni, while names that end in "os" or "us" are typically male. "It's not a clear-cut rule," says Russell, but it applies to "about 95 per cent of Iron Age British names".

Secondly, coins bearing Verica's name tend to show images of female warriors on horseback, says Russell. "Verica's images are all female warriors," he says.

Meanwhile, there is little or nothing specifying that Verica was male. Verica's coins sometimes have the inscription "COM F" or "COMMI F", which has been interpreted as *Commios filus* or "son of Commios". However, argues Russell, it could just as easily be *Commios filia* or "daughter of Commios".

"In Iron Age Britain, names that end with 'a' are usually female, like Boudica of the Iceni"

"It's a highly compelling argument," says Katharina Rebay-Salisbury, a prehistoric archaeologist at the University of Vienna. However, she is sceptical of the imagery on the coins, because they aren't anatomically exact: "I find it a bit difficult to differentiate a naked female body from a naked male body in these very stylised images." However, Russell has "multiple lines of evidence", she says.

The idea also fits our emerging understanding of the northern European Iron Age, says Rebay-Salisbury. While the preceding Bronze Age was "highly gendered" and "people differentiated a lot between women and men", she says, in the Iron Age, there was more emphasis on social status rather than gender, so women sometimes held power.

"There are, by now, so many of these instances," says Rebay-Salisbury, yet "people keep being surprised". She wonders: "When do we just accept that this happens on a more or less regular basis?" ▮

Environment

Microplastics could be changing the colour of the Pacific

THE sea around the Great Pacific Garbage Patch is changing colour, and microplastics may be to blame.

The Great Pacific Garbage Patch (GPGP), located between Hawaii and California, covers around 1.6 million square kilometres and is thought to contain nearly 80,000 tonnes of plastic debris.

While most concern about the patch has focused on its impact on sea life and environmental health, three datasets have shown distinct colour changes in the ocean itself.

Shea Cheatham at the University of Bergen, Norway, and her colleagues analysed three satellite datasets collected between 2002 and 2022. The data showed that parts of the GPGP saw an approximately 10 per cent increase in blue light and a 2 to 4 per cent increase in green light over the 20-year period (*Communications Earth & Environment*, doi.org/rwqk).



SHUTTERSTOCK/WONDERFUL NATURE

Ocean microplastic impacts may go beyond sea life and environmental health

To work out what was causing the brightening, the team used computer simulations to test how the ocean's colour would theoretically change if microscopic pieces of plastic were added to the water. They also simulated how the ocean's colour would change from natural things, like more or different micro-algae.

"When we included microplastic particles in our simulations, this pattern we saw near the Great Pacific Garbage Patch of brightening in both blue and green light became more than four times as likely," says Cheatham.

Microplastic particles, in contrast to most natural contributors to ocean colour, do not absorb very much light, she says, but scatter light strongly. "This means that as their quantities increase in the ocean, they cause the ocean to brighten, and this brightening happens most strongly at blue-green wavelengths." ▮

James Woodford

Palaeontology

Oldest-known dinosaur red blood cells discovered

James Woodford

A NONDESCRIPT 115-million-year-old fragment of leg bone has yielded spectacularly preserved red blood cells, which may be the earliest ever found in dinosaurs.

Red blood cells have been found in dinosaur remains in the past, including 75-million-year-old bone fragments collected in Canada in 2015.

Now, Kliti Grice at Curtin University in Perth, Australia, and her colleagues say they have isolated the oldest-ever dinosaur red blood cells from the hind-limb of a theropod dinosaur, *Aratasaurus museunacionali*, found in Brazil in 2008.

The *Aratasaurus* individual studied by the team wasn't yet fully grown, with an estimated body length of just over 3 metres, and weighed about 34 kilograms.

Grice cut thin sections of bone, mounted them onto glass slides and used hydrochloric acid to remove surrounding rock – and she was shocked at what she saw.

"I was jumping up and down," says Grice. "I ran up to my head of school's office and was so excited that he gave me a whisky to calm me down. No one has ever seen dinosaur red blood cells in high resolution before."

The cells she found were abundant: in a single slide, just a fifth of a millimetre wide, there were 20 blood cells. All of the cells were within fossilised blood vessels, providing further evidence that they really were red blood cells.

Liquid chromatography-mass spectrometry analysis revealed the presence of haem B, a constituent of haemoglobin that binds to oxygen, adding molecular evidence of the type of cell.

"I was so excited that my head of school gave me a whisky to calm me down"

The team also had to rule out the possibility of contamination, especially from the sediments in which the fossil was preserved, which were dominated by algae. The cells found outside the bone were dominated by chlorophyll-derived compounds, whereas those inside contained haem-derived molecules, which strongly suggests that the latter cells weren't a result of contamination (*PNAS*, doi.org/rwt8).

The researchers also compared the blood cells to those of the closest living relatives of the dinosaur fossil, birds and crocodiles. The *Aratasaurus* red blood cells are significantly larger. This could indicate that the cells swelled during fossilisation, or that the species grew much bigger than the fossilised specimen.

Susannah Maidment at the Natural History Museum in London says previous studies reporting red blood cells in fossils tens of millions of years old are contentious, with some researchers suggesting they could be the result of bacteria or artefacts of the fossilisation process. "This paper is further evidence that fossilised soft tissues such as red blood cells can preserve over geological timescales," she says.

Grice says the discovery may mean that other dinosaur fossils that have been locked away in museum collections may hold secrets. "There's drawers and drawers of fossil material, which don't look very nice," she says. "This kind of work opens up a whole new opportunity to unlock those collections and bring modern technology and molecular techniques to these specimens." ▮



CURTIN UNIVERSITY



VICTOR O. LESHYK

A fossil (above) from an *Aratasaurus museunacionali* dinosaur (right) harboured a surprise

Environment

Small oil and gas wells have outsized pollution impact

Madeleine Cuff

SATELLITE imagery has revealed that most of the methane pollution from oil and gas infrastructure in the US comes from hundreds of thousands of small wells scattered across the country.

These emissions are a "major underappreciated mitigation opportunity", says Mark Omara at the Environmental Defense Fund, a non-profit organisation in the US.

Together with colleagues, Omara collated methane emissions data covering more than 80 per cent of US onshore oil and gas production, sourced from the methane-spotting satellite MethaneSat, for the period May 2024 to June 2025.

The researchers then extrapolated to estimate methane emissions from oil and gas infrastructure across the contiguous US, establishing emissions rates for different production sites.

They found that marginal wells, which produce less than 15 barrels of oil equivalent per day, collectively contribute about 5 per cent to US oil and gas production. But they are responsible for about 58 per cent of all methane emissions from well sites, and 40 per cent of methane emissions across the oil and gas supply chain.

Compared with high-producing wells, these marginal wells are 10 times more polluting per unit of fuel extracted (EarthArXiv, doi.org/rxg4). "That is a significant contribution from a large population of very low-producing well sites across the country," says Omara.

Tougher regulation of these marginal wells – or even shutting the sites down – offers a quick route to reducing methane emissions in the short term, without significantly denting oil and gas production overall. But Daniel Jacob at Harvard University warns this will be a difficult challenge to address because there are so many emissions sources to deal with. ▮

Peanut allergies may not last

An unexpectedly large proportion of babies with peanut allergies quickly grow out of the condition, but it is unclear what causes the transience, finds **Alice Klein**

MORE than a third of babies who were previously diagnosed with peanut allergies safely tolerated them during subsequent testing. This suggests that a surprisingly high proportion of infants' peanut allergies last less than one year, allowing them to be freed from a lifetime of food restriction and worry.

"Being able to identify those children early allows them to avoid an unnecessary allergy label and the burden of avoiding peanut," says Tim Brettig at Murdoch Children's Research Institute in Melbourne.

Since 2024, Australia has offered free treatment to all babies diagnosed with peanut allergy under the age of 12 months. The treatment, overseen by 10 public children's hospitals across the country, involves feeding small but gradually increasing doses of peanut flour to allergic infants over two years to try to desensitise them, a strategy known as oral immunotherapy.

Before beginning the programme, babies are required to undergo an "oral food challenge" to confirm their allergy and assess its severity. It involves feeding them gradually escalating doses of peanut flour on a single day under medical supervision to see how much they can tolerate. The total given is 2500 milligrams, equivalent to 2 teaspoons of peanut butter. This is "above the threshold where we'd expect all children of this age to react if they have an allergy", says Brettig, the medical lead of the programme.

However, of the first 778 babies with previously diagnosed peanut allergy who undertook the oral food challenge, 35 per cent didn't react to any dose of the peanut flour. This was despite the fact that they had previously developed rashes, swelling, hives or other signs of allergic reactions after consuming peanut-containing foods, and had skin prick or blood test results consistent with a peanut allergy (*The Journal of Allergy and Clinical Immunology: In Practice*, doi.org/hcq6p3).



SHUTTERSTOCK/DMITRIY KOZHANOV

Allergies to peanuts are relatively common in babies, but aren't always lifelong

"We expected a small proportion might pass the food challenge, but not 35 per cent"



SHUTTERSTOCK

"This was a surprising result for us – we expected a small proportion might pass the food challenge, but not 35 per cent," says Brettig.

The parents of these babies were given the good news that their child was no longer considered to have a peanut allergy and didn't need to begin the oral immunotherapy programme. They were also assured that they could safely reintroduce peanuts into their child's diet at home.

The average time between the initial diagnosis of the peanut allergy and the oral food challenge was six months. It is unclear why a third of the infants stopped having reactions in this short window. "It might be that they had a transient allergy, where the immune system has an aberrant response to a food initially, but it doesn't continue to occur," says Brettig.

Previous research has found that roughly a third of children with peanut allergies naturally grow out of them by age 6, but this is the first time a high proportion of peanut allergies have been found to resolve on their own in infants.

Challenging restrictions

The finding will "make a huge difference" to the children whose allergy labels were removed, says Brettig, because they won't have to spend their lives being burdened by restricted food choices, anxiety about accidental exposure to peanut and the need to carry emergency medication. It may also prevent them from developing a true peanut allergy down the track, since peanut avoidance in early life is known to increase the risk of allergies later on, he says.

The results also have wider implications for how peanut allergy is diagnosed and managed, says John Ziegler at the University of New South Wales, Sydney. Peanut allergy is commonly diagnosed based on clinical history and the results of skin prick or blood tests, usually without an oral food challenge.

Routinely conducting oral food challenges would identify those who don't need require treatment, and thus be cost-effective, says Ziegler. "The study confirms the importance of confirmation of the diagnosis of peanut allergy before embarking on oral immunotherapy," he says. ▮

Due to the risk of severe reactions like anaphylaxis, such allergy treatments should only be conducted under medical supervision.

Physiology

Foot-stiffening socks could help you run further for longer

James Woodford

INTRODUCING tight bands in socks around the ball of the foot seems to make walking and running easier. The effects of these socks, which stiffen the feet, are equivalent to the reduced energy expenditure that the average person would experience if they lost 2 kilograms.

Human feet are much stiffer than those of other apes, which has assisted our bipedalism. Owen Beck and Hui Tang from the University of Texas at Austin first wondered if they could take this stiffness further by tweaking footwear. However, previous attempts to reduce walking and running effort using shoes with stiffer midsoles or inserts have failed, so they turned to socks.

They are made of a common synthetic yarn blend, typical of athletic socks. Beck and Tang tightly knitted three 1-millimetre-wide bands at a 30-millimetre-wide region around the ball of the foot. This results in 24 times more pressure being applied to feet compared with regular socks.

To test them, they recruited 12 adults of both sexes who had no known health conditions. The researchers analysed how they walked while wearing the foot-stiffening socks, control socks and no socks.

Participants then walked on a treadmill while wearing shoes with the stiffened socks and control ones for 5 minutes. Beck and Tang measured their VO_2 max, the maximum amount of oxygen the body can absorb during high-intensity exercise. This allowed them to determine how much energy they burned in each of the walking experiments, known as metabolic expenditure.

> "The reduction in metabolic expenditure is equivalent to the average person losing 2 kilograms"

The foot-stiffening socks reduced this expenditure in 10 of the 12 participants by 2 per cent more than the control socks. That is equivalent to the average person losing 2 kilograms, according to the researchers (*Proceedings of the Royal Society B*, doi.org/hcq6w2).

This reduced expenditure probably doesn't mean the socks would lead to wearers getting fewer health benefits, such as weight loss, from walking or running compared with regular socks, says Beck. "Reducing the whole-body metabolic rate means we have better walking endurance, we sweat less during hot days and we can walk faster for the same effort [that we would use] using commercially available socks."

The socks work by enabling the ankle and its muscles to push off at a slower velocity, he says. This requires less activation and less metabolic energy, leading to more economical muscle contractions. Unlike a stiffened shoe, the socks allow the toes to flex and the arch to recoil more freely, he says.

Thomas Püschel at the University of Oxford says the idea that a stiff foot makes walking less metabolically costly has been around for a long time, but nobody had managed to show it in people while they were walking until now. "The team's clever insight was that those earlier attempts [with shoes] also stopped the foot moving when it needs to, right at the end of the step."

The applications of the socks are yet to be tested. But Beck says that, in theory, anyone whose feet have lost some of their shape, say through old age, could benefit. The researchers already have a sponsored research agreement with the shoe company New Balance to commercialise the socks, says Beck.

But, Püschel warns that other explanations for the results cannot be ruled out, such as the volunteers changing how they walked when they knew they had the socks on. ▮

Archaeology

Inca children were drugged before being sacrificed

YOUNG children selected to be sacrificed as part of Inca rituals were given psychedelic and intoxicating substances, possibly to relieve the terror of their imminent death or in the belief that the drugs would help them communicate with the gods.

The Inca kingdom dominated along South America's west coast from the late 13th century until the 16th century.

In a ritual known as capacocha, children and young women were sacrificed to the mountain gods. According to an account by a Spanish friar written in 1590, the capacocha ceremony was conducted to ensure there would be "no famine nor lack of fruits of the earth, nor would there be drought, nor pestilence, nor rebellion".

Dagmara Socha at the University of Warsaw, Poland and her colleagues studied eight frozen, mummified children, seven of whom were girls, discovered between the 1920s and 90s at sites in Peru, Argentina and Chile. They are thought to have been aged between 6 and 14 when they died. It is thought some were killed with sharp weapons, while others were buried alive, says Socha.

The researchers analysed hair and nail samples to determine which psychoactive plants were given to children during the capacocha ritual.



J. REINHARD

Figurines depicting coca leaves being chewed were found with the mummies

Toxicological screening detected cocaine in all the hair samples, along with markers of alcohol and coca leaf chewing in half of the individuals. The team also identified harmine, a hallucinogenic compound found in the ceremonial drink ayahuasca, in one of the nail samples (*Antiquity*, doi.org/rwjg).

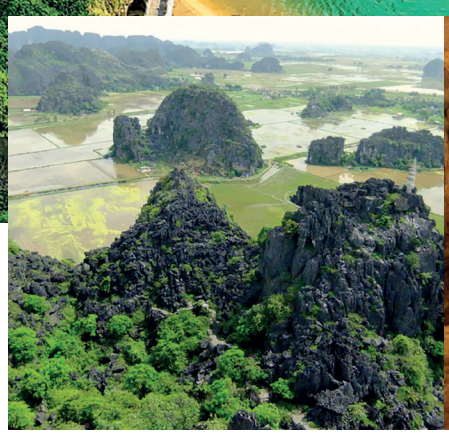
Socha and her colleagues suggest that the antidepressant properties of harmine could have been used to calm the children and maintain a positive mood.

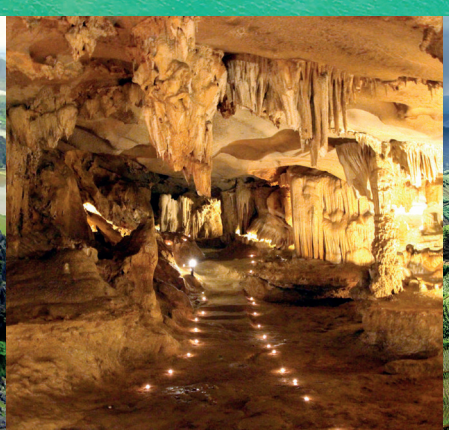
Each sacrifice seemed to be associated with a unique chemical signature preserved in the child's hair and nails. This may indicate that each child was "prepared" in a different way, perhaps to direct their sacrifice towards a specific deity. ▮

JW

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To find out which players were ranked the most suspicious at each round table, scan this QR code

Turing versus *The Traitors* I came up with a mathematical model I hoped would help me win *The Traitors*. Unfortunately, events then got in the way, says **Hannah Fry**



FRAN PULIDO



Hannah Fry is a mathematician, author, science presenter and professor of the public understanding of mathematics at the University of Cambridge

IN THE late 1980s, in Soviet-era Russia, a young psychologist called Dmitry Davydov came up with a game. He called it *Mafia* and originally intended it as a teaching device, a way to demonstrate how a small, informed minority could manipulate the dynamics of a much larger, uninformed group and wield outsized power over those who were left floundering in uncertainty and paranoia.

That game has now evolved into *The Traitors* – a TV show that is a massive cultural phenomenon in the UK. And recently, I found myself in the middle of it.

The premise is simple. A small number of players, the traitors, secretly know who is on their side and get to "murder" someone each night. The remaining players, the faithful, are tasked with working out who the traitors are, voting to banish one suspect each evening. Inevitably, they spend most of their time rounding on innocent people.

When I got the call asking if I wanted to be on the show, of course I jumped at the chance. A game of incomplete information? That's a mathematician's dream, I thought.

The challenge, as I saw it, was to find a way to cut through the uncertainty. All I had to do was monitor the evidence as the game unfolded, use the patterns in people's behaviour to identify the traitors and then just persuade everyone else to vote them out. Bish bash bosh, victory.

I started by combing through every previous series of the UK show, turning the joyful, chaotic mess of the series into a clean, delicious spreadsheet, determined to use all the statistical tricks I had at my disposal. Were there subtle statistical differences in the way traitors and faithful behaved that might give the game away?

It turned out there were. For example, I discovered that traitors often make what I think of as "burn votes". They don't necessarily want to send down an innocent person, nor do they want to persuade others into joining a stampede, drawing attention to themselves in the process. So, instead, they throw their vote away on someone nobody else is voting for.

There were clues pointing in the other direction, too: failing to vote for a traitor on the night they are banished turned out to be a good signal that someone is faithful.

As far as I could tell, there were no surefire ways to identify someone as a traitor. The faithful are so unpredictable that anything suspicious could almost as easily have been done by an innocent player. But even so, buried in the noise, there were some signals that could accumulate over time.

Fortunately, there is a neat mathematical way to combine lots of weak evidence together – and it just so happens to have been used by Alan Turing to help crack the enigma code in the second world war. So, inspired by Turing, with a little help from our mutual friend Thomas Bayes, I set about building a Bayesian model that I could bring with me into the castle.

It's actually pretty simple: a points system that lets you update the odds of someone being a traitor as you go. The scores came from what had happened in previous series, and are mainly based on voting patterns. +0.47 for a burn vote. -0.83 if you fail to vote for a traitor on the night they go down.

Unfortunately, there was one rather significant problem with my plan: they made me a traitor. I went back to my room and sobbed into my spreadsheets.

Still, I'm not about to let the small matter of being made a traitor get in the way of a good mathematical experiment. So, now that the final has aired and I know the way that the votes fell, I can finally run the numbers to see how the model would have played out.

And I'm delighted to say that the maths worked. At every single round table, the maths has a traitor as top, or joint top. Not every innocent player escaped suspicion, and the model certainly wasn't infallible. But there really are signals buried in that noise, and you can use maths to detect them.

The trouble is, a mathematical model has one huge advantage over a contestant on *The Traitors*. It doesn't have to convince anyone to trust it. It doesn't have to worry about being murdered or defend itself against accusations. And so, even if I'd been a faithful, I suspect there was never any realistic chance of putting the mathematics to use within the game itself. Because, as *Mafia* was designed to demonstrate, the real power in a game like this isn't just knowing the truth, it's being able to shape what everyone else believes.

Signals and their suspicion score

Type of signal	Score*
Burn vote (voted for someone nobody else voted for that round)	+0.47
Votes for the banished traitor for the first time	+0.40
Named on a revealed traitor's past votes (excluding traitor-banishment nights)	-1.69
Was last in at breakfast with a revealed traitor	-1.73

SOURCE: HANNAH FRY

*LOG-LIKELIHOOD RATIO

Too hot to handle Will frogs really boil to death if their environment warms too slowly to notice? While it is considered a myth, the frogs in **James Woodford**'s backyard suggest otherwise



James Woodford is a reporter at *New Scientist* based in Sydney, who mainly writes about nature, ancient humans and palaeontology

James's week

What I'm reading
Anthony Doerr's book Cloud Cuckoo Land*, a lovely weaving together of science fiction, history and personal redemption*

What I'm watching
World War II *With Tom Hanks*

What I'm working on
Several stories

THE boiling-frog tale is too good an allegory for our modern times to ignore. It goes like this: frogs will obliviously stay in water as it gradually warms until they eventually boil to death, blissfully unaware that their environment has become incrementally deadly.

As a metaphor, it is almost as frequently cited as a parable for our times as it is decried as a ridiculous myth. As a journalist who has spent decades writing about the natural world, I'd always heard that it wasn't true. Or is it?

I am here to break some news – I have personal, first-hand, long-term evidence that frogs will indeed stay in water as it slowly heats until they die.

On my property in New South Wales, Australia, I have installed an outdoor timber hot tub. It's a new-fangled hot tub: instead of chlorine, the water is kept clean and chemical-free using ozone and a UV lamp. I heat the water using a wood fire and it is an extremely slow process.

From day one, I have had to share the tub with my local frog species, Peron's tree frogs (*Litoria peronii*). Sure, I initially worried about what would happen to my companions, but I believed that the boiling frog syndrome was unscientific. So, I decided to soak away my concerns.

But in the early days of having the tub, I would find dead frogs floating, splayed out with rigor mortis and ghostly white in the hot water.

So now, each day, before I light the fire, I catch every one of the hot tub squatters, moving them to an actual frog pond nearby. And then, at frequent intervals during the heating process, I check for stragglers.

So, what is going on? A quick search reveals that the science on which the boiling frog story is based stems mostly from a series of bizarre 19th-century experiments. For example, in 1875 a scientist called Carl Fratscher showed that frogs stayed put when the water they were in was warmed from 20°C to 38°C (68°F to 100°F) over 2 hours and 15 minutes. But when a large flame was used to raise the temperature from 26°C to just 29°C (79°F to 84°F) in a mere 5 minutes, they tried to escape.

This doesn't seem to have been rigorously tested since, and it is easy to see why such an experiment wouldn't be conducted today. One researcher commented, when approached for this story, that they "hope no one has knowledge of this, as it's not the sort of experiment you'd easily get past an ethics committee".

Despite Fratscher's upsetting experiments and my hot tub observations, Jodi Rowley at the Australian Museum in Sydney says the frog-boiling myth is just that. "It's a well-quoted saying, but in most situations, frogs would perceive the increase in temperature, become more active and likely jump out of the water," says Rowley. "In fact, frogs are highly sensitive to even small, gradual changes in temperature in both the lab and the field, and are some of the first animals to respond to climate change."

Marco Gallio at Northwestern University in Illinois, inspired by the boiling-frog parable, studied fruit flies to see what happened when they were slowly heated.

"Our work shows that the fly brain has circuits that are especially tuned to respond to rapid, but not slow, temperature change and that alert them to escape even before the conditions reach physically dangerous limits," says Gallio.

He and his colleagues believe these results are generalisable to other species. But he, too, thinks that frogs will eventually escape if it becomes dangerous.

Which leaves me caught between a frog and a hot, wet place. I know what I know and, at my property, the boiling-frog parable is very real. I am stuck in a *Groundhog Day* loop, catching frogs each morning to save my amphibious tub buddies from themselves. ▮



Peron's tree frogs after being rescued from James's hot tub

JAMES WOODFORD

Facing the facts Your body uses collagen to give your skin strength and elasticity, so supplements seem to make sense to reduce wrinkles. But **Alice Klein** finds it isn't this simple

WHILE I was writing my forthcoming book on the science of the skin, the number one thing that friends asked me to look into was collagen supplements. Do they really reduce wrinkles as promised? As a 40-year-old with increasingly crinkly skin, I wanted to know the answer to this, too, so I spent a long time poring over the evidence and interviewing skin scientists and doctors.

Collagen is the major structural protein in our skin, forming a strong but flexible woven network of fibres. As we age, our skin produces less collagen to maintain this structure, leading to sagging and wrinkling.

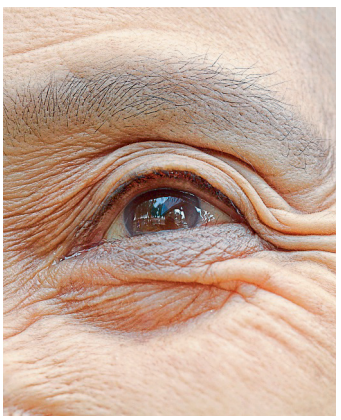
The logical solution to declining collagen levels is to top them back up, which is the basis for taking collagen supplements. However, I discovered that it isn't that simple, because taking in collagen through your mouth doesn't magically transport it to your skin.

Collagen for supplements is usually sourced from the skin of cattle, pigs or fish left over from meat and seafood processing. It is treated with chemicals to chop the collagen proteins into smaller bits that are easier to process into pills and powders. Whole collagen is made of three protein chains of more than 1000 amino acids each, arranged as a triple helix, whereas

"Taking in collagen through your mouth doesn't magically transport it to your skin"

processed collagen that is used in supplements, called hydrolysed collagen, contains single chains of 40 or fewer amino acids.

When we ingest hydrolysed collagen, our digestive systems break it into even smaller fragments of just one to three amino acids. These tiny fragments add to a pool of amino acids that we get from other proteins in foods like meat, dairy and legumes. The skin uses these amino acids as building blocks to make new collagen.



FANGXIANUO/GETTY IMAGES

Can collagen supplements really reduce the appearance of wrinkles?

But James Varani, a pathologist at the University of Michigan, and his colleagues found that our skin does not lose collagen with age because it lacks the ingredients for making it. Instead, its cellular machinery for assembling these ingredients into collagen becomes less efficient. That means that taking collagen supplements to fix wrinkles is like buying more sugar to fix a broken assembly line at a chocolate factory.

Plenty of studies claim to show that collagen supplements smooth away wrinkles, but they need to be taken with a grain of salt. Some, for example, report significant reductions in wrinkle depth in participants taking collagen supplements compared with those taking a placebo, but if you look at their actual numbers, the difference is a fraction of a millimetre.

In September, dermatologist Anjali Mahto at clinic Self London and biostatistician David Grimes at Trinity College Dublin published a paper highlighting "substantial methodological concerns" in existing studies of collagen supplements that "temper [their] optimistic conclusions". They also noted that "an overwhelming proportion of studies are industry-funded or involve authors with commercial ties to collagen manufacturers, raising concerns about selective reporting and bias".

It's disappointing that collagen supplements don't live up to the hype, but there are some other collagen-optimising strategies with better evidence to support them, including regular exercise, which has been found to increase the expression of collagen genes. Every dermatologist I have ever interviewed has also stressed the importance of sun protection, because it is well established that ultraviolet radiation from the sun stimulates the release of enzymes in the skin that chew up collagen.

One of the most promising treatments I have come across is a gene therapy that was developed for people with low collagen levels due to a rare genetic condition called recessive dystrophic epidermolysis bullosa. The disease is characterised by extremely fragile skin and large, painful wounds.

The gene therapy, which introduces new collagen genes into the skin to enhance collagen production, was approved in the US in 2023 and in the UK this year for people with this condition. Now, a modified version is being evaluated in clinical trials involving people with aged skin to see if it has rejuvenating effects.

Our desire for younger-looking skin is largely driven by vanity, but as I also explore in my book, there is growing evidence that the health of our skin directly affects the health of our inner organs, which is another reason to look after it. I've decided not to waste my money on collagen supplements, but I have invested in a very dorky wide-brim hat, to at least try to protect the collagen I still have. ▮



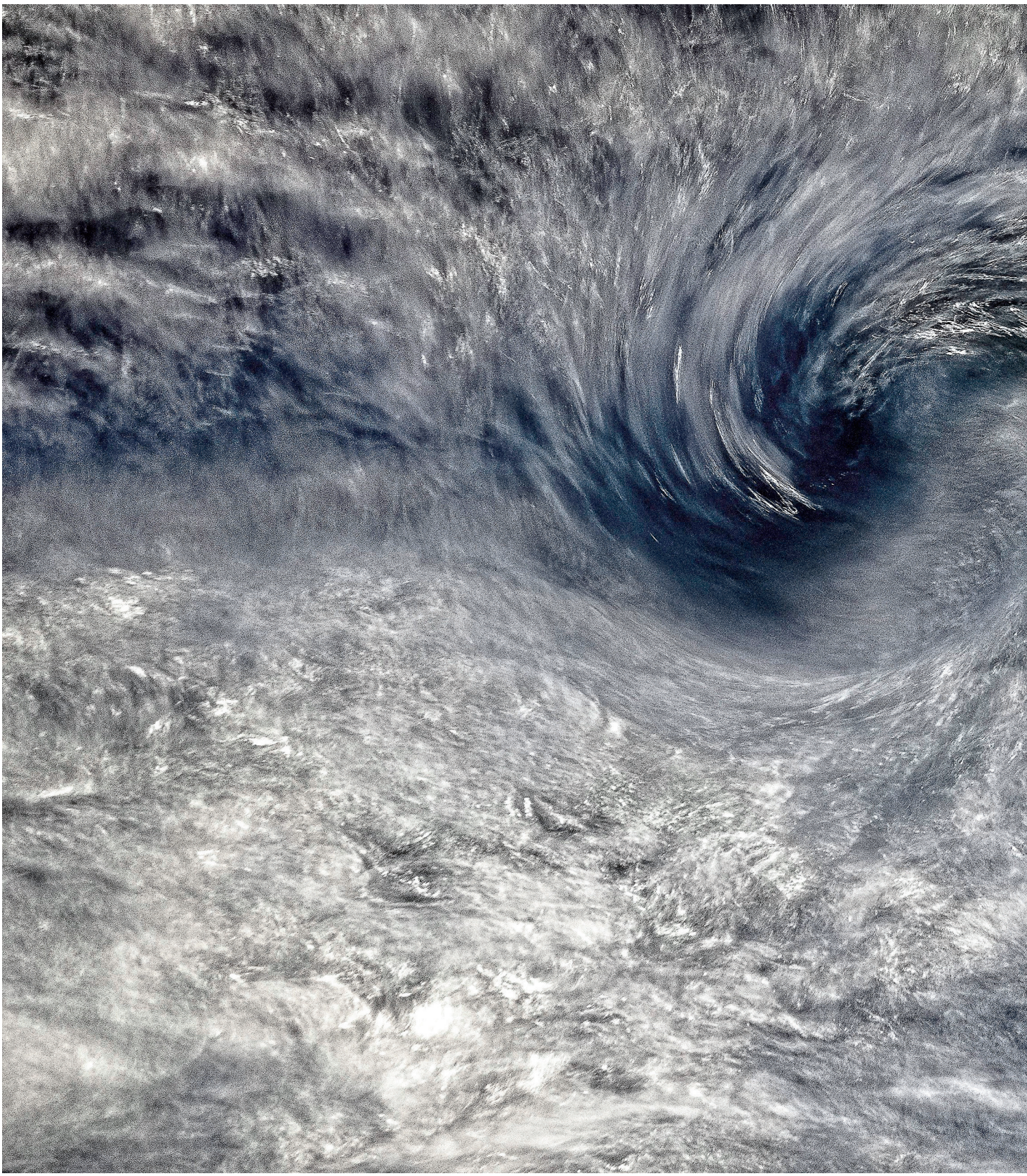
Alice Klein is a reporter at *New Scientist* based in New South Wales, Australia, who mainly writes about health and medicine. Her book *Skin Deep: How skin works, and why it matters* is out in January 2027

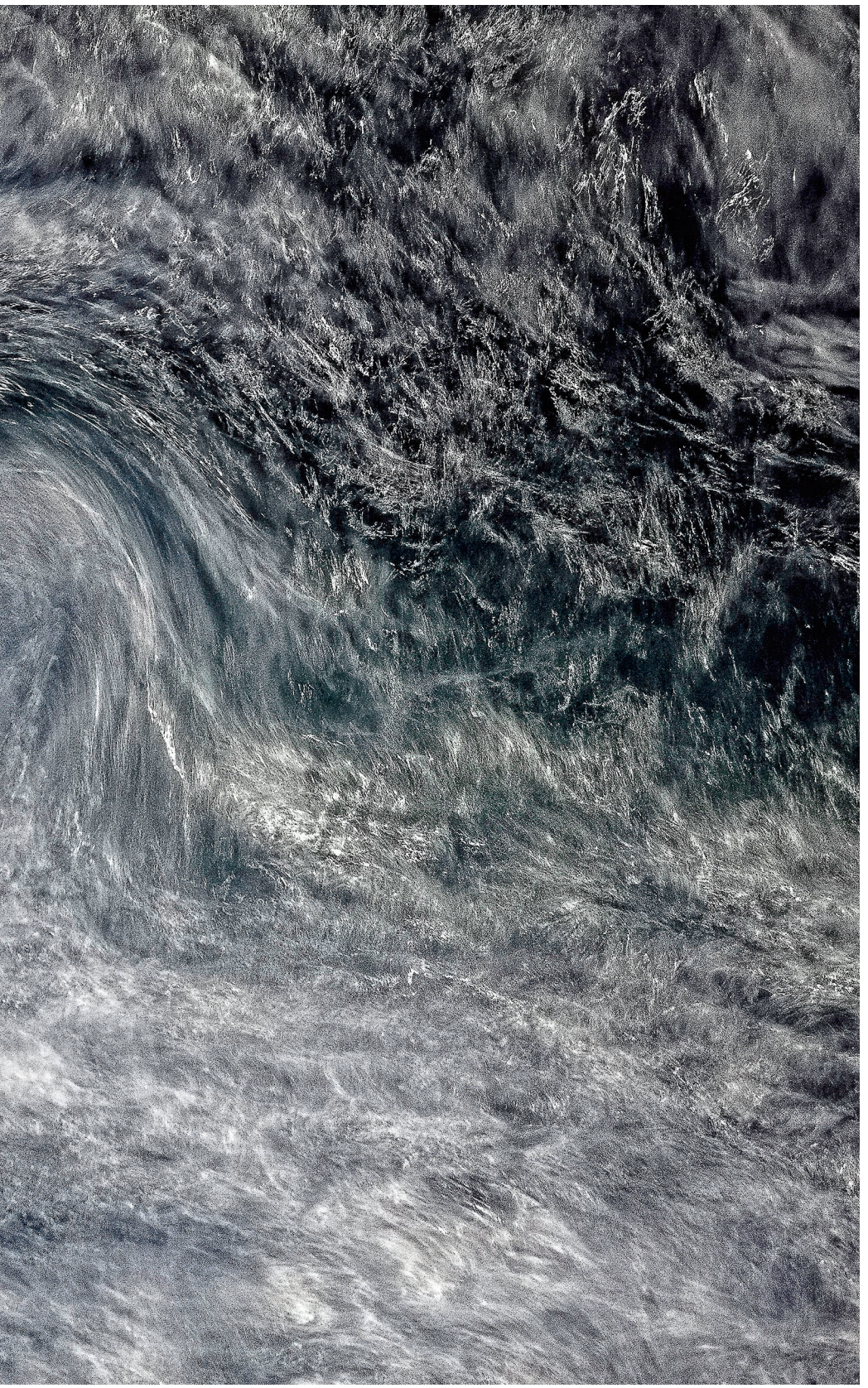
Alice's week

What I'm reading
I'm devouring post-US midterm election analyses

What I'm watching
Kylie, *the Netflix documentary about Kylie Minogue*

What I'm working on
An article about a new balding treatment





Light wave

Prix Pictet
Tom Fecht

ON THE edge of twilight, the surface of the sea glows. Millions of tiny dots produce an eerie blue light, barely visible to humans. Each one is a single plankton shining with bioluminescence, and the dots' light blurs together as the waters churn around them.

Tom Fecht captured this image in Brittany, France, looking down into the Atlantic Ocean under a bright moon. The luminescence of the plankton is dim, so his first attempts to catch it resulted in nothing but darkness. "I figured something must be going on which you couldn't see with the naked eye, so I just blindly started opening the shutter every time a wave broke," says Fecht. Finally, he captured the light from the plankton mixing with reflections of moonlight in a churning wave. He titled the image *Lucifer's Vortex* after the compounds, called luciferins, that generate this light.

While these plankton aren't officially endangered – no plankton species is, in part due to the impossibility of tracking them individually – their future is highly uncertain. Warmer waters force them to migrate polewards and, in some places, die off, their access to nutrients blocked by changing ocean currents.

The word "luciferin" comes from the Latin for "light-bringer", and Fecht hopes the plankton's otherworldly glow also brings light to the plight they face. "If you want to engage in protecting nature, you first of all need an understanding of its beauty," he says.

This image is part of the touring *Storm* exhibition from the Prix Pictet award, on view at Fotografiska Shenzhen in China until 29 November.

Leah Crane

Losing touch

A new book argues that we are outsourcing our thinking to AI, with dangerous consequences for our brains. **Tom Knowles** weighs up the evidence

Book
The Collision
Eric C. So
W. W. Norton
US: out now; UK: out 20 November

IT WAS the type of question that Eric C. So had posed to his class for years. As a professor of behavioural economics at the Massachusetts Institute of Technology, So liked to ask his students what impact they believed technology was having on our way of thinking.

But this time, before he could even finish asking the question, a student raised her hand. "I just ChatGPT'd it," she said, before reading out the answer the AI chatbot had given. When So asked her what she thought, the student seemed genuinely puzzled. ChatGPT's answer was now what she thought.

"She couldn't distinguish between her own reasoning and AI-generated reasoning. Or perhaps she could. But she didn't see why the distinction mattered," So writes in *The Collision: What AI does to us*, which explores its impact on our brains.

It is the sort of anecdote people are hearing – and worrying about – around the world. Are we embracing a technology that will see us all become like this student, outsourcing our thinking to AI without even realising?

So certainly seems to think so. *The Collision* uses research from the fields of behavioural science and neuroscience to argue that AI, especially generative AI tools like chatbots, can cause many of us to suffer from "cognitive atrophy". This is the claim that intellect is like a muscle, with our brains rewiring neural pathways around our habits and pruning skills we no longer have use for. If we don't use our independent thinking skills, they will deteriorate, while the "cognitive reflex" to use AI for anything mentally challenging will strengthen, So argues.

"Eric C. So proposes the interesting idea that we have evolved over millennia to find the lure of AI irresistible"

He points to a study that revealed how people learning to juggle over three months showed visible tissue growth in the regions of the brain designed to track movements, but after three further months of not practising, this brain tissue then regressed. In other words, use it or lose it.

You can see the problems that could cause, especially in children. "When we hand students AI tools before they've built their own cognitive foundations, we may be preventing those essential connections from ever forming properly," So warns. The same risks apply to the skills we usually build up over a career. Within a generation, for example, we could have doctors "whose brains never developed the architecture for independent diagnosis".

So was inspired to examine what AI was doing to our minds after he found himself asking ChatGPT to finish a simple email he was writing to a colleague and realised "some fundamental relationship between me and my own thinking had shifted".

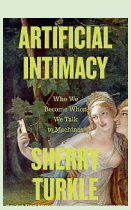
The danger of writing a book on such a premise is that it becomes tempting to selectively pick the arguments that support it. So falls into that trap, relying on a few small studies to do the heavy lifting and he doesn't feature any interviews or case studies. I would have loved to have seen some insight from neuroscientists on the latest thinking around what AI is doing to our brains.

One of the small studies So describes measured the neurological activity of three groups of students writing an essay, with one set allowed to use only their mind, another, search engines and the final group ChatGPT. While completing the task, the unassisted writers' brains were "alight with widespread, robust connections", but the brains of the ChatGPT group had "gone quiet".

Straight after finishing, participants were asked to quote

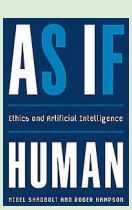


Three more great reads exploring an AI future



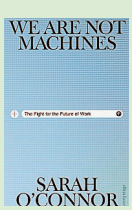
Artificial Intimacy: Who we become when we talk to machines by Sherry Turkle

This book examines the rise of people using chatbots as a replacement for real human company and shows how that deprives us of personal growth and stunts our emotional development.



As If Human: Ethics and artificial intelligence by Nigel Shadbolt and Roger Hampson

A book that explores different schools of philosophical thought to ask what the ethics of AI should be and how humans should treat chatbots, in the hope it can influence how these tools are regulated in the future.



We Are Not Machines: The fight for the future of work by Sarah O'Connor

Written by the *Financial Times*'s associate editor, this book argues that we should fight back against some employers' expectation that we adjust how we work and live to fit into an AI-led world, rather than the other way around.



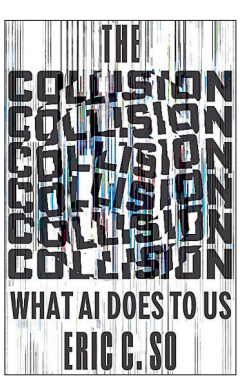
ANDRIY ONUFRIYENKO/GETTY IMAGES

any sentence from their essay. For those who wrote unassisted or used a search engine, recall was nearly flawless. But 83 per cent of the ChatGPT users struggled to recall any direct quote at all.

"The information was never encoded," So writes. This, he argues, shows how we are in danger of creating a world of "hollow competence", with a generation that can "produce without comprehending". But the book doesn't mention that the study was of just 54 participants, 18 per group, and they were given only 20 minutes to write the essay.

The Collision never provides quite enough solid scientific evidence to back up its bold claims. Still, it is a well-argued and thought-provoking read. The book points to studies that show how AI can warp our perception of how good we are at something, essentially mistaking its knowledge for our own. Yet because AI makes us feel more capable, we become even more inclined to rely on it, further eroding our thinking skills.

So also proposes the interesting idea that we have evolved over millennia to find the lure of AI almost irresistible, because our brains use up a lot of the body's energy on thinking and so a preference for "cognitive ease" has become encoded in our very nature. This makes it "extraordinarily difficult for us to resist off-loading our thinking to AI", So states. "Our biology practically demands it."



"AI gravity" might compel us to use the technology as much as possible

Again though, the author pushes this argument slightly too far by claiming the world is experiencing something he calls "AI gravity" – a force acting on us constantly to use AI as much as possible, unless we actively work against it. That would be an apt description of the smartphone, but it still feels some way off for AI. At times, it felt like this book was written for the small subset of people who are already completely addicted to chatbots. At one point, the author asks: "If AI vanished tomorrow, what would you be capable of doing? Most people don't know until they try." Really? I think most people know they would be completely fine.

So posits that the key factor to working with AI successfully is implementing friction into the process. He points to studies that suggest when people have to work through prompts before they get an answer, then AI as a "cognitive partner" can extend our intellectual capabilities.

Otherwise, our intellects could be in trouble, the book warns. "You won't notice the moment you stop thinking for yourself. No bells will ring, no alarms will sound. The slow surrender will be... almost imperceptible."

Here's hoping, for all our brains' sake, we don't let that happen. ▮

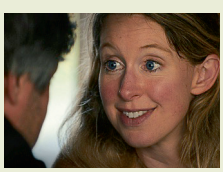
Tom Knowles is a technology and business journalist based in London

New Scientist *recommends*



Grace Wade
Features editor
New York

I wasn't sure what to expect from **You Can See Everything**, a documentary that follows the disgraced founder of Theranos, Elizabeth Holmes (pictured). At the very least, I thought I would gain insight into who Holmes is and why she defrauded investors of millions of dollars. But I left the film disorientated, my mind whirring like one of her faulty blood-testing machines.



I suspect that was the point. The film's directors, Nathan Fielder and Lance Oppenheim, have made their careers unsettling audiences. Fielder moves in with Holmes and her family for the month preceding her surrender to federal prison. The result is about as absurd as you might imagine.

Holmes is adamant she is innocent. She tells Fielder she has nothing to hide. But it becomes increasingly apparent that isn't the case.

This is a film worth watching. Just don't go in expecting Fielder to crack Holmes. If anything, she cracks him, which is even more fascinating to watch.

A24

Things you people wouldn't believe A new *Blade Runner* TV series is out this month. Sci-fi columnist (and superfan) **Emily H. Wilson** rereads the source material, Philip K. Dick's seminal novel *Do Androids Dream of Electric Sheep?*



Emily H. Wilson is the author of the *Sumerians* series (*Inanna*, *Gilgamesh* and *Ninshubar*, all published by Titan) and she is currently working on her first sci-fi novel. She is a former editor of *New Scientist* and you can follow her on Instagram @emilyhwilson1

Book

Do Androids Dream of Electric Sheep?

Philip K. Dick

Gollancz

Emily also recommends...

Film

Blade Runner (1982)

Ridley Scott

I consider this a great work of art... the sets, the music, the everything. There are different cuts available, and all are interesting. By the way, one of the most famous scenes, the "tears in rain" monologue, isn't in the book and was entirely a creation of the film-makers (and actor Rutger Hauer).



WARNER BR/EVERETT/SHUTTERSTOCK

Harrison Ford plays a cooler version of Rick in the 1982 adaptation

WITH the new miniseries *Blade Runner 2099* coming out on 25 November, this seems a good moment to return to the source material behind it and the two blockbuster *Blade Runner* films. That pot-of-sci-fi-gold source material is, of course, *Do Androids Dream of Electric Sheep?*, a shortish novel by renowned sci-fi writer Philip K. Dick, published in 1968.

I read the book as a teenager, but any memory I had of it was then wiped away by the zillion times I watched *Blade Runner*, the 1982 movie directed by Ridley Scott, and the handful of times I watched Denis Villeneuve's 2017 follow-up, *Blade Runner 2049*, which cleaved closely to Scott's original vision. I returned to the book, therefore, with few preconceptions.

There are a lot of differences between page and screen. Just for starters, the book version of Rick Deckard, the bounty hunter who tracks down rogue Nexus-6 androids that have entered his city illegally from off-world colonies, isn't quite the super-cool hero that Harrison Ford gives us on screen.

Book Rick is married to an unhappy woman named Iran, rather than being moodily single in a stunning designer apartment. The couple have a machine that allows them to set their moods every day, but no piano covered in artful photographs. They also have an electric sheep grazing up on the roof where they park their flying car. (The electric sheep, to be clear, isn't in the movies.) It is a matter of embarrassment to Rick and Iran that they cannot afford a real sheep, when their neighbour has a real horse. In this heavily polluted, post-apocalyptic world, nothing is as precious as a live animal.

"You can see why Ridley Scott ditched the pet strand, as well as Rick's wife, to give us the hero from the films"

This matter of the electric sheep sets the scene for an absurdist strand that runs heavy through the whole novel. Book Rick dreams of one potential pet after another, including an ostrich, before finally buying a black Nubian goat. You can see why Scott ditched the whole pet strand (including the goat), as well as Rick's wife, in order to give us the more sexually available and less ridiculous hero we know from the movies.

Another big difference is that, in the book, a religion called Mercerism is central to the plot. Our characters plug themselves into machines in order to fuse with Mercer, their religious leader. I found this confusing and unnecessary, and I can see why Scott bunged it on the scrap heap.

So, lots of differences. Yet a surprising amount of the novel is rendered very faithfully indeed on the big screen. There's the whole set-up, of course – a post-fall world, illegal androids, bounty hunters – and the strong connection between Rick and the android Rachael Rosen. (You may choose to ignore his musings on her breasts being too small, this being the work of a male sci-fi writer in 1968.) And then there's the sympathy that Rachael elicits from both Rick and the reader.

It also preserves the very cool, futuristic vibe that you get from the book, especially when Rachael and Rick are together. The special tests that Rick carries out on suspected androids, with all their weird animal-related questions and focus on pupil reaction, are all essentially lifted from the page.

Would I recommend the book? I think rereading it has given me a deeper understanding of many key elements of the films. The use of animals in the first movie now makes perfect sense, for example. But even if you aren't a big fan of the films or have never seen them, I would say yes, this is a classic, and well worth tucking into. ▮

New Scientist



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Editor's pick

Two important roles for humans in AI maths

17 October, p 19

From Stephen Cadney, Manchester, UK

The current flap over AI's ability to solve difficult mathematical problems seems to require us to have more mathematicians, not fewer. In other areas of science and technology, it is vital to first truly understand how a computing application works before using it, to avoid good stuff in and rubbish out. It seems like more mathematicians will be needed to check and understand AI-generated proofs and to not rely solely on AI, as people increasingly do in everyday life.

To attract students to mathematics, I suggest a series of TV programmes by a public-interest broadcaster explaining the mathematical jokes in *The Simpsons*. A very high proportion of the first team who wrote the episodes were serious mathematicians, some with PhDs. The jokes were frequent, but barely noticeable, as they didn't want to interrupt the narrative flow. All great fun.

From Roy Smith, Burntwood, Staffordshire, UK

We are hearing a lot about AIs solving mathematical problems set by humans. I think the real question is, can AIs set problems for humans to solve, or indeed for other AIs to solve? That would be more truly creative.

Deciding not to have a cold has served me well

24 October, p 20

From Dyane Silvester, Arnside, Cumbria, UK

The conclusion that your mindset can influence how severely an infection affects you comes as no surprise, given that the placebo (and indeed nocebo) effect has long been shown to be real and significant, not to mention our increasing understanding of the mind-body connection. Anecdotally, I have long believed that if I, when I feel the first signs of a cold, decide that I am not going to have it, I suffer less severe symptoms and get over it more quickly. This caused a number of disagreements with a former partner, but he always suffered colds worse than I did!

Gender doesn't help us understand autism

24 October, p 36

From Richard Kennaway, Norwich, Norfolk, UK

Twenty years ago, psychologist Simon Baron-Cohen proposed the "extreme male brain" concept of autism, we are told. To me, bringing in gender seems to do nothing but confuse things. Men are, on average, taller than women, but it would be absurd to describe someone of 6'5" as having "extreme male height". They just have extreme height. Is the same true of the relation between autism and gender?

The article says Baron-Cohen stands by the idea of an extreme "male profile", but not that of an extreme "male brain", and that he has found much higher rates of autism in non-binary people – few of whom, I expect, are examples of extreme "maleness".

Animal consciousness isn't a yes-or-no question

31 October, p 36

From James Buzolic, Christchurch, New Zealand

Rowan Hooper's article on animal consciousness and emotional responses made for fascinating reading. The question in many people's minds is: are animals conscious, yes or no? But consciousness isn't so black and white.

Firstly, we are conscious *of* something, never just "conscious". The pet cockatoo I had as a child was aware of me, but was it aware of itself? We try for a background awareness of self so as to be less robotic and more human, yet it is easy to lose self-awareness when we concentrate on our work.

To me, consciousness isn't something in itself. It is a relationship: with myself, with others and even, if I am a *Drosophila* fruit fly, with the eye looking at me through a hand lens. It doesn't imply that the fruit fly is conscious of itself or that it is conscious of me as an intelligent life form. Fruit flies and other animals notice things, but do they know they are noticing?

An alternative explanation for Neanderthal's death

24 October, p 13

From Caroline Hurr, Adelaide, South Australia, UK

I was intrigued by the finding of a Neanderthal's remains with two separate injuries – one earlier, healed wound to the jaw and another, probably fatal, spear hole in the shoulder – and the suggestion in your article that the latter may be attributable to hunting or violence.

Given the fact that the jaw wound "would almost certainly have required a period of intensive care from the individual's group", my mind immediately leapt to at least one possible further explanation for the shoulder injury. As the research team states, such an injury would have "penetrated all the way through the chest, including the lungs and potentially major blood vessels, likely leading to a rapid death". Is it therefore within the realms of scientific possibility that this represents an early example of what we might today call a mercy killing, to spare the individual what was described as terrible pain from the jaw?

Intense exercise and its role in growing neurons

31 October, p 32

From Ann Davies, Sheffield, UK

As a personal trainer who works with people with long-term health conditions, I read with interest your article on the growth of new neurons in the adult brain.

I have trained to work with people with Parkinson's disease. That training made it very clear to me that the brain can and does grow new neurons. During exercises like high-intensity interval training, brain-derived neurotrophic factor is produced, which protects existing neurons and encourages new ones to grow.

There are better ways to keep clocks and sun in line

24 October, p 11

From Eric Kvaalen, Les Essarts-le-Roi, France

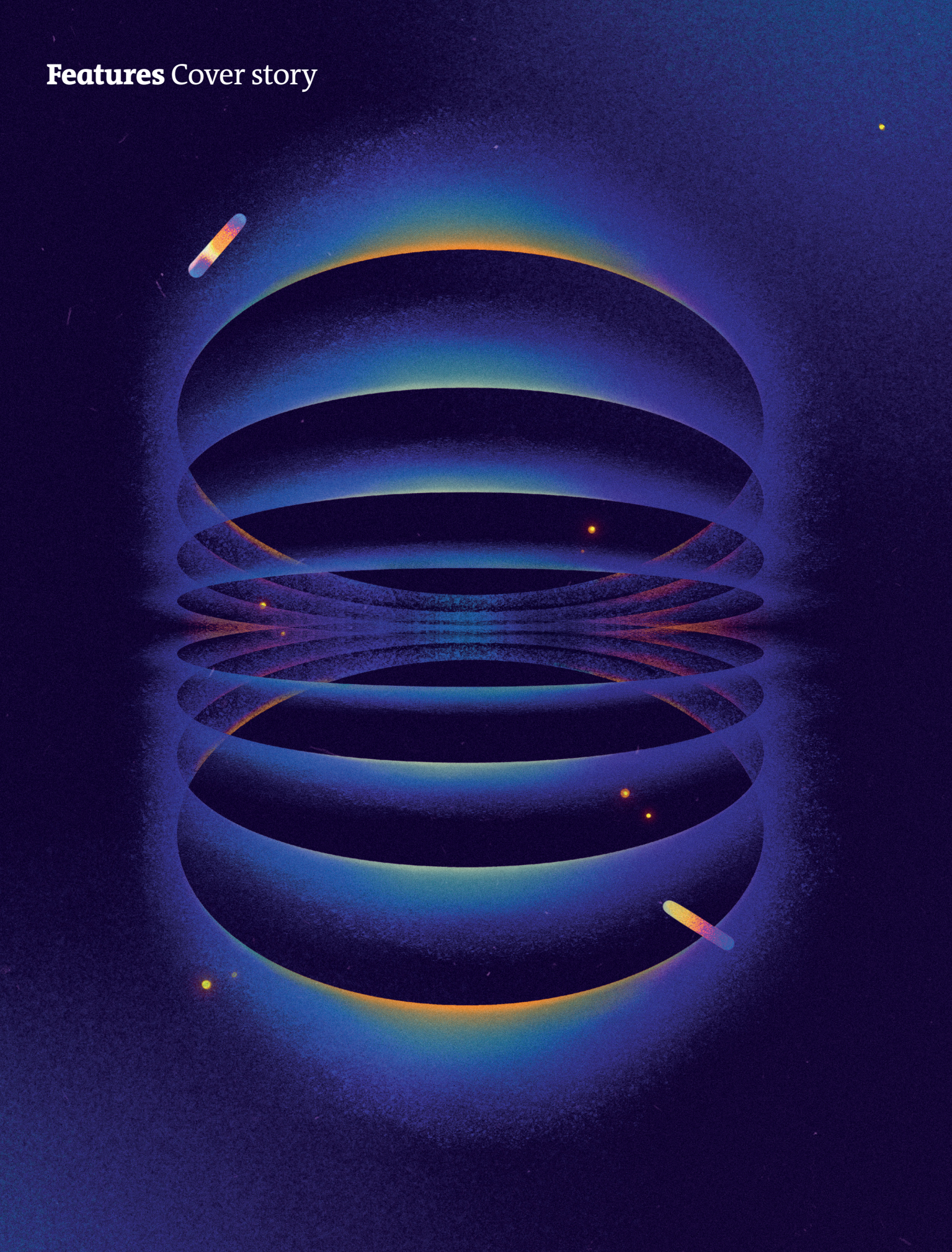
I am disappointed that scientists at the International Bureau of Weights and Measures have decided to no longer use leap seconds to keep our clocks in sync with Earth's rotation, instead opting to put people in the future into permanent daylight saving time, with universal time drifting up to an hour from astronomical time before being corrected.

It would have been fine to simply pause the leap seconds for a few decades, but there is a better long-term solution, which is to define the universal second as slightly longer than the astronomical second. The universal second would be redefined every century or so. This would be easy to implement, and would keep clocks aligned with the sun.

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Back to the past

Quantum physics assumes the past doesn't matter. But if that's is wrong, we might solve one of the deepest riddles in physics, says **Karmela Padavic-Callaghan**

TODAY, for breakfast, I had a smoothie. This isn't unusual: I drink the same smoothie every weekday morning. At some point in the past, I discovered I particularly liked it and made it a habit. It is a simple example of something that makes intuitive sense – that our past experiences determine our present actions, and they, in turn, determine our future trajectories.

But what if I told you that the past never actually existed? Or, at least, that it doesn't matter? It sounds left field, but I would only be channelling an assumption that lurks within many laws of physics largely unchallenged: that the present moment is all we need to know about to predict the future. Without making this assumption, the amount of information you need to predict the future is at risk of blowing up, making it impractical to say anything at all.

Or so we thought. Now, there's a move afoot to reclaim the past for physics. Its proponents think that could resolve long-standing questions at the core of quantum theory, such as why it is so weird as it is, but equally not as weird as it could be – and, along the way, clarify the true nature of time itself. "I think it's a big deal. I think it will be a big thing for the foundations of physics," says quantum information researcher Jacob Biamonte at École de Technologie Supérieure in Montreal.

To begin to understand how physics cancelled the past, imagine a game of marbles. To predict where any marble will be in a second's time, all we need to know is its current position, speed and direction of travel, all effectively ignorant of the marble's deep past. We then roll the relevant physical laws – in this case, Isaac Newton's laws of motion – forward into the future. We don't need to know anything about the collisions that brought the marble to its present position – luckily, as calculating the myriad possibilities might overwhelm our computational ability.

The marble's present is agnostic about its past, and its past is largely immaterial in determining its future, so long as we know about the present. It is like saying that all that matters with my smoothie choice is that memories of past mornings are stored in my present mind. Even if the past vanished entirely, I can continue my breakfast routine. In this way of thinking, there's no way of telling if the universe began just 5 minutes ago.

This principle of neglecting the past is called Markovianity, after Andrey Markov, the Russian mathematician who laid the groundwork for the idea. And it is everywhere in physics – even in quantum theory, our best stab at characterising how the weird realm of particles behaves.

Unlike objects in the classical world, quantum particles can appear to be in a mix of different states at once – in multiple positions, for example. This leads to dramas such as the infamous Schrödinger's cat thought experiment, in which a cat is kept in a box in a quantum "superposition" of being alive and dead. Each of the two states can be assigned its own probability, encoded in a mathematical object called the quantum wave function.

"In this world, cats are never both dead and alive, but the past is indispensible"

Just as with classical mechanics, standard quantum mechanics doesn't much care about the cat's past. As far as its future goes, there are two possibilities. You can keep the box closed, in which case, all you can say is a matter of percentages – the cat could be alive or dead and currently seems to be existentially fuzzy. Or you open the box, in which case, the cat's wave function "collapses" into a single state and the animal is definitively dead or alive, too.

Schrödinger's cat lifted the lid on a load of problems that physicists and philosophers have anguished over in the century since the inception of quantum mechanics. What physically happens when you open the box – is it you who somehow potentially kills the cat? What about the nanosecond when you have just barely moved the lid – is the cat somehow slightly less mixed at this time? What, indeed, does anything about the wave function say about the cat in the real, physical world? Is the wave function itself "real"? "It's been 100 years, and we still don't have a consensus on the right way to think about quantum theory," says philosopher David Glick at the University of California, Davis.

Jacob Barandes, a philosopher of physics at Harvard University, thinks he has identified the problem. He says that the shenanigans surrounding the wave function are merely a smokescreen, behind which the true culprit for the cat's bizarre situation is hiding: the influence of the past.

In a paper published last year, he showed that something like quantum theory can be built on equations for inherently probabilistic, non-Markovian processes that are always influenced by their past. In this world, cats ›

ADA ZIELINSKA

are never simultaneously dead and alive; rather, everything is inherently chancy, and the past indispensable.

Here, the wave function doesn't represent any physical reality, but is just a form of mathematical bookkeeping for all the ways in which the past touches the cat from across time. Let's go back to our marble and make it quantum. Barandes likens this marble's wave function to a collection of "ghost marbles". Each of these ghost marbles embodies the real quantum marble's state but, say, 1 second ago – or 2, or 3, or as far back as you like. "Each ghost marble is a little weird. It's invisible. It's unobservable," says Barandes. But if you have information about the ghost marbles, you can predict what the real marble can do next. Consequently, the world that contains real and ghost marbles seems to follow tractable, Markovian laws, because everything about the real marble's past is encoded in the ghost marbles' present. The price of pretending that the past doesn't matter is filling the universe with ghosts. The quantum wave function is just an elegant arrangement of such spectres.

Barandes thinks our mistake is to read physical reality into this spooky parlour trick. In his alternative framework, quantum peculiarities such as superposition states and wave function collapse are consequences of treating the wave function as something overly real. We can't know what state Schrödinger's cat is in, not because its state is somehow existentially fuzzy, but because quantum objects are inherently a little random. "They're always behaving probabilistically, in a chancy way that depends on the past," says Barandes. Acts of measurement, such as opening the cat's box, aren't special, but merely physical interactions that make the object "forget" some of this past, suppressing some of its chanciness and history-ladenness.

Entanglement win

This picture provides a way to counter the objection that calculations become intractable if you must account for the whole prior history of the universe. In standard quantum theory, it is well accepted that as objects get larger and interact with more of their environment, they lose their quantumness. In Barandes's picture, that maps onto objects relinquishing some of their past and becoming more Markovian as the past recedes.

His framework hasn't yet produced a distinct, experimentally testable prediction, but it has already had one notable win: explaining the degree to which quantum objects can be correlated, thanks to the phenomenon of quantum entanglement.

When two quantum objects are entangled, the results of measurements of their properties maintain a correlation, even if they are first pulled very far apart. These correlations are stronger than would be possible with any non-quantum connection – by a maximum of about 41 per cent, a number known as the Tsirelson bound. Mathematician Boris Tsirelson derived this number in 1980 from standard quantum theory, but Barandes says it had never been properly explained. Later, in 1994, physicists Sandu Popescu and Daniel Rohrlich showed that some hypothetical theories could, in principle, achieve correlations 100 per cent greater than non-quantum theories without information being exchanged faster than light speed, which would contradict Albert Einstein's special theory of relativity. "Forty-one per cent is not even half of 100 per cent, so why so little?" asks Barandes.

His framework elegantly brings this back to the speed of light. In a universe of quantum marbles, each marble moves in its slightly random and history-laden way, but because it can't move or communicate with other marbles faster than light, those parts of its past that lie beyond a horizon of influence set by the speed of light can be neglected. Working with David Kagan and Mahmudul Hasan at the University of Massachusetts Dartmouth, Barandes has calculated that this constraint is exactly what keeps the strength of quantum correlations from exceeding the Tsirelson bound.

Simon Milz, a physicist at Heriot-Watt University in the UK, is intrigued. Standard quantum theory is abstract and mysterious, so there is merit in uncovering processes that offer some underlying picture, he says – and the Tsirelson bound is one of the most talked-about things in quantum information theory. "It's quite an interesting thing to find a new principle that leads to it," says Milz.

David Wallace, a philosopher of physics at the University of Pittsburgh in Pennsylvania, echoes that. But he is uncertain how far Barandes's approach can go, in particular because of the way it denies the wave function any physical reality. Standard quantum theory works incredibly well as a description of our world, he says. "If you just take quantum mechanics as we find it, there doesn't seem to be any way to read it that doesn't basically commit you to the wave function representing physical goings-on," he says.



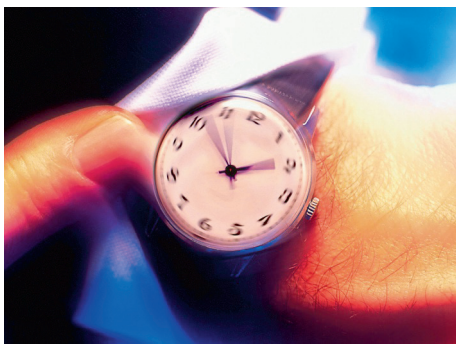
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"The quantum wavefunction is just an elegant arrangement of spectres"

ERIC MEOLA/GETTY IMAGES



Rethinking the role of the past in the Schrödinger's cat thought experiment might also lead us to reconsider time itself



GETTY IMAGES

He would like to see the framework reproduce more complex calculations, such as from quantum field theories that underpin the standard model of particle physics. Historically, this is where non-standard interpretations or reformulations of quantum physics have tended to fail. Barandes says that his framework ought to work for quantum fields, and he plans to extend his work in this direction.

His isn't a lone quest to bring the past back. Cristian Mariani at the University of Italian Switzerland in Lugano works on an unorthodox approach to quantum theory known as spontaneous collapse. It depicts wave function collapse as something that doesn't happen only when you try to measure things, but can spontaneously occur at any time. Spontaneous collapse models produce predictions that are distinct from those of standard quantum theory, but no experiment has yet provided enough reason to reject standard quantum mechanics in favour of spontaneous collapse. But if quantum laws are amended in a non-Markovian way, allowing spontaneous collapse models to become history-laden, then new experimental tests open up, says Mariani.

Questioning the role of Markovianity in quantum physics is important in itself, he says. "In physics, and in philosophy of physics, this was the kind of assumption that we made without explicitly defending it." In part, that's because of the mathematical complexities of non-Markovian theories, and the enduring appeal to philosophers of Occam's razor, the idea that the simplest solutions are the best. Grappling with the assumption might lead researchers to rethink the nature of physical laws themselves, says Mariani.

It isn't just our understanding of quantum theory that could be sharpened either; so could our conceptions of time and the present moment. Until the 20th century, philosophers had long argued that the present moment is privileged. In the sense that the past has ceased to be and the future is yet to exist, you might indeed argue that only the present can claim to be truly real. This point of view is known as presentism, and it depicts us as observers living on a wavefront of "now", ploughing from the past into the future.

The illusion of now

Einstein's space- and time-warping theories of relativity seemed to put paid to that privileging of the present. Within relativity, it is impossible to get all observers to even agree on a single, simultaneous "now". The alternative view, which Einstein's relativity is more friendly towards, is called eternalism. It states that all of the past, present and future exist simultaneously. We exist at a fixed point in this block of space and time, and the flow of time past us is essentially an illusion.

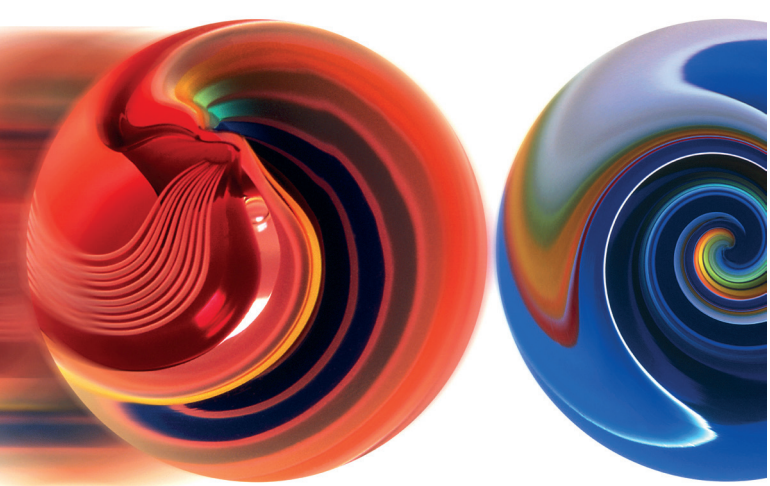
Since the advent of Einstein's relativity, "most people think that presentism is always on the defensive", says philosopher David Builes at Princeton University. In 2025, he and his Princeton colleague Michele Odisseas Impagnatiello went on the offensive, arguing that presentism is backed by centuries of experiments whose outcomes haven't deviated from predictions of Markovian laws of physics that only really require that the present be real. "This isn't an argument from the armchair; it's an empirical argument," says Impagnatiello. Conversely, the pair argue, if a non-Markovian, history-laden interpretation of quantum physics prevails, it will force them to abandon presentism.

We're a long way off any such proof as yet. "Ideally, we would have a case in which a non-Markovian interpretation is superior in the sense that it makes novel predictions that orthodox quantum mechanics doesn't make," says Impagnatiello – a view echoed by Wallace.

Barandes says that one place where his framework may touch the world of experiments is in quantum computing. Quantum computers derive enhanced capabilities through superposition and entanglement effects that, in Barandes's view, are all really fronts for influences of the past. "A quantum computer is secretly a non-Markovian computer," he says. "It's not just the present arrangement of the bits that matters, but also the past arrangements." There are currently only a few cases where researchers have unambiguously proved that using quantum computers is the only way to solve a particular problem. Thinking about them in a non-Markovian way might lead to the identification of new situations in which they are clear game changers, says Barandes.

Glick agrees there is value in seeing how far weakening or dropping the Markovian assumption can get us, even if other descriptions of nature never get fully ruled out. "At a certain point, we might find that, well, it's better to drop that assumption, that then we get a more fruitful result," he says. "That's not a direct, empirical kind of confirmation or disconfirmation, but this is how science often works."

Taking the past seriously touches the foundations of physics in a sweeping and profound way, and that makes it worth pursuing, says Barandes. "I think that this framework may have something to tell us about the way the world really is," he says. "As a philosopher, I care about that." It's certainly food for thought as I prepare my morning smoothie. ▮



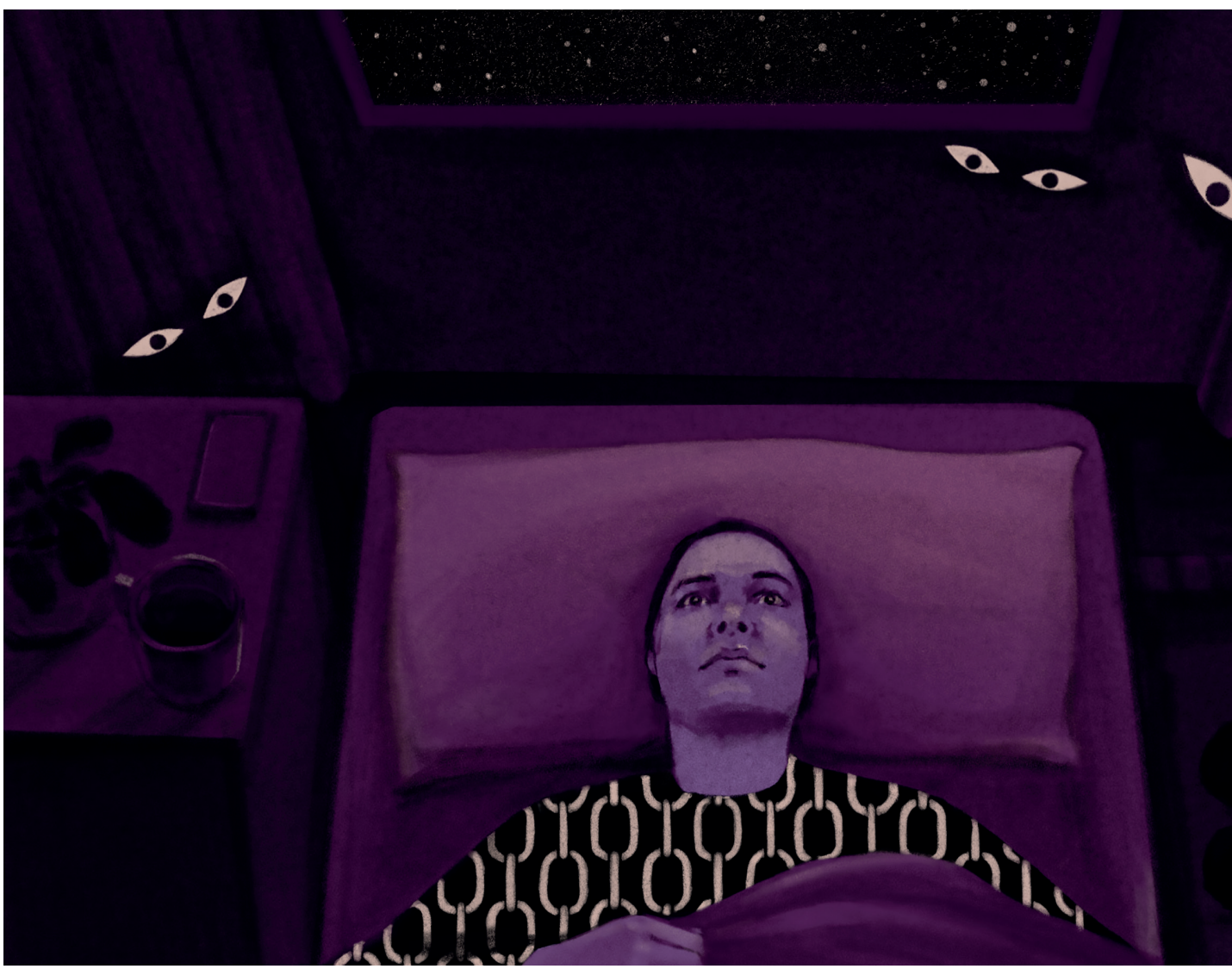
Imagining quantum marbles helps us think about the influence of the past



Karmela Padavic-Callaghan is a reporter for *New Scientist* covering physics

"I felt this looming presence, a shadow-like creature"

After **Baland Jalal** experienced a terrifying episode of sleep paralysis, he decided to become a neureoscientist and study it. He tells Grace Wade what he has learned about the deep mind-body connection



ŪLA ŠVEIKAUSKAITĖ

YEARS ago, I woke to see a darkly cloaked figure towering over me. I thought it was going to kill me, but I couldn't move. I wasn't dreaming. I could see my room and feel my body beneath my sheets. I was consciously aware, yet hallucinating a figure that didn't exist.

I was experiencing sleep paralysis, a phenomenon that affects approximately 30 per cent of people worldwide. Episodes are usually benign, but for roughly 1 per cent of people, they reoccur weekly, raising the risk of insomnia. Even isolated instances can leave a lasting impression. I still think about my experience today. While I know the figure wasn't real, the fear it instilled in me was.

In his latest book, *The Phantom Mind: Insights from the borderlands of sleep*, Baland Jalal reveals how and why sleep paralysis can take hold. A neuroscientist at Harvard University, his research has brought us closer to understanding what affects the appearance of so-called "sleep paralysis demons" and how we can potentially prevent these frightening experiences.

Jalal sat down with *New Scientist* to discuss what all this tells us about the mind-body connection.





PETERSON ACADEMY

Baland Jalal is a neuroscientist at Harvard University who studies sleep paralysis

Grace Wade: I am curious – have you experienced sleep paralysis?

Baland Jalal: I have. I had my first episode when I was about 18 or 19. I was sleeping and suddenly realised: I am awake, yet I can't move. I can't speak. I felt this looming presence, this shadow-like creature approaching me. And then it strangled me. It pressed on my chest, and I saw my legs flying up and down. I was sure I was going to die. But eventually, I managed to wrestle myself out of it. It was a horrifying, but also life-changing, experience because this was the trigger for me to become a scientist.

That sounds awful. What happens in the brain during this phenomenon?

Sleep paralysis emerges out of rapid eye movement (REM) sleep, when we have our most vivid dreams. During REM sleep, we are completely paralysed from head to toe so that we cannot act out our dreams. What can happen is that the outer layer of the brain can suddenly activate and jolt you awake while you are still in REM paralysis.

We know what can trigger this. Deep in the brain, you have the limbic structures, the emotional department of the brain. If you are aroused during the day – you have a lot of anxiety, a lot of stress – that part of the brain is hyperactive. When you go to sleep, it will stay activated and sort of tickle the outer layers of your brain, and you jolt awake. Now, if the emotional part of the brain wakes you when you are supposed to be in REM sleep, you have sleep paralysis, because you can't move.

But why do people see or hear things that aren't there?

Sleep paralysis is really being awake and asleep at the same time. And what happens in REM sleep? All these parts of the brain are turning on and off, and that creates a surreal dream world.

For example, the dorsolateral prefrontal cortex, the rational part of the brain, shuts down during REM sleep. It puts the world together in a logical way, and for that reason, dreams are bizarre. The cingulate cortex, which has to do with conflict monitoring and empathy, is hyperactivated during dreams. It is why we can create theory of mind, meaning we can project agency and intentions onto other beings in our dreams.

The temporoparietal junction, which creates a sense of body image, also takes a hit during ›



TETRA IMAGES, LLC/ALAMY

REM. So your sense of self is all fluid. And then the emotional part of the brain, the limbic structures, is about 30 per cent more active in REM than when awake. That explains why dreams are so emotional, so intense.

Now you have sleep paralysis, where you start waking up, yet these elements of the REM dream are spilling into waking reality.

How do we know this?

In terms of the brain regions that turn on or off during REM sleep, that comes from brain-imaging studies. In terms of why we see monsters during sleep paralysis, that is all theoretical. It would be interesting to conduct brain-imaging studies of people while they see [them] to find the exact neural pathways that light up. You might think that isn't important, but I think it could be. It might show us the pathways governing extreme dread, religious fear and mysterious experiences.

Why haven't we done that? I imagine capturing sleep paralysis with a brain scanner would be challenging.

I don't think it would be that challenging. You would have people that are already predisposed to sleep paralysis and then disrupt them during REM sleep with a scanner on. I think the reason it hasn't been done is because, in most cases, sleep paralysis is benign. It would be hard to get grant money.

In your book, you suggest that sleep paralysis is a unique window into consciousness. What do you mean by that?

You have the dreaming brain, with all these different parts being shut down or hyperactivated, and then it blends with the waking brain, where you have some conscious awareness. I think that gives us a potential window into understanding aspects of consciousness.

The ability to choose is a key aspect of conscious experience. If you were able to communicate with someone in sleep paralysis and ask them to choose, say, Pepsi or Coca-Cola, they would be able to. Compare this with sleepwalking. From the outside, that person might look conscious, but they aren't because they cannot choose.

Sleep paralysis has shown us that mixed states of consciousness are possible and that you can have some self-agency in these states. I think one of the most important insights is that your own mind can potentially trigger an event that seems comparable to trauma.

We also know that if you have a certain cultural idea about sleep paralysis, it becomes more common and it seems to last much longer. That is a big insight of the mind-body connection.

Your research has focused on the role beliefs and expectations play in sleep paralysis. Tell me about those findings.

After my sleep-paralysis episode as a teenager, I decided to become a scientist and study it. I went to Egypt, got into The American

The environment can affect your experience of sleep paralysis (above). *The Nightmare*, by Johann Heinrich Füssli (below), depicts a demonic figure



DETROIT INSTITUTE OF ARTS



> "Terrifying castles? Terrifying sleep paralysis. The environment primes the experience"

University in Cairo. I am originally from Denmark, where we have very secular views. Everything is as you see it. Egypt, on the other hand, is a very superstitious place. So I thought, how would sleep paralysis differ in these two cultures? And it differed quite severely.

My colleague, David Hinton at Harvard, and I surveyed hundreds of people in Denmark and Egypt, asking them whether they experienced sleep paralysis and, if so, what it was like. About 90 per cent of people in Denmark said it is just your brain. It is stress. It is physiology. Nothing supernatural about that. The people in Egypt were completely different. They would say it is a genie – evil genies, not the nice blue one from *Aladdin* – and they feared it intensely. About 50 per cent of people who had sleep paralysis [in Egypt] thought they might die from it.

And this seemed to influence their experience of sleep paralysis. So, people in Egypt would say their episodes last much longer [than people in Denmark]. It was also twice as common in Egypt than in Denmark. We think that has to do with how the idea spreads from person to person.

I was once told that you can only experience sleep paralysis after learning about it from someone else. Then, boom! I had my first episode.

That isn't the only way, but it definitely becomes more common, which has to do with a phenomenon called priming. This is how it works. Let's say you have this girl who has never heard about sleep paralysis. Then, her grandmother warns her of these monsters that come at night.

Now what happens? She goes to bed and the emotional core of her brain is hyper-alert, which is this perfect disaster for sleep paralysis, because you are so likely to jolt out of REM. Then, in REM, she feels something holding her down, which is just her brain paralysing her. When she tries to move and can't, she panics. Then her dream imagery will create these vivid hallucinations. She wakes up terrified, tells her friend and the scenario starts all over. It keeps spreading.

This is a personal question, but what form does your sleep paralysis demon take?

It has evolved. My first encounter was a shadowy sense of presence. It was the most terrifying episode ever.

When I was in Egypt, it was during the Libyan revolution, and Muammar Gaddafi [the former Libyan prime minister] was on the news all the time. One day, I was sleeping and it was Gaddafi hovering over me. That was very spooky. Later, as a PhD student in England, I would go to these castle-like hotels to give talks, and they seemed so haunted. I would have terrifying episodes there.

So it isn't only cultural beliefs that shape sleep paralysis, but also environment?

Absolutely. Terrifying castles? Terrifying sleep paralysis. Somebody who doesn't know the neuroscience of sleep paralysis would think it is a haunted hotel. We have data from people reporting that if they have a poster on their wall, suddenly that would morph into a dangerous face, or a little glass on their table would morph into a skull. So the environment primes the experience, for sure.

If our beliefs and expectations are partly to blame for sleep paralysis, could they also help us manage it?

Absolutely. I developed four steps people can do during sleep paralysis. It is very simple. First is a cognitive reappraisal, which is a fancy way of saying "reinterpret the whole thing". Remember, it is just the brain playing tricks on you. Then, you do emotional distancing. Since you know it is the brain, it makes no sense to be scared. I may have those emotions, but I am going to distance myself from them.

The third step is key: you meditate on something positive, your mother's face or God or the sunset, whatever is positive for you. That can make the frontal parietal part of the brain, the part that has to do with attention, bias the brain toward positive emotions. Number four is that you will still have paralysis. You can't avoid those physiological symptoms, so ignore them.

We did a study with six people in Italy who had sleep paralysis frequently. Their episodes decreased by about 50 per cent after using this for eight weeks. This is very promising, but very preliminary. We are now working on a follow-up study of this therapy.

Why is treating sleep paralysis important, given we know people aren't actually being attacked by a monster?

Because of the pervasive nature of the experience, the way it spreads, the way it can harm people psychologically. Even having a few episodes a year can be destructive. And a small percentage of people have several episodes a month. That is when it is really pernicious and pathological. You just can't get rid of it, and it is causing insomnia.

Have you tried this technique yourself?

A few times. It seemed to work. Sleep paralysis has evolved for me from being terrorised by this shadow-like creature to now [when] I can take control. I have learned to have my prefrontal cortex kick in and regulate some of the fear structures. ▮



Grace Wade is a features editor at *New Scientist* covering health and neuroscience

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The tours our guests love best

From expert-led discoveries to unforgettable destinations, here's what guests have been saying about their recent New Scientist Discovery Tours.









Human origins, Neolithic and Bronze Age Turkey

Next departure: 13 May 2027

"Travelling with other guests who shared my interest in archaeology provided a common focus for conversations. We were all interested in the same topic and that provided an easy way to get to know my fellow travellers". **Kathleen**

Evolution and wildlife cruise in Darwin's Galapagos: Ecuador

Next departure: 26 July 2027

"It was just as amazing as I thought it was going to be, which I didn't think was possible! It was really important to me to understand what I was seeing, both from a scientific and historical perspective, and that made the experience more meaningful." **Lindsay**

Mycenaean and Peloponnesian archaeology: Greece

Next departure: 19 May 2027

"It takes it a step further having an archaeologist as a guide versus having just a general expert, because it's someone who has actually spent their whole life working here. He knew everything about Mycenae and it added so much to the experience." **Thalia**

Science-led journeys for curious minds

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A grand voyage

As our most distant envoy into the cosmos reaches a light day from Earth, **Leah Crane** looks back at what Voyager 1 saw in our solar system – and what it showed us about ourselves

EVERY day, we send a ping. A signal leaves Earth from one of three Deep Space Network sites – depending on the rotation of the planet, it originates in either California, Spain or Australia. A parabolic antenna projects radio waves towards the lonely outer reaches of the solar system, far beyond the planets. There, after 24 hours of travelling at the speed of light, they reach a small spacecraft hurtling away from us. Voyager 1 is the most distant human-made object from Earth, and on 18 November, it will reach 1 light day away: a milestone it was never meant to hit.

We have been doing this for almost half a century, the time between messages sent and received expanding with every passing day. When Voyager 1 and its twin, Voyager 2, launched in 1977, the duration of their mission was expected to be five years. Yet both remain operational and still take measurements. While Voyager 2 beat its partner to launch by a few days, it took a slower trajectory past Uranus and Neptune, and Voyager 1 quickly took the lead – it will be another nine years before Voyager 2 slips beyond a light day away.

Despite its main thrusters starting to break down, NASA operators have been able to fire a set of backup thrusters and maintain contact with Voyager 1, even bringing in data from the interstellar medium beyond our solar system. "These are the things that make us feel that our child is out there, and we want to keep it going as long as possible," says Stamatios Krimigis at Johns Hopkins University in Maryland, the youngest of the principal investigators for Voyager 1 when it launched and the only one of that original group still working with the mission. "There are still a lot of things to learn because these are uncharted waters." All of Voyager 1's instruments bar two have been shut off to conserve power – the magnetometer and plasma wave instrument are still humming along, though they may soon need to be switched off. It is most likely that it will drift out of radio contact around 2036, headed for a 30,000-year journey through the Oort cloud, a region of trillions of small, icy bodies at the periphery of our cosmic neighbourhood.

After that, it will continue to fly away from Earth, the most distant vestige of humanity, leaving in its wake profound insights about the solar system that have broadened our knowledge with every light second it travelled.

PETER GREENWOOD



Rings and volcanoes (1979)

Voyager 1's visit to the Jupiter system was one of the most scientifically fruitful parts of its mission. It took more than 18,000 images of the gas giant and its moons, all much sharper than those from the Pioneer 10 and 11 spacecraft that had visited Jupiter in prior years. These led to groundbreaking discoveries, including Jupiter's ring system, and the lightning strikes and auroral lights sparkling amid its swirling clouds. The flyby of Jupiter's moons proved particularly illuminating, revealing them to be far more complex than anyone had previously imagined. "The sense of novelty would probably not have been greater had we explored a different solar system," wrote imaging team lead Bradford Smith in a 1979 paper.

Enormous webs of ridges and fractures were found on the moons Ganymede and Europa, and Amalthea turned out to be elongated rather than spherical. Io's volcanoes were spotted for the first time, an unexpected – and even shocking – finding. Smith called them "probably the most spectacular discovery of the Voyager mission". Data from Voyager 1 painted the entire Jupiter system as dynamic and diverse, and the flyby marked the beginning of an epic and ongoing undertaking to better understand it.

Navigating the asteroid belt (1977)

After it departed Earth, Voyager 1's first big task was to journey through the asteroid belt that lies between the orbits of Mars and Jupiter. This nine-month period was spent in a cruise phase with the scientific instruments off, conserving power for the craft's time near the giant planets. Unlike representations in science fiction, the asteroid belt is fairly sparse, with around 1 million kilometres, on average, separating any two asteroids, so there was little danger of Voyager 1 hitting anything. During this time, it overtook its sibling craft, Voyager 2, allowing it to reach Jupiter and Saturn first.

The pale blue dot (1990)

From far beyond Neptune, 6 billion kilometres from the sun, Voyager 1 turned its cameras to look back towards home one last time before they were shut off for good. It took a series of 60 images, capturing the sun, Venus, Earth, Jupiter, Saturn, Uranus and Neptune, for a mosaic that became known as the "family portrait" of the solar system. Mercury was too close to the sun to be seen, and Mars was obscured by a stray sunbeam. This remains the only time our home solar system has ever been photographed as a whole. The mosaic was the brainchild of astronomer Carl Sagan, who was a member of the Voyager team: he saw it as a way to demonstrate Earth's place in the cosmos, with every planet appearing as a speck of light floating in the vacuum of space.



NASA/JPL-CALTECH

Despite its lack of detail, this series of pictures has become a poignant symbol of the vastness of space and the seeming uniqueness of our little blue world. The iconic image of Earth in particular, dubbed the "pale blue dot" (inset), took hold in the popular imagination, in part because of Sagan's writing about it in his 1994 book of the same name. "There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world," he wrote. "To me, it underscores our responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we've ever known."

Far out (1998)

At about 10.3 billion kilometres from the sun, Voyager 1 overtook the Pioneer 10 spacecraft and became the most distant human-made object from Earth – a title it has retained ever since. No spacecraft launched to date is travelling fast enough to catch up, so it will remain the most distant spacecraft for the foreseeable future.

A menagerie of moons (1980)

The Saturn system flyby was the end of Voyager 1's primary mission. Over just two days, it shed unprecedented light on Saturn, its rings, its moons and the complex interplay between them. Regarding the planet itself, measurements from the wide-field imager revealed how different Saturn's circulation is from Jupiter's, teaching us volumes about how the atmospheres of giant planets work. They unveiled intricate details of Saturn's rings and the fact that particles fall from the rings towards the planet. "The atmosphere of discovery was absolutely intense at the planetary flybys: many of us were reluctant to go to sleep for fear of missing something," says William Kurth at the University of Iowa. "There was no doubt we were rewriting textbooks in real time and our colleagues would be poring over the data for years to come."

For the first time, the combination of the moon Enceladus's strangely bright surface and the structure of Saturn's faint, outermost ring led researchers to suggest it may come from particles spewing out from the icy moon. It was also suggested that Enceladus might have liquid water beneath its surface. Both suggestions turned out to be true. As for the other moons, eight of them that had previously been seen only as distant dots finally had their surfaces revealed. Voyager 1 also discovered three new inner moons. But the crown jewels of the Saturn observation campaign were the close-ups of Titan, the only moon in the solar system with a thick, relatively Earth-like atmosphere. These observations were the first to unveil its structure and atmosphere, hinting at how similar to Earth – and how potentially ripe for life – it really is.

Traversing purgatory (2011)

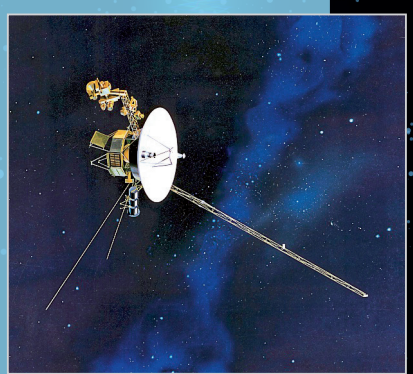
The beginning of the end of our solar system is an area known as cosmic purgatory, or the stagnation region. About 18 billion kilometres from the sun, it is where the solar wind's speed slows dramatically and stops bolstering the sun's magnetic field against interstellar space. At the edge of its reach, the magnetic field is compressed as the solar wind suddenly hits resistance from the interstellar medium, doubling in strength and marking the edge of the solar system's protective bubble, the heliosphere. While it had been theorised to exist, no spacecraft had ever travelled through cosmic purgatory before Voyager 1 in 2011.

"Nobody had imagined that the influence of the solar atmosphere would be that far away," says Krimigis. "We were anticipating, if we continued much beyond Saturn, we would get new things, but not the kind of revolution that was produced by the Voyager spacecraft." While it crossed into the margins of the solar system, Voyager 1 measured a sharp increase in cosmic rays, hinting that particles from elsewhere in the galaxy are trickling into the solar system.

Measuring the Milky Way (2011)

Earth's proximity to the sun has often made it tricky to take measurements of the wider Milky Way. In particular, solar interference made it impossible to measure our home galaxy's Lyman-alpha radiation, a particular wavelength of light emitted during the hottest phase of a young star's lifetime. Observed in other galaxies, it is a telltale sign of star formation. In our own, sunlight had long drowned it out.

But in 1993, out beyond the orbit of Neptune, Voyager 1 finally escaped the glare of the sun and measured Lyman-alpha radiation from the Milky Way for the first time – although researchers didn't realise it until they reanalysed the data in 2011. We know much more about star formation in our own galaxy than in distant galaxies, so we can use this data to connect those two bodies of knowledge, making our measurements of the Milky Way a better laboratory in which to understand the rest of the universe.



NASA/JPL-CALTECH

Outward bound (2012)

The definition of the edge of the solar system is a slippery one – Voyager 1 may or may not be beyond it, depending on which line in the cosmic sand you prefer – but the very edge of the heliosphere is called the heliopause. The heliosphere has a long, comet-like tail, and in 2012 Voyager 1 exited on the opposite side of the sun from that tail, about 18.1 billion kilometres from the star. Most of its scientific instruments had long been switched off, but it continued to measure the plasma in its immediate environment. An extraordinary increase in the density of electrons surrounding it indicated it had entered interstellar space, the first human-made object to do so. The crossing gave us valuable data on the heliosphere's properties, and our first direct data on interstellar space.

Still a long way to go

The Voyager 1 mission hasn't just shown us the vastness of our solar system, though its unparalleled contributions to solar system science can't be overlooked. It also revealed the vastness of our ambitions. Bolted to its side is a golden record (pictured), a sort of audiovisual time capsule depicting humanity and life on Earth. Should any intelligent life form find the spacecraft as it continues out into the universe, they will be able to tell where Earth is and who lives here. They will see Earth's sights: its natural and architectural wonders, its snowflakes and seashells, its myriad peoples. They will hear its sounds: greetings in 55 languages, symphonies, songs, bird calls, the rumble of thunder, the rising of the tide. They will know how far Voyager 1 has travelled from home.

"I would hope finding Voyager would tell them that we are curious and seek knowledge about the universe," says Kurth, who has been on the Voyager team for more than 50 years. "I hope they would realise that it takes many individuals working together as a team to send such a device into the unknown." And even if aliens never find our cosmic ambassador, we now know those things.

For those of us here on Earth, Voyager 1 represents a small tendril of humanity reaching out into the wider universe. "I think it's the distance that fascinates people, and it's also the fact that now we have two observatories out beyond the influence of the sun's atmosphere, out in the galaxy," says Krimigis. The idea that we have reached beyond not just Earth, but our entire solar system, is



NASA

astounding – let alone the fact that against all odds, the spacecraft is still functioning and still producing science.

That is due in part to what Krimigis refers to as a "conspiracy" among the engineers on the original Voyager team to equip it with enough fuel to reach the outer solar system and perhaps beyond. "The engineers made a pact to make no decision that would limit their ability to continue after the Saturn flybys," says Kurth. "Clearly, this approach has worked." The degree to which the spacecraft still functions, though, astonishes even those who built it. For example, a part on the charged particle instrument was intended to last just past Saturn, designed to rotate 250 times. It has now spun more than 8.5 million times, even after the instrument heaters were turned off. It is out there at -61°C, still chugging along. "I was prepared to see the thing frozen in place, and I almost fainted when it was still working," says Krimigis.

While its functionality will eventually fade, Voyager 1 may well outlast humanity. The only way it would stop hurtling along its trajectory is if it were either captured by aliens or smashed into something, and it isn't expected to pass near anything at all until it reaches the star Gliese 445, which is 17.1 light years – 6242 light days – away. Even then, it will stay well over a light year from the star. "When we realise that the next close passes will be 40,000 years from now, we realise that space is really empty: Voyager is going to keep going forever and ever and probably not run into anything," says Krimigis.

This brings our own tiny world, our pale blue dot, into cosmic perspective. "I believe that this mission is very significant in two ways. One is that humanity was able to send a spacecraft outside our solar system proper and into the galaxy. But it also highlights how small an achievement that is when one looks at the grand picture," says Krimigis. "Everything is so far away, and we have a long ways to go."

That is what Voyager 1 reminds us of. The reach of humanity is so long it is almost unimaginable, and yet we have only barely reached the edge of our solar system. The vast cosmos is still out there, unexplored. And even though we cannot press very far into it, Voyager 1 shows us that the further away we go, the better we can see our place in the universe. ▮



Leah Crane is a senior reporter at *New Scientist*, covering space flight, physics and cosmology

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Helen Thomson
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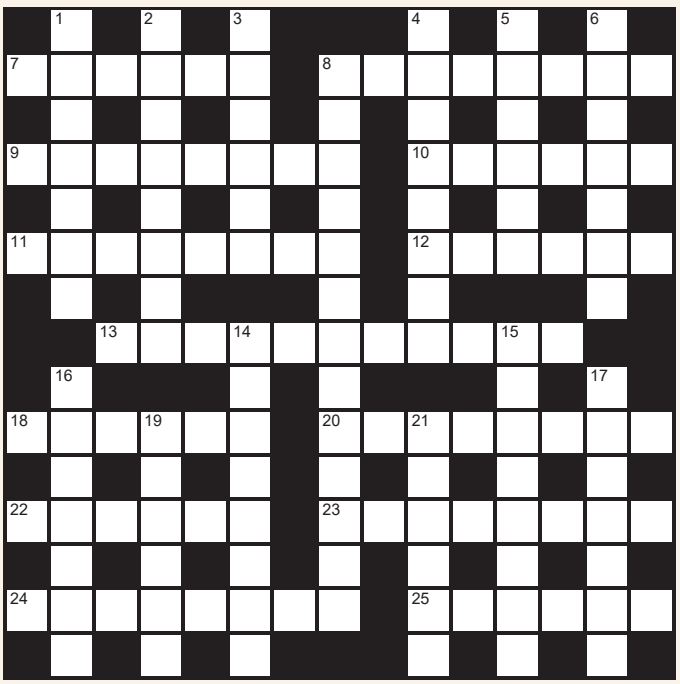
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Alzheimer's Society
It will take a society to beat dementia

Quick crossword #221 *Set by Richard Smyth*



Scribble zone

Cryptic crossword next week

ACROSS

7 An organism's genetic material, as a whole (6)
8 Coal tar-based wood preservative (8)
9 Nuclear weapon (4,4)
10 Colour traditionally thought to lie between blue and violet in the visible spectrum (6)
11 Large Hadron ___, CERN experimental structure (8)
12 Normal, comfortable breathing (6)
13 ___ principle, concept introduced by Werner Heisenberg in 1927 (11)
18 Response; solution (6)
20 Experimental clothing? (3,5)
22 Moving picture technology developed by the Lumières, among others (6)
23 Invisible form of electromagnetic radiation (8)
24 The US Army's T40/M17 rocket launcher (8)
25 Frozen stalactite-like structure (6)

DOWN

1 Subatomic particle (7)
2 CH_2O trade name (8)
3 Make note of (6)
4 Thiamine deficiency (8)
5 Exhausted (4,2)
6 Walk unsteadily (7)
8 Form of online harassment (13)
14 Tube-like part of the hearing organ (3,5)
15 Concerning the chest (8)
16 Analytical intelligence (7)
17 At a substantial incline (7)
19 Breathe with difficulty (6)
21 Expert, scientist (informally) (6)

Quick quiz #378
set by Chelsea Whyte

1 Astronomers at the Vera C. Rubin Observatory in Chile spotted an object out past Pluto large enough to qualify as what?

2 A material that is the lightest solid on Earth could be used to insulate homes and help achieve net-zero goals. What is the material made of?

3 To produce Mars's ancient atmosphere, the underwater surface may have reacted with which element in the planet's crust?

4 The biggest cryptocurrency heist ever resulted in billions of dollars' worth in losses. Which crypto exchange experienced the hack?

5 On long flights across the Atlantic, Manx shearwaters can fly off course because they experience which condition?

Block Universe
created by Puzzlr

The goal is to divide the grid into non-overlapping rectangles. Each rectangle must contain exactly one number, and have an area equal to that number. For example, a 6 should have a rectangle covering six squares.

	9							
						4		2
							9	
2								
		6	15					
2			4					
					15		4	
	5	5					4	
							4	
4			2		3			

Answers to this week's puzzles on page 47

Our games are now playable online
newscientist.com/games

Emotional tunes

Why do certain pieces of music evoke emotions such as joy or sadness, and do people from different cultures react in the same way?

Michael Ellison
University of Bristol, UK
Happiness and sadness depend largely on whether the harmony and modes involved use natural overtonal intervals or their inversions (with the inversions typically sounding less happy). Of course, nuances and gestures (how one plays) and specific instrument sounds can influence this, but the psychology of music lies in its tuning and harmony.

There is, of course, a lot of difference between musical cultures as to what, by convention, connotes happy and sad. Indeed, those categories themselves seem to derive from a Western common-practice era reduction into two main modes, major and minor, when other cultures may have a lot more modes to choose from.

"There is, of course, a lot of difference between musical cultures as to what, by convention, connotes happy and sad"

Even within Western music, major is not always happy (try Ludwig van Beethoven's *String Quartet Op. 59 No. 3*), nor minor sad (listen to the song *Happy* by Pharell Williams, which is in minor!).

Black and white

Why do humans enjoy black-and-white photos or videos, but have less tolerance for images that have only two other colours?

Robin Maguire
Hobart, Tasmania, Australia
The human eye contains two types of light detectors: rods, which work well in both good and bad light but do not detect colour, and cones, which can distinguish colours but only work in good light. The brain has therefore evolved to cope comfortably with the monochrome images that it receives in low-light conditions.

One might ask why the brain chooses to perceive monochrome images in black and white, rather than some other pair of colours from the available palette, say red and green, or blue and orange. Presumably the reason lies in the strong contrast between them, with black corresponding to a total absence of light and white to a mixture of multiple wavelengths. Thus, we prefer pictures in black and white rather than two other colours because this is a presentation with which we are thoroughly familiar, and which conveys contrast more efficiently than other colour pairs.

As a rough check of the latter point, I ran a mini experiment: I asked a simple AI engine to produce a new version of a well-known painting (Georges Seurat's 1884 painting *Bathers at Asnières*) using only shades of red and blue, then printed it out and took a black-and-white photocopy.

After dark, when my cones no longer worked out of doors (no colours visible in the landscape), I compared the two images, both now presenting in shades of grey. The black-and-white copy was still clear and distinct, whereas the red-and-blue version was reduced to a largely indistinguishable blur.



KEVIN FRAYER/GETTY IMAGES

This week's new questions

No more mozzies **Would the total eradication of mosquitoes cause any specific or irreparable destructions to the ecosystem?** ***Babatunde Adedoyin****, Lagos, Nigeria*

AI Einstein **If Albert Einstein hadn't come up with his great theories, could artificial intelligence do it now?** ***Colin Frizell****, Colchester, Essex, UK*

What would eradicating mosquitoes do to the ecosystem?

Smelly illusions

There are optical illusions and audio illusions. Is there also such a thing as an olfactory illusion? (continued)

Andrew Vickers
Lancaster, UK
Olfactory aura is a feature of temporal lobe epilepsy. Smells are usually described as unpleasant; burnt rubber is something I remember from my medical school days. The olfactory aura can be associated with other unpleasant sensations such as a feeling of impending dread.

Reality check

If the world we observe is just our brain's interpretation of the electrochemical signals it receives from our eyes, what is the world actually like? (continued)

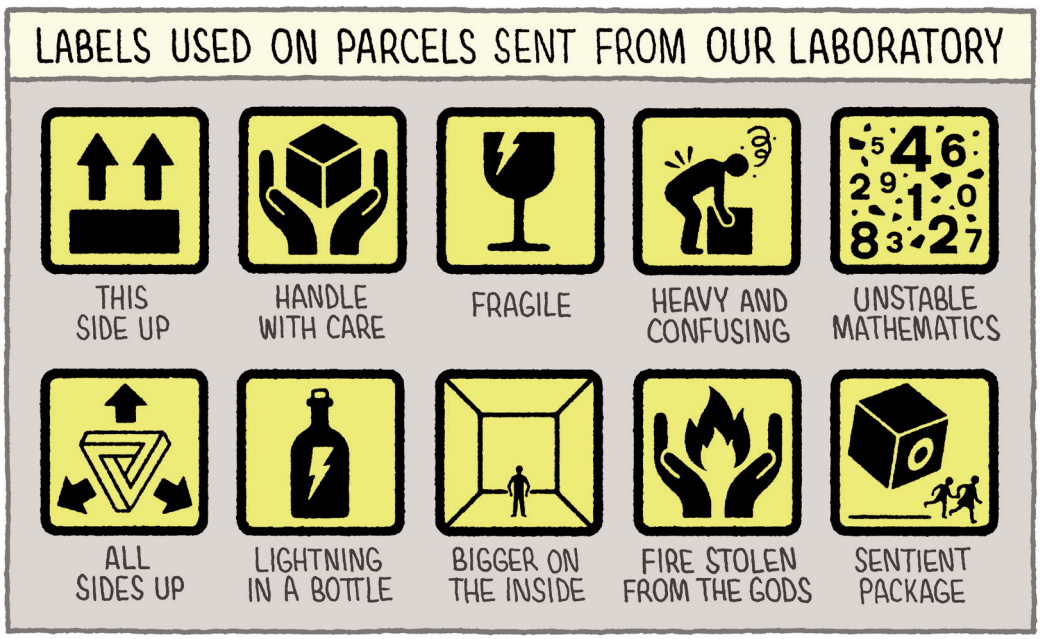
Biram Desai
Brighton, UK
To paraphrase the words of philosopher Alan Watts, a question that is perpetually difficult to answer may indicate that the question needs to be reframed. If indeed there are only relative realities and no objective reality, then the question is only relevant in relation to the observer. So, the world is whatever you perceive it to be!

Brian Balke
Via Facebook
In precise terms, we don't "see" our brain's interpretations. We generally see our brain's expectations. These expectations are categorisations of sensory patterns that prepare downstream networks to initiate muscle and endocrine control.

Tools enhance our power over the world and our understanding of it. As the tools shrink, we build abstract models of their elements, eventually achieving control at scales far below our natural

Want to send us a question or answer?
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Tom Gauld
for New Scientist



sensory sensitivity. This requires that we develop enhanced sensory tools as well as manipulators.

What this all boils down to is that we don't just "see" with our senses. We have enhanced our senses using our expectations about the world. Those enhanced senses include ultrasonic imaging, X-ray scanners, particle colliders and pressure sensors. Those enhanced senses, in their agreement with our expectations, confirm that there is a world beyond our perceptions.

Despite this conclusion, we should be aware that there is a great deal in our sensory data that cannot be replicated by artificial sensors. The ability to shift attention to acquire additional detail, the tingle of excitement upon seeing a romantic partner, the disorientation felt during a bout of the flu: these are all subjective experiences that differentiate, in their richness, human consciousness from any form of artificial consciousness built upon linguistic abstractions. That we struggle to convey our subjective experience is also an aspect of the world. It may not be measurable, but I actually kind of like that.

"In precise terms, we don't 'see' our brain's interpretations. We generally see our brain's expectations"

Tony Cusano
Via Facebook
The world is actually just like our brain's interpretation of what we see. But it's a trick question, because it's not just "our brain", but all of our brains linked in a social network.

We can be fooled by randomness, but if the world were purely random, repetitive events would not be as persistently predictable as they are. Unpredictable events becoming predictable with more measurements of more underlying variables also undermines pure randomness.

Thunder and lightning are good examples of events that appeared random for generations, then, with better observations, gradually gained predictability to the point where they can now be prepared for well in advance of them occurring, though not yet with perfect accuracy.

No one brain learned that, but the human social network did.

Julian Gold
Via Facebook
All those "brain in a jar" arguments neglect the fact that we are all, in fact, brains in (meat) jars.

Yes, our brains help us approximate the state of the external world. The question as to how close that approximation is depends on a lot of things, but the granularity is extended by our ability to build sensors that augment the range of what we can see, which was originally dictated by the survival needs of 4 billion years of evolution and predation.

Asking what it's "really" like is meaningless though. ▮

Answers

Quick quiz #378

1 A dwarf planet

2 Aerogel

3 Iron

4 Binance

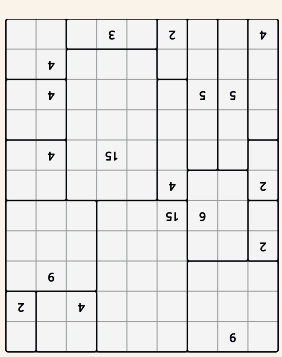
5 Jet lag

Quick crossword #221

ACROSS 7 Genome, **8** Creosote, **9** Atom bomb, **10** Indigo, **11** Collider, **12** Eupnea, **13** Uncertainty, **18** Answer, **20** Lab coats, **22** Cinema, **23** Infrared, **24** Whizbang, **25** Icicle

DOWN 1 Neutron, **2** Formalin, **3** Record, **4** Beriberi, **5** Used up, **6** Stagger, **8** Cyberstalking, **14** Ear canal, **15** Thoracic, **16** Insight, **17** Steeply, **19** Wheeze, **21** Boffin

Block Universe



Caught on camera

One of the defining features of conspiracy theories is that they are "self-sealing". If you confront a conspiracy theorist with the lack of evidence for their claim, they will turn this back on you and argue that this very lack of evidence is proof of how powerful the conspiracy is.

This is foreshadowing.

Feedback is interested in watching the new documentary *Capturing Bigfoot*. We can't, because we live in the UK and it isn't available here, but if anyone would care to rectify that, we will stick ourselves in front of it immediately.

The film is about the classic footage that purports to show a Bigfoot loping alongside a river in California. Shot by Roger Patterson and Robert Gimlin in 1967, the clip became one of the canonical pieces of evidence for the existence of Bigfoot: a mythical humanoid that supposedly lives in the forests of North America. Bigfoot is one of the icons of cryptozoology, the search for probably-nonexistent creatures. It has hordes of devotees.

In *Capturing Bigfoot*, film-maker Marq Evans uncovers what really happened in 1967. He speaks to Patterson's associate Bob Heironimus, who says he wore an ape costume in the footage.

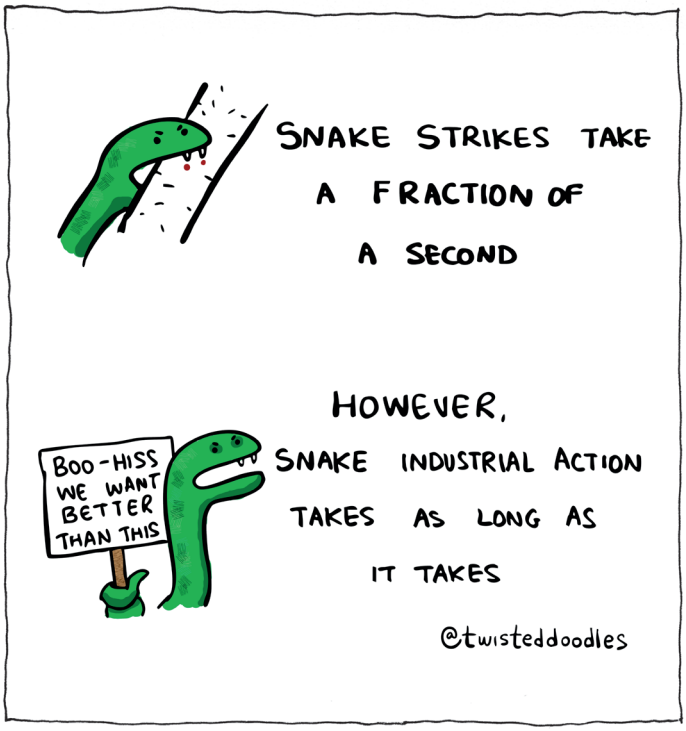
Crucially, Evans also finds a lost piece of 16-millimetre film, shot in 1966, showing a rehearsal for the final Patterson-Gimlin video. A review of the documentary in *Variety* calls this footage "the smoking gun". It is, Feedback would suggest, a case no defence lawyer could wriggle out of.

So, the Patterson-Gimlin film purporting to show Bigfoot was fake. Feedback and our editor worried if we were legally safe saying that, but then, as our editor said, "come on".

It is perhaps telling that, when we mentioned this to Mrs Feedback, her response was "I could have sworn I already knew that". Indeed, these accusations have been made before, notably in Greg Long's 2004 book *The Making of Bigfoot*. The new thing is that rehearsal footage.

Naturally, then, this footage is what the Bigfoot Field Researchers Organization pushed back on. Its president is quoted in *The Times* as saying: "My initial reaction is, how could you believe that in the age of AI?... Even if they found some reel, how would you know whether what they're showing in the documentary is what's on the reel?" And thus the foreshadowing pays off.

Twisteddoodles *for New Scientist*



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A not-so-helpful acronym

In late October, a lot of websites suddenly went offline. This was because of a vulnerability in the PHP programming language, which had been known since 2024 but was thought to be too difficult to exploit, until AI tools found how to do it.

Reader Chris Hall had never heard of PHP. This seems to have been a common experience: even the BBC's cyber correspondent Joe Tidy only learned of the existence of PHP when the story broke. Tidy got a lot of online abuse for this, which Feedback thinks is unfair: his job is to explain things clearly, not to be a walking technical manual. In the interests of solidarity, Feedback will say that we still don't know what distinguishes a baryon from a boson, and at this point we refuse to find out.

Anyway, Chris looked up PHP and was given "the helpful information" that it stands for "PHP: Hypertext Preprocessor". "I can understand the 'H' and second 'P'," he says, "but what does the first 'P' mean?"

Feedback is happy to clarify that PHP originally stood for "personal home page". When it was upgraded in the late 1990s, the programmers kept the letters and had to think of something new for them to stand for. Hence the recursive backronym that is "PHP: Hypertext Preprocessor".

They just said it

Sometimes, scientists fake their results. The problem is spotting the fakery, because it isn't always obvious. Often, images have been copied from other papers, necessitating systematic searches. Or you have to perform careful statistical analyses on the raw numbers to identify the trends that reveal they have been made up.

Or, sometimes, the authors might just flat-out tell you – leaving you to decide whether or not they mean it.

Nihar Shah is a computer scientist at Carnegie Mellon University in Pennsylvania, who mostly studies AI scientists: those systems that can do research and write papers with little or no human intervention. However, he is also the author of the blog Research on Research, about "academia, research, and peer review", where he writes about some of the weird stuff that finds its way into peer-reviewed journals.

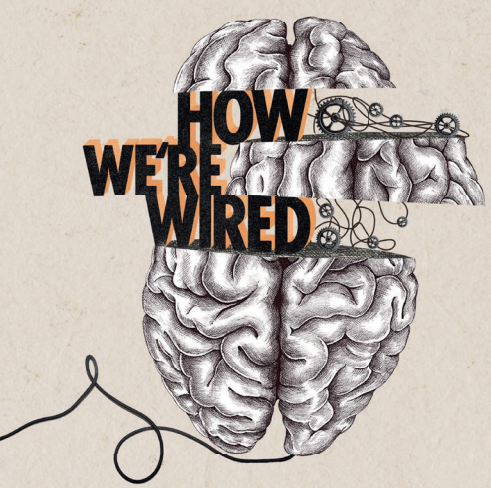
In October, Shah looked at a host of recent scientific studies and found that many of them included variations on the same phrases. These remarks showed up over and over again, in at least 60 papers. Phrases like: "The values in this table are illustrative placeholders for formatting purposes and must be replaced with results obtained from actual experiments". Or "Planning scenario, not measured results". Or "note: the values shown are placeholders and should be replaced with your actual experimental results".

What on Earth is going on? On the face of it, the authors are just admitting that they have made up data. However, Shah says (and Feedback agrees) that there is no reason to assume chicanery. Perhaps all of these papers are built on real results, and the authors just forgot to remove these placeholder texts from early drafts. In other words, this could all be the result of really, really sloppy editing on the part of all concerned. Which is, we guess, reassuring? Um.

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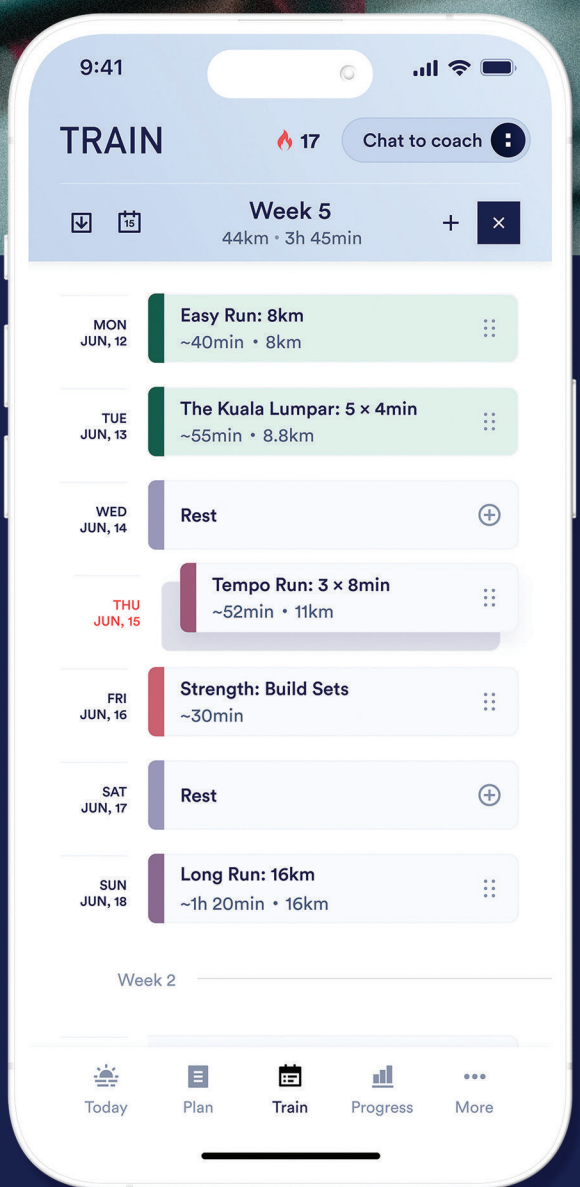
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