New Scientist

WEEKLY 6 June 2026

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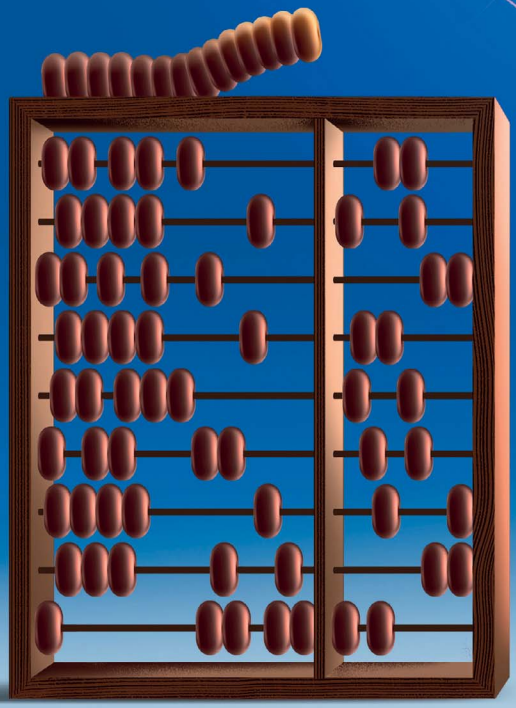

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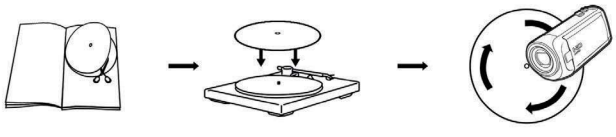

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XPENG

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Sealandheir

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AI Einsteins

Superintelligent machines may well need us after all

IN 1915, Albert Einstein stood before the Prussian Academy of Science and revealed the now-famous equations of his general theory of relativity. Einstein and relativity are synonymous today with genius, but these revelations were initially met with indifference, in part because the maths was too radical for his peers to fully digest.

Today, tech firms would have us believe we are on the brink of "superintelligent" artificial intelligence capable of outperforming experts in most domains, producing scientific breakthroughs on a par with Einstein. As Anthropic CEO Dario Amodei put it, we will see "a country of geniuses in a datacenter". Claims like these are often provided with little evidence, and identifying genius or elevated intelligence is a murky endeavour.

But one corner of academia that might be seeing superintelligence come to pass is mathematics. In this week's cover story, on page 30, we learn how mathematicians are in a state of wonder and panic about the rapid rise of AI's mathematical ability.

This glimpse of the future doesn't

"AI's successes also show how integral human mathematicians are to the scientific process"

appear to exclude us, however. AI's successes also show how integral human mathematicians are to the scientific process. The most impressive AI-fuelled discoveries, such as OpenAI's recent falsification of an 80-year-old conjecture, are credible only because mathematicians say so. We report on page 7 how humans are already using AI's ideas to make progress on other maths conundrums.

If this spreads to the other sciences, then it suggests we won't be following AI geniuses, but will instead look to people who know how to use these tools and insights best. This might not be quite like the superintelligence that AI companies proselytise, but it could be closer to how human genius has always functioned.

Without Einstein's colleagues, like Karl Schwarzschild or Willem de Sitter, who went on to apply relativity to our universe, predicting black holes and an inflationary universe, it wouldn't have had the outsize impact on our understanding of reality that it does today. Genius, by itself, has never been sufficient. ▮

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Climate change

Is this how to stop sea ice melting?

There are plans to preserve Arctic ice by pumping water onto the ice sheet and letting it freeze, but early trials have delivered mixed results, reports **Alec Luhn**

EACH winter, Canada builds more than 7000 kilometres of ice roads, in part by drilling holes in lake ice and pumping water onto the surface, where it freezes and thickens the ice for massive vehicles.

If we did the same thing on top of Arctic sea ice, could we thicken it enough to stop it from disappearing? That's the question tested by geoengineering researchers in field trials in Canada and Norway in 2024 and 2025. It's one relevant to the whole planet, since Arctic sea ice, which is expected to disappear completely in the summertime as early as the 2030s, reflects more of the sun's warmth back into space than open ocean.

While both trials thickened sea ice, the scientists in Canada said this slowed the ice's melt when summer came, while those in Norway found it didn't. Both groups have continued doing trials.

"Yes, the ice is getting thicker, but how it delays the eventual disappearance of the ice remains an open question," says Christian Haas at the Alfred Wegener Institute in Bremerhaven, Germany, who worked on analysing the Norway trial results.

There, the Dutch company Arctic Reflections drilled a hole through nearly a metre of ice in a lagoon in the Svalbard archipelago in April 2024 and shoved an ice road pump into it. For a little over an hour, a stream of seawater flooded the roughly 20-centimetre layer of snow on top of the ice.

The team repeated the process the following day to create a 1500-square-metre puddle of slush that froze hard within the next three days, increasing the total sea-ice thickness from 90 centimetres to 1.16 metres (*JGR Oceans*, doi.org/q8xd). But a camera left at the site until the end of June showed that although the thickened ice started "rotting" later, it ultimately still melted away on the same day as a control site in the lagoon.

REAL ICE

A pump delivers seawater to the surface of an ice sheet in Canada (above), and researchers measure the ice's thickness (below)

"The ice is getting thicker, but how it delays the disappearance of the ice remains an open question"

A second opinion

Then, between December 2024 and February 2025, the UK company Real Ice drilled holes and pumped water onto sea ice at eight sites in the Northwest Passage, just south of the Inuit village of Cambridge Bay, Canada. These researchers flooded and froze the snow layer over a total of 250,000 square metres, thickening some sites twice.

By May 2025, the average thickness at sites flooded in January and February was 1.93 metres, compared with 1.62 metres at three control sites (*Earth's Future*, doi.org/q8xf).

When seawater freezes, it expels salt as a briny liquid. The thickening process heated the sea ice and made it saltier as this brine drained through pores in the ice.

If the thickened ice remains saltier and more porous into the melt season, that could speed up its melt, much like putting salt on an icy road, worries Haas. "It's not about the thickness, but about the quality of the ice," he says.

But the brine pores could also drain meltwater and slow the ice's disappearance, according to Andrea Ceccolini of Real Ice. Long wires of temperature sensors drilled into the ice suggested the test sites in Canada melted more slowly than the historical average, lasting an estimated seven to 10 extra days.

Both trials found thickening made ice brighter, with Real Ice's test sites showing up as white spots amid blue meltwater in satellite imagery in June. "We were contributing to reducing the heating of the planet," says Ceccolini.

The Arctic Reflections study, however, estimated that the cooling effect barely compensated for the warming from pump and vehicle emissions.

A few years of research is needed to assess whether thickening could help preserve Arctic sea ice, says Michel Tsamados at University College London.

If sea-ice thickening proves to be feasible, someday 500,000 underwater drones could refreeze 1 million square kilometres of sea ice, boring upward through the ice with heated hoses, according to Real Ice.

However, last year, 42 scientists authored an article arguing that polar geoengineering, including sea-ice thickening, was unfeasible and could distract from reducing emissions.

"This technique might have limited use as a small-scale stopgap in some localised regions, but it doesn't represent a practical large-scale solution," says Michael Meredith at the British Antarctic Survey. ▮

Huge study of Alzheimer's genetics finds new drug targets

Chris Simms

THE biggest genetic study of Alzheimer's disease so far has identified 127 gene locations that are associated with the condition, of which 48 are new. The study also pinpoints several genes that could be prioritised as drug targets and cell types linked to a higher genetic risk of the condition.

"It's an exciting time for Alzheimer's genetics," says Rudolph Tanzi at Massachusetts General Hospital, who provided evidence of the first Alzheimer's-linked gene, *APP*, in 1987.

Alzheimer's disease, the most common cause of dementia, is highly heritable, with twin studies showing genetics can account for about 60 to 80 per cent of a person's risk. Many genes have been found to play a role, chief among which is *APOE*. Inheriting one copy of a variant of this, known as *APOE4*, from a parent makes someone two or three times as likely to develop Alzheimer's as someone without the variant, and getting a copy of *APOE4* from both parents can increase risk up to 12-fold.

But health and lifestyle also play a big part, and even people who seem genetically destined to develop Alzheimer's sometimes avoid it. "There are people who have those two risk variants and never develop Alzheimer's," says Danielle Posthuma at the Free University of Amsterdam.

To get a better handle on the genetics, Posthuma and her colleagues have analysed genome data from almost 110,000 people diagnosed with Alzheimer's, plus about 74,000 people with at least one parent who had the condition but were too young to have developed it themselves. They compared this with data from about 2.6 million people without Alzheimer's to reveal 127 genes associated with the condition, of which 48 haven't been linked to the condition before (medRxiv, doi.org/g983dp).

Finding clues

These newly identified genes offer clues to the mechanisms behind Alzheimer's, which are still poorly understood. The disease features an abnormal build-up of the proteins amyloid-beta and tau in the brain. Immune cells, including a type called microglia, also move to the area, at first helping to clear the protein accumulations, but leading to inflammation as the disease progresses.

Looking at additional data to reveal the activity of different genes in specific cell types, Posthuma's team saw that Alzheimer's risk variants may lead to heightened expression of microglia genes and reduced expression of neuronal genes, which fits with previous reports of inflammation and reduced neuronal functions in Alzheimer's.

"While the first four Alzheimer's genes discovered all pointed to amyloid-beta deposition, many still implicate amyloid, but the majority of the new genes implicate the roles of immunity and neuroinflammation," says Tanzi.

The team identified three types of neurons that express genes more weakly when people have Alzheimer's-linked variants of those genes, compared with other variants. "These are some of the first neurons to disappear in the Alzheimer's brain," says Posthuma, although she can't say whether the disappearance is a cause or effect of Alzheimer's.

Posthuma and her colleagues highlight five potential drug targets among the newly flagged genes. Three of these are known to be involved in the immune response.

"Maybe we should be thinking more about drugs that target the immune system, rather than just anti-amyloid, which is where most of the funding has gone previously," says Shea Andrews at the University of California, San Francisco.

The other two targets they flag are *UBE2V1* and *SPATA2*, which seem to be relevant to multiple neurodegenerative conditions.

"Risk for Alzheimer's disease is multifaceted, and there isn't just one biology or cell type at play"

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Healthy lifestyle choices can also help prevent cognitive decline

ZEPHYR/SCIENCE PHOTO LIBRARY

Alzheimer's is associated with the abnormal build-up of amyloid proteins in the brain

Andrews thinks a multi-drug approach will be needed to treat Alzheimer's, with some drugs targeting amyloid, some tau and others the immune system, with all used alongside healthy lifestyle choices to prevent cognitive decline.

"This work shows that risk for Alzheimer's disease is multifaceted and there isn't just one biology or cell type at play," says Rebecca Sims at Cardiff University in the UK.

About 90 per cent of the people in the study were of European ancestry, so it might not be representative of a wide range of ancestries, says Sims.

Genetic tests currently have limited power to predict people's Alzheimer's risk, but Andrews says research like this might make them more useful.

Improved tests could identify people with a slightly higher risk who could be screened more regularly or encouraged to develop a lifestyle to try to offset that risk. "We don't want to be too deterministic about it because the increase in risk is not determinative," he says. ▮

Zoology

Salamanders' secret glow

An amphibian's fluorescent secretions may be used for communication

Michael Dalton

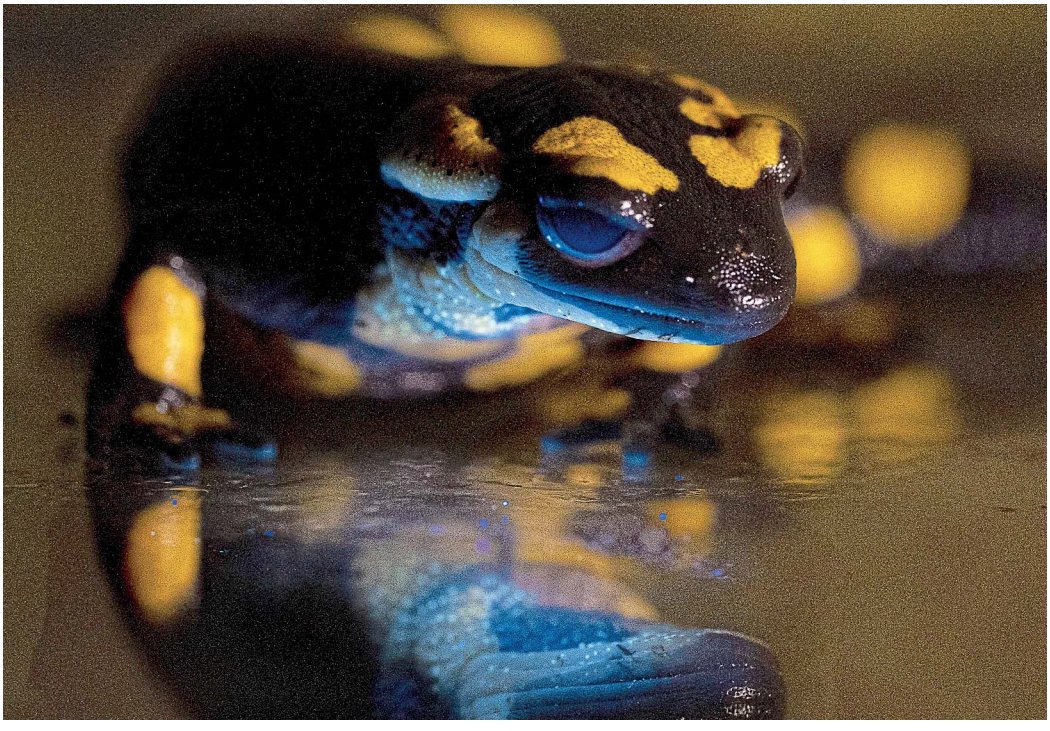
FOR the first time, fire salamanders (*Salamandra salamandra*) have been shown to biofluoresce, absorbing and re-emitting light at different wavelengths.

In this instance, 10 fire salamanders in Catalonia, Spain, gave off a blue-green glow after being exposed to ultraviolet light (*Royal Society Open Science*, doi.org/hb5p92).

This ability had never been recorded in fire salamanders before, despite being a very well-studied species.

The fluorescence, which was produced by secretions from the salamanders' skin glands, appeared primarily on the side and underside of their bodies.

The researchers behind the work believe that this biofluorescence may help the animals to attract mates, or perhaps even protect themselves from predators. ▮



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Climate change

Glaciers in the 'roof of the world' are now melting

ONE of the world's last stable glacier regions may have finally succumbed to global warming, with researchers recording an unprecedented loss of ice across the Pamir mountains of Asia.

For decades, glaciers all over the world have been retreating due to rising temperatures, but in central Asia, a region dubbed "the roof of the world" has bucked this trend.

From the 1970s to the early 21st century, glaciers in the western Kunlun mountains, the Karakoram mountains and the eastern Pamir mountains have remained stable or grown slightly.

Fan Yu at the Chinese Academy of Sciences and his colleagues have been monitoring the 3-kilometre-long Kangxiwa glacier in the Xinjiang Uyghur Autonomous Region, China. The glacier is within the eastern Pamir range and is 5350 metres above sea level at its highest point.

Before 2022, the ice mass of the glacier exhibited some fluctuations but remained in a stable pattern of moderate mass loss, with occasional years showing slight growth.

But since then, ice loss has accelerated. In 2025, the team recorded a record-high loss of ice, equivalent to the entire surface of the glacier losing 1.5 metres of water. This is more than four times greater than the glacier's average for 2011–2024 (*Advances in Climate Change Research*, doi.org/q8wh).

The record-breaking melt seen at Kangxiwa, mirrored at other glaciers across the Pamir mountains, was driven by exceptional heat. Unlike other years, when extreme temperatures were confined to a single month, high temperatures in 2025 persisted throughout the entire melt season.

"The glaciers of the Pamir-Karakoram region are no longer an exception to the global trend"

The findings suggest the glaciers of the Pamir-Karakoram region are no longer an exception to the global trend, and extreme events are likely to further accelerate glacier melt there, say the researchers.

Shaun Eaves at the Victoria University of Wellington, New Zealand, says the results are consistent with predictions that human-induced climate change will increase the probability of extreme warm temperatures that can drive glacier melt, but it is too early to conclude that such melting is locked in.

Glacial ice mass measurements have been undertaken at Kangxiwa glacier only since 2011, so it is hard to describe 2025 as extreme in a historical context, he says. ▮

James Woodford

Mathematics

AI helps researchers crack a 50-year-old problem

Alex Wilkins

JUST a week after an AI disproved an 80-year-old conjecture, another conjecture has been refuted via a similar method. This time, though, it was written entirely by humans.

Last week, an unreleased AI model from OpenAI disproved an important conjecture first posed by mathematician Paul Erdős concerning the number of similar-sized connections you can make between dots on a flat surface.

Erdős had set an upper ceiling on this number, but the AI model showed that this number could in fact be much larger, using an obscure trick from algebraic number theory to make complex structures with extremely high dimensions. These could then be used to arrange the dots in a very different arrangement than humans had considered.

Now, Thomas Bloom at the University of Manchester in the UK and his team have used a similar argument to disprove another claim, which Erdős first posed in 1976.

Erdős's sum-product conjecture concerns collections of numbers, or sets. It says that if you either add or multiply all the numbers together in this set, one pair at a time, to create a further two sets, then at least one of these sets must be much larger than the original set.

Erdős set a bar for how small the larger of the two added and multiplied sets could be, and proposed this should hold for any set of numbers. But Bloom and his colleagues used the same high-dimensional trick to find a set where both its sum and product are smaller than Erdős thought possible (arXiv, doi.org/q8wq). "The real surprise for me was that it was so simple," says Bloom. ▮

To read more about AI and mathematics, turn to page 30

Health

Cancer-killing virus halts the growth of pancreatic tumours

Alice Klein

A VIRUS has stopped pancreatic cancer in its tracks in three people in a clinical trial in the US. Further evaluation is needed in larger trials, but the early results are encouraging, especially since only small doses of the virus were administered for initial safety testing.

"We only injected one-tenth of the dose we are eventually aiming at, so the efficacy is better than I expected," says Masato Yamamoto at the University of Minnesota, who led the development of the viral treatment.

Pancreatic cancer is notorious for being the deadliest type of the condition. One reason is that symptoms tend to appear late, when the cancer has spread and can't be surgically removed. Once diagnosed, people usually live only around three to six months.

Another reason why is that pancreatic tumours have tough, fibrous interiors that block chemotherapy drugs from getting in. Immunotherapies that boost immune activity against cancer are also ineffective, because pancreatic tumours can hide from the immune system.

The first patient in the trial, who had a pancreatic tumour 7 centimetres across, was administered the treatment a year ago, and the other two have been since then. At the time, their tumours hadn't spread beyond the pancreas. Since being treated, their tumours haven't grown any further. "They are all still alive and have clinically stable disease," says Yamamoto, who presented the results at the annual meeting of the American Society of Gene and Cell Therapy in Boston, Massachusetts, last month. Another 15 patients will now be given higher doses to find the optimum level.

"We injected one-tenth of the dose we are aiming for, so the efficacy was better than expected"

"I think this is an interesting early signal, but as a pancreatic surgeon, I think it's important to keep perspective," says Kai Brown at Royal North Shore Hospital in Sydney. He notes that the trial so far hasn't included a control group, so it is hard to know whether the virus works better than other treatments or none at all.

The virus is an adenovirus that has been genetically engineered to replicate only inside tumours. Its replication is activated by an enzyme called cyclooxygenase-2 (COX-2), which is present at much higher levels in cancer cells than in normal ones. After cancer cells become infected with the virus, they burst open and die, releasing more virus that can infect neighbouring cancer cells.

In the trial, the virus was injected directly into the patients' tumours through a thin tube that was guided down the throat to their pancreas. The tube had an ultrasound probe on the end of it to allow visualisation of the tumours.

The reason the tumours have stopped growing but haven't become any smaller may be due to the low treatment dose, says Yamamoto. He thinks they may start to shrink as the virus has more time to replicate.

As the tumour cells start to break apart and leak their contents, the immune system may also be able to recognise and fight the cancer, says Yamamoto.

To try to supercharge this natural immune response, Yamamoto and his colleagues are planning to combine the viral treatment with immunotherapies like checkpoint inhibitors – drugs that block proteins that stop the immune system from attacking the cancer cells – in future trials. ▮

JEAN-FRANCOIS MONIER/AFP VIA GETTY IMAGES

Pancreatic cancer often spreads before symptoms start to appear

Biology

Debate rages over mirror-life threat

Bacteria created using mirror images of natural biomolecules pose a risk to life on Earth, some researchers warn, but others say they have a key weakness, finds **James Woodford**

ANY "mirror life" made in the laboratory would have a hard time surviving in the wild, according to a modelling study. To do so, it would need a ready supply of "mirror food", or some novel way to feed itself.

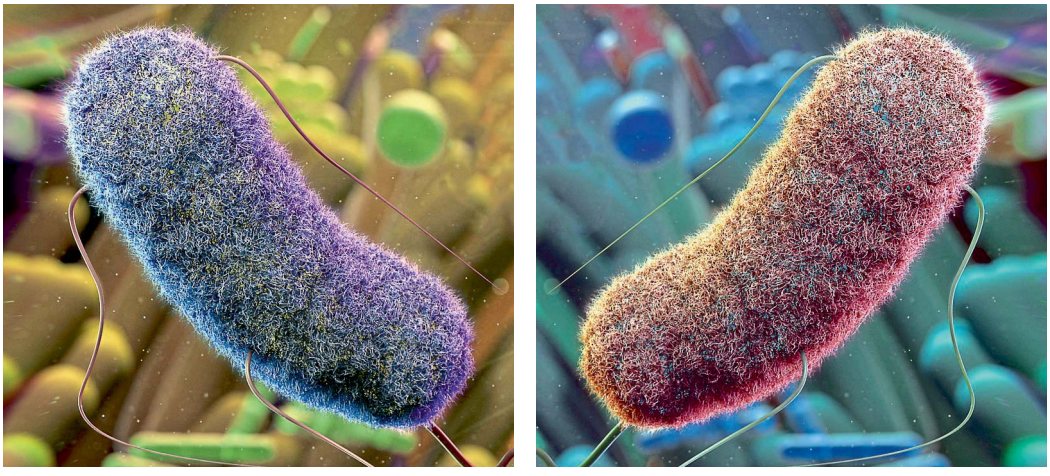
But the research has drawn a backlash from other experts in the field who warn that it may underestimate the grave risks posed by these organisms.

Many biological molecules, such as DNA and proteins, are chiral, which means they can exist in either left-handed or right-handed forms. Like your left and right hands, they are mirror images of each other, and cannot be superimposed. But all life on Earth uses right-handed DNA molecules and left-handed protein molecules, which enables cellular machinery to fit together properly.

While it isn't yet technically feasible, one day it may be possible to manufacture organisms in which the handedness, or chirality, of molecules is reversed. In 2024, 38 scientists published a paper in *Science* calling for work towards the creation of mirror life to be halted because of the dangers such organisms may pose – for example, immune systems may not be able to recognise and defend against mirror bacteria.

"Mirror life would likely face very severe barriers under a broad range of ecological conditions"

In the new study, Ricard Solé at the Santa Fe Institute, New Mexico, and his colleagues explored what would happen if a tiny population of mirror organisms appeared in Earth's biosphere. They used computer models to determine what constraints would be placed on mirror life forms in a range of different real-world scenarios.



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One day, it may be possible to create "mirror organisms" in the lab

For mirror life to pose a threat, it must first be able to exist in some kind of self-sustaining way, says Solé. The biggest hurdle mirror organisms would need to overcome is that life forms can digest food made up of molecules only with the same chirality as themselves.

"One could imagine engineering dedicated 'mirror food' together with mirror organisms. But that shifts the problem rather than solving it," says Solé. "A mirror biosphere would require not just isolated nutrients, but a continuous industrial infrastructure capable of producing large quantities of mirror-chiral biomolecules."

The team's models specifically addressed whether mirror organisms could establish themselves autonomously in real ecological environments, not whether they could temporarily survive under controlled laboratory or industrial conditions with engineered feeding systems.

"Our view is that mirror life would likely face very severe barriers under a broad range of ecological conditions, making successful establishment difficult," Solé says.

The study has been published as a preprint before being peer-reviewed (Biorxiv, doi.org/q8wk). But a group of scientists who study mirror life have already responded with a statement calling for the paper to be revised.

A second tree of life

Vaughn Cooper at the University of Pittsburgh, Pennsylvania, one of the authors of the statement, told *New Scientist* that although mirror microbes would initially grow more slowly than native microbes because of a nutritional mismatch, there are plenty of nutrients that aren't chiral, which could support their growth. "Further, the mirror cell population would rapidly evolve and adapt to new conditions, creating essentially a second tree of life," says Cooper.

The study also suggests that existing biodiversity on Earth would act as a "firewall" against invasion, since natural organisms are better adapted to the environment, and some may be able to outcompete the mirror organisms.

But Cooper argues that mirror bacteria would be largely resistant to predation by natural microbes. "There are countless examples of invasion biology that indicate the vulnerability of biodiverse ecosystems to invaders lacking predators," he says.

Kate Adamala at the University of Minnesota, one of the authors of the 2024 *Science* paper, says Solé's team is correct that the supply of food containing the same chiral molecules would be a constraining factor for mirror organisms.

But she points out that there are ways such organisms could make their own food using photosynthesis. They could also be engineered to make use of chiral molecules that are found in nature. "It would be extremely hard to make such an organism, but it's not impossible to imagine," says Adamala.

Solé says his team did consider the possibility of mirror organisms exploiting non-chiral nutrients or using photosynthesis, but argues they would face the same ecological challenges. ▮

Health

3D-printed lymph nodes could widen access to cancer therapy

Carissa Wong

CAR T-cell therapy, when someone's immune cells are genetically engineered to kill cancer cells, is highly effective for treating certain types of cancer, but it is too expensive to be widely available worldwide. But utilising 3D printing could mean that these engineered cells are produced for less money and – crucially – faster.

"When you're treating very sick patients, some patients might never get the therapy because they've deteriorated so much in the three or so weeks it might take to make the CAR-T therapy," says David Coe at CoED Biosciences, a biotechnology company in Cardiff, UK, who wasn't involved in the latest research.

CAR T-cell therapy involves extracting immune cells called T-cells from someone's blood before genetically engineering them to recognise and destroy cancer cells.

This is usually done by mixing the cells with tiny beads that activate their proliferation. They are also mixed with a harmless virus that delivers them the genetic code for a protein that targets molecules on the surface of cancer cells, called a chimeric antigen receptor (CAR). Typically, 30 to 70 per cent of the T-cells are successfully reprogrammed, with a higher proportion tied to better outcomes.

All of the cells are then multiplied for a few weeks before being infused back into the body, meaning the entire process can take about a month. Another issue is that just one round of the therapy can cost more than £280,000. "CAR T-cell therapy is phenomenally expensive, so it's only really available in wealthier nations," says Gillian Griffiths at the University of Cambridge, who wasn't involved in the research.

To address these limitations, Judit Guasch Camell at the Materials Science Institute of Barcelona, Spain, and her colleagues 3D printed a gel to form structures that resemble the texture and arrangement of human lymph nodes, where T-cells are usually activated upon recognising a threat.

Prior studies suggest that T-cells sense the physical properties of lymph nodes, which helps them

"3D printing could mean that engineered cells are produced for less money and faster"

activate and proliferate more efficiently, said Guasch Camel, who presented the research at the Biophysical immunoengineering conference at The Royal Society in London in May. During the standard approach for making CAR T-cells, the T-cells are activated while they interact with flat plastic surfaces – like lab dishes or bags – that fail to provide many of these tactile cues, which limits their proliferation and uptake of the CAR genetic code, she said.

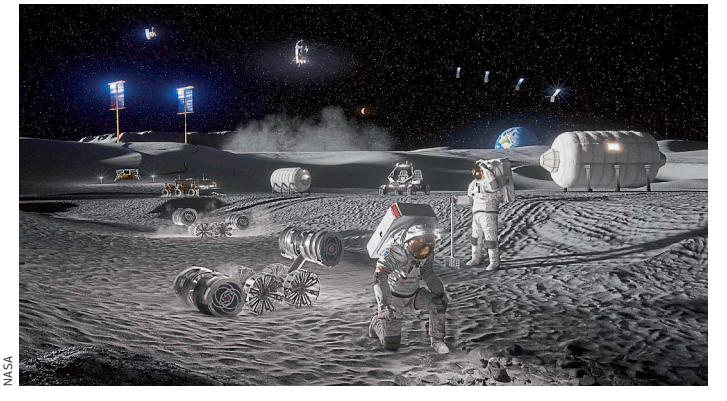
To test their 3D approach, the researchers added human T-cells, a virus encoding a cancer-specific CAR and the beads to the lymph-node-like structures. For comparison, they also mixed the same components in plastic dishes.

Five days later, about 50 per cent of the T-cells grown with the standard approach had successfully become CAR T-cells, compared with 75 per cent grown with the lymph-node method.

The T-cells also grew about twice as fast in the lymph node structures, which could cut down on labour costs and ensure patients are treated before it's too late, says Coe.

Solar system

We've taken one small step towards a base on the moon



NASA

Astronauts could be living and working on the moon in the next decade

PLANS for a lunar base have been part of NASA's Artemis programme for years, but until recently there were few solid details on a timeline. On 26 May, it was announced that the first three missions to build a lunar base will be targeted for this year, with at least a further nine to be announced before 2027.

The overall programme will consist of three phases, with the first lasting until 2029 to "secure reliable access" to the moon's surface. The second will last until 2032 for "initial moon base operating capability", and the actual base itself is to be built near the lunar south pole in the third and final phase, lasting up to 2036.

This year's missions won't be crewed and will look to study the lunar surface in detail, in order to reduce the risks for future landing missions. The first of these missions, Moon Base I, will launch towards the end of this year and will feature a lander built by Jeff Bezos's space company Blue Origin, which hasn't yet tested a lunar lander.

NASA has also given further details of its MoonFall mission, which will see four drones make short, hopping journeys across the lunar surface in 2028, taking high-resolution pictures to find suitable landing sites for future Artemis missions. While NASA will make the drones in-house at its Jet Propulsion Laboratory in California, the company Firefly Aerospace will build the spacecraft that takes the drones from Earth to the moon.

However, there are still scant details of crucial elements of a future moon base, such as how it might be powered. Previous NASA administrator Sean Duffy had announced that a nuclear fission reactor would be built on the lunar surface by 2030, but there were no updates about this in the most recent announcement.

Alex Wilkins

Society

Individualism gets in the way of love

People with a more individualistic mindset may experience romantic love less intensely

Carissa Wong

MORE people are prioritising their own goals over those of the wider community, and according to one of the largest ever studies on love, it is affecting how we feel about our partners.

Previous research suggests that individualism is increasing around the world. "My opinion is that younger generations [today] are likely to be more self-obsessed [and] more individualistic [than previous generations at the same age]," says Julie Aitken Schermer at Western University in Ontario, Canada, who wasn't involved in the latest study.

But when it comes to the consequences of individualism, specifically around romantic love, research has been mixed. This is probably because the studies were focused on just one or two countries, says Marta Kowal at the University of Wrocław, Poland, who presented the new study at the Love, Actually and in Theory conference in Edinburgh, UK, last month.

She and her colleagues recruited more than 61,000 adults, aged between 18 and 90, from 81 countries, who had been in a romantic relationship for anywhere from weeks to years.

"If you're constantly worried about you as an individual, you feel a lot more competition"

The participants completed online surveys on how intensely they loved their partner. This involved ranking on a scale of 1 to 5 how strongly they agreed with statements such as "I feel a deep emotional bond with this person" and "I am committed to maintaining this relationship".

They also completed surveys where they indicated, on a scale from 1 to 7, how much they agreed with statements such as "group success is more important than individual success" and "individuals should pursue goals only after considering the welfare of the group".

Together, the surveys revealed that participants with a more individualistic mindset seem to experience romantic love less strongly, even when accounting for factors such as sex, age and economic background. The researchers found similar results when they replicated the study in a separate group of more than 6000 partnered adults from 50 countries.

It may be that individualism is making us love less intensely because it affects our ability to connect, says Thomas Curran at the London School of Economics and Political Science. "If you're constantly worried about you as an individual [and] the way you're perceived as an individual, you feel a lot more competition because you think everybody's an individual fighting for scarce resources," he says. "So, whenever you're interacting with someone else, you're thinking, how do I put my best face forward?"

This could make it harder for people to be vulnerable, which is a core part of loving intensely, says Curran.

If you find that individualism is negatively affecting the intensity of love you feel, there may be ways to overcome it. For instance, encouraging people to view themselves as a part of a wider community, like through talking therapy, could be effective, says Schermer. ▮

Space

Supermassive black holes may give rise to strange worlds

MASSIVE amounts of dust swirl around active nuclei at the centres of galaxies, and these discs could bring about vast numbers of rocky planets, some even the size of stars.

Most galaxies in the universe, such as our own Milky Way, host a supermassive black hole at their centre. Most of the time, these black holes are quiescent, as there is no matter falling into them. But occasionally they become active and consume huge amounts of dust and gas, perhaps from a merger with another galaxy, becoming an active galactic nucleus for millions of years.

Barry McKernan at the City University of New York and his team modelled the disc of dust and gas around a typical active galactic nucleus. They found it would be a prime location for planet formation, with the dust clumping together into bigger and bigger objects. Eventually planets would begin to grow in huge numbers, and with strange properties (arXiv, doi.org/q8rq). "If these things exist, they're quite unlike planets that we know and love," says McKernan.

NASA AND M. WEISS/CHANDRA X-RAY CENTER

Large discs of dust and gas can swirl around supermassive black holes

The planets would grow to enormous sizes because active galactic nuclei contain massive amounts of dust, much more than the protoplanetary discs around young stars that formed solar systems like our own. That could lead to giant rocky planets the size of Jupiter – or even bigger – forming, something not known to happen anywhere else in the universe, many with surfaces covered in lava because of frequent collisions with other worlds.

Some of the planets would become so large that they could ignite nuclear fusion at their cores, says McKernan, becoming "very weird alien stars" made of rock, or swallow up large amounts of nearby gas and collapse into objects known as intermediate-mass black holes.

The disc of dust around an active galactic nucleus can extend for dozens of light years, meaning this process would take place at huge scales. "You could get millions of planets around the central supermassive black hole," says McKernan. ▮

Jonathan O'Callaghan

Climate change

Rich, eco-minded people emit the most

Alec Luhn

MARK KERRISON/IN PICTURES VIA GETTY IMAGES

PEOPLE who care the most about the environment also do the most environmental damage with their jet-setting lifestyle, at least among high earners.

This finding shows that changing policy is more important than changing values when it comes to halting the climate and biodiversity crises, scientists say.

"We do not want to suggest that individuals are solely responsible for their carbon footprints", since low-carbon alternatives to activities like flying are often still hard to find, says Malte Dewies at the University of Cambridge, one of the researchers behind the study.

It's long been known that a person's footprint tends to increase with their income. This study, however, brought personal beliefs into the equation. The team first asked 5000 people across Canada, France, Germany, Italy, the UK and the US about their income, wealth, education and job prestige to establish socioeconomic status.

Then, they asked them about their views on nature, climate and wastefulness. Finally, they asked about factors like meat and dairy consumption, vehicle use and hours spent flying to estimate a broad "ecological footprint".

The use of private jets by wealthy individuals is a big contributor to emissions

For most respondents, the more importance they placed on preserving nature, the lower their ecological footprint. But among the top 30 per cent by socioeconomic status, the people who cared the most about the environment had an even larger footprint than their peers (*Nature Communications Earth & Environment*, doi.org/q8wb).

The main reason was that high-income nature lovers fly frequently, one of the most emissions-intensive individual activities.

"Targeting the environmental attitudes of individuals with campaigns will not do the job" of reducing emissions, says team member Micha Kaiser at the University of Cambridge. "We need at some point to come up with stronger measures."

Countries like the UK and Germany have raised taxes on aviation, and airfares have increased 24 per cent due to the Iran war. The researchers said the price hikes probably aren't enough to put off high-income air passengers, though. ▮

Physics

Photons behave strangely if you try to cut them

Karmela Padavic-Callaghan

IN GREEK mythology, cutting one head off the Hydra of Lerna simply resulted in two more heads growing to replace it – and it turns out it's even worse for photons. If you try to cut a piece off a particle of light, the result is infinitely many more of them being created.

Some particles are elementary, which means that they cannot be broken into smaller pieces. For instance, a proton can be torn into three quarks, but each quark cannot be subdivided further. But what would happen if you tried to cut an elementary particle anyway?

Johannes Skaar at the University of Oslo in Norway and his colleagues have looked into the case of a photon encountering a mirror that could do just this.

Because it is quantum, light can be described both as made from photons and as being an electromagnetic wave.

"In quantum theory, a complicated object can masquerade as being utterly simple"

Accordingly, a photon isn't perfectly localised, like a solid object, but rather has a tail that extends across space. In the proposed scenario, the mirror would be able to move fast enough to just reflect part of the photon, equivalent to snipping off its tail.

Using quantum equations for the electromagnetic field, the team uncovered that this snipping would create a quantum state of light that is a mix, or superposition, of infinitely many photons (*Physical Review Letters*, doi.org/q8xg). This happens because, at the quantum level, empty space isn't empty, but rather filled with quantum fields, such as the electromagnetic field, all of which have tiny fluctuations and can be excited into producing particles. The mirror trimming the photon triggers such a process.

"Whenever you change a mirror or a shutter quickly, you stir up the vacuum and conjure photons out of empty space," says Samuel Braunstein at York University in the UK. But any local measurements – observations made from nearby – would find the superposition state to be indistinguishable from a single photon on one side of the mirror and an empty vacuum on the other, underlining how differently the idea of observation works in the quantum realm compared with our everyday experience. It shows how in quantum theory "a fearsomely complicated object can masquerade as something utterly simple", says Braunstein.

Ulf Leonhardt at the Weizmann Institute of Science in Israel says that experiments have found that a sufficiently fast shutter operating in empty space does really create photons, but experimentally testing the new idea may be more technically challenging. Manipulating light on ultrafast timescales is increasingly becoming an experimental reality, but the shutter from the new study is still faster than what is available in labs, he says.

The new work also points to phenomena arising from the quantum vacuum as having to be explored further, possibly leading to refining or amending quantum field theories of electromagnetism, says Leonhardt. ▮

Environment

Attack on Iran had volcanic impact

A plume with almost 30,000 tonnes of sulphur dioxide passed over a number of countries

Alec Luhn

ISRAELI airstrikes on oil facilities in Tehran on 7 March led to sulphur dioxide emissions equivalent to a small volcanic eruption, potentially exposing people as far away as China to acid rain and toxic air pollution.

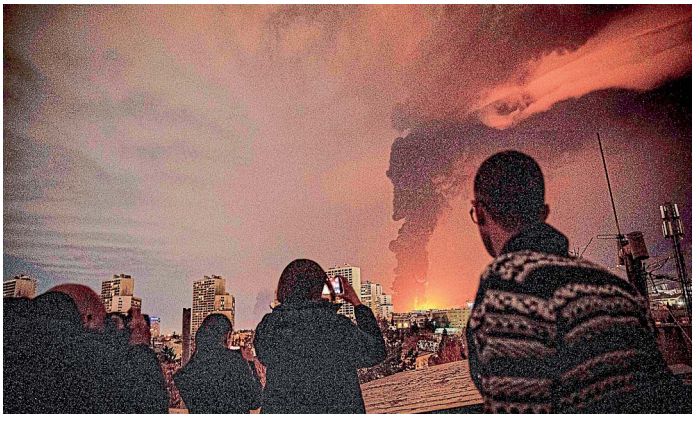
As part of the US and Israeli campaign against Iran, warplanes struck several oil depots and a refinery that night, sparking massive fires that spewed smoke for days. Black rain containing soot and hydrocarbons fell on the Iranian capital, and residents reported eye and skin irritation and difficulty breathing.

Now, data from a new generation of Chinese satellites has shown that the plume of sulphur dioxide released by these explosions and fires covered 300,000 square kilometres, passing over Turkmenistan, Uzbekistan, Kyrgyzstan, Kazakhstan and China (*Advances in Atmospheric Sciences*, doi.org/q8r9).

The brief attack prompted a days-long spike in emissions, releasing a total of 29,800 tonnes of sulphur dioxide into the air, according to Zhenping Yin at Wuhan University in China and his team. Iceland's Eyjafjallajökull volcano was emitting about 20,000 tonnes of sulphur dioxide per day when its ash cloud shut down air travel in Europe in 2010.

The concentrations of sulphur dioxide measured by the satellites reached levels that could impair lung function, irritate the eyes and throat, and exacerbate asthma or bronchitis, especially among children and older people, says Yin.

The pollution was caused by airstrikes on oil facilities in Tehran on 7 March



ALIREZA SOTAKBAR/ISNA/AP/ALAMY

"Although the major emission event lasted only one to two days, the research notes that the potential impact on the regional atmosphere should not be neglected," he says. Pollutants may have been rained out over water sources and agricultural land, potentially contaminating drinking water and food, he adds.

Sulphur dioxide reacts with different compounds of hydrogen and oxygen in the air to form sulphuric acid, which can lead to smog and acid rain.

Besides sulphur dioxide, the burning oil facilities emitted soot and heavy metals. According to Lucy Carpenter at the University of York, UK, the massive quantity of sulphur dioxide emitted suggests the plume held harmful quantities of even more dangerous pollution. This might include nitrogen oxides and polycyclic aromatic hydrocarbons, as well as unburned hydrocarbons like benzene, all of which have been linked to cancer.

"That amount in one single fire has huge implications for people's health... over thousands of kilometres," says Carpenter.

The plume lasted for only about three days, which probably isn't enough time to cause cancer. And the satellites measure sulphur dioxide concentrations through the entire atmosphere, so the toxin concentration at ground level is unclear. But the pollution could potentially have triggered asthma attacks, strokes or even heart attacks in especially vulnerable people, according to Carpenter. ▮

Archaeology

People were using anaesthetic over 600 years ago

TWO medical instruments recovered from the 15th-century tomb of a Chinese surgeon carry traces of an anaesthetic compound, the earliest chemical evidence ever found of doctors attempting to reduce the pain of a medical procedure.

The surgical scissors and tweezers were unearthed in 1974 from the tomb of a famous doctor named Xia Quan who lived from 1348 to 1411, in Jiangsu province.

Congcang Zhao at Northwest University in Xi'an, China, and his colleagues used lasers to study the composition of residues on the instruments, revealing traces of aconitine (*Antiquity*, doi.org/q8f6). This compound is produced by plants of the *Aconitum* genus, commonly known as wolfsbane and monkshood.

Aconitine interacts with sodium channels in the cell membranes of neurons. At the right dose, it has an anaesthetic effect, but it is highly toxic and is rarely used today.

The residues are concentrated on the blades of the scissors and the tips of the tweezers, making it unlikely that the presence of aconitine was due to contamination, the researchers say.

Carney Matheson at Griffith University in Brisbane, Australia, says there's no doubt that this is the earliest direct evidence of the use of anaesthetics.

The research suggests that early surgeons knew more about reducing pain than they have previously been given credit for, he says. "Now we can understand why this surgery may have been present, or may have been so prolific and actually manageable in the past," says Matheson.

"This suggests that early surgeons knew more about reducing pain than they have been given credit for"

Historical texts indicate that Ming dynasty doctors like Xia Quan had methods to mitigate the toxicity of aconitine, such as "preparation with boys' urine, soaking in a black soybean decoction, vinegar-boiling, detoxifying with mung beans and removing the outer skin of the aconite tuber", write Zhao and his colleagues. ▮

James Woodford

Quantum physics

First quantum grandfather clock could probe where gravity comes from

Karmela Padavic-Callaghan

RESEARCHERS have designed a quantum version of a pendulum clock using a single atom, tiny mirrors and light. Building it could help our understanding of what makes any clock accurate in the quantum realm and explore ideas at the edge of physics.

At the most rudimentary level, time can be measured with something simple, like sand trickling through an hourglass. But timekeeping became a lot more accurate once mechanical clocks, like the grandfather or pendulum clock, were invented in the 17th century. Matteo Brunelli at the College of France and his colleagues have now shown that such clocks have a quantum equivalent.

"We asked ourselves the question: 'Can a pendulum clock work according to the laws of quantum mechanics?' We couldn't be sure," he says.

Each pendulum clock has three basic elements, starting with the pendulum that defines the clock's ticks with its swings. Next are the weights within the clock that leverage gravity's downward pull to make the pendulum move. Finally, a pendulum clock requires an "escapement mechanism", which converts the pendulum's swings into the motion of the clock's arms and provides the pendulum with little kicks of energy to prevent friction from slowing it down.

Specifically, for the pendulum to keep swinging left to right by the same amount every time, the escapement mechanism must control the up-and-down motion of the weights.

The researchers developed a mathematical model that replicated all these features with quantum objects. In their design, the clock is a cavity comprising two mirrors that face each other – one is fixed and the other can oscillate back and forth.

Between the mirrors sits an atom that can have three different energies. Tiny temperature fluctuations in the cavity's environment make the atom transition from one energy to another, and some transitions are accompanied by the atom emitting a photon. This photon bounces between the mirrors, making one of them oscillate – analogous to falling weights setting the pendulum into motion.

> "The team replicated all the features of a pendulum clock with quantum objects"

The atom plays the role of the escapement mechanism, repeatedly moving through its energy states, ensuring a sequence of ticks and tocks. Brunelli says that this is the smallest an escapement mechanism can possibly be. The team's mathematical analysis showed that if everything was tuned correctly, the quantum clock would settle into stable, reliable, ticking behaviour – just like a pendulum clock should (*Physical Review A*, doi.org/q8kg).

Brunelli says that unlike the world's best atom-based clocks, which need to be controlled by lasers, this clock would be autonomous, operating more like a self-standing thermodynamic machine. Autonomous quantum clocks have been designed before, but because they didn't maintain the same even oscillations through the escapement mechanism, they were less accurate, he says.

In fact, the new clock broke an accuracy limit, called the "thermodynamic uncertainty relation", that constrained many past autonomous clocks. This is because any clock's accuracy relates to how much effort it would take to make it run backwards – and the new clock's accuracy was proportional to its irreversibility, in the way thought to be favourable for particularly good timekeeping.

IMAGEBROKER/SHUTTERSTOCK

The invention of pendulum clocks made timekeeping more accurate

Time will tell

Sreenath Manikandan at the Tata Institute of Fundamental Research Hyderabad in India says that understanding autonomous clocks is critical for understanding timekeeping because they don't rely on another clock to remain accurate, so they capture the most elementary version of the process. And the more we understand quantum clocks at the most elementary level, the more useful they can be for probing new physics, such as how gravity behaves in the quantum realm, he says.

"A deep understanding of the working mechanisms of a clock is highly desirable, and I think that the new work presents a major progress in this direction," says Manikandan.

Experiments with tiny cavities and photons are common, so many of the ingredients that would be necessary for building the new clock in the lab already exist.

However, Brunelli says that the escapement mechanism is novel enough to make building such an experiment technically challenging. "But it's not completely unreasonable," he says. ▮

Transport

Space storms could cause train chaos

Critical safety equipment in train systems around the world may need to be modified due to the threat posed by solar wind, finds **Michael Le Page**

A NUMBER of electrical systems in the railways of many countries, including the UK, are vulnerable to space weather. In the worst case, a red signal could be turned green, potentially causing a deadly train crash, says Cameron Patterson at Lancaster University in the UK.

"You could have disruptions to signalling systems, which are crucial to railway safety," he says. "We have to prepare for these things now, and getting that message across, I think, is really important."

The sun is constantly blasting out charged particles, as well as light. This solar wind is what causes auroras. Sometimes, the sun emits more material than usual in what's known as a solar storm, which can affect Earth's magnetic field.

The main danger is to satellites, but solar storms can also affect electrical systems on the ground because any change to a magnetic field can induce unexpected currents, including in railway tracks.

That's a problem because many railway systems rely on direct currents running through sections of track to detect the presence or absence of trains, says Patterson. When a train passes through, it changes the amount of current flowing.

"When you introduce geomagnetically induced currents into the mix, that can cause all kinds of anomalies, turning signals that should be green red, or the reverse," Cameron told a recent meeting of the European Geosciences Union in Vienna.

"You've got to remember these trains are going at very high speeds. If they don't have advance warning, it might be too late to slow down," he says.

Patterson knows of only one clear case of signals being affected during a solar storm, in Sweden in July 1982. "They saw signals switching and linked it to geomagnetically induced currents flowing through that track section," says Cameron.

ANDY SOLOMAN/UCG/UNIVERSAL IMAGES GROUP VIA GETTY IMAGES

Railways in the UK are particularly vulnerable to space weather

He suspects there have been many more cases like this, but that it seldom occurs to engineers that space weather might be to blame. By the time engineers reach the scene, the storm is usually over and they find nothing wrong, he says. In Russia, research has found correlations between solar storms and signalling anomalies.

While red signals turning green is the biggest danger, green signals turning red can also cause major disruption. If trains get stuck and electrical systems fail, passengers may leave the train, putting themselves in danger, says Patterson.

"You could have disruptions to signalling systems, which are crucial to railway safety"

The risk is thankfully low. Solar storms strong enough to cause this kind of issue happen only around once every 30 years, he says. "But a 1-in-100-year event might very well happen next month." Very large storms could cause widespread blackouts, causing major disruption.

On the right track

Some countries use a different signalling system in which magnetic sensors count the number of passing train wheels, says Patterson. It isn't clear if these systems are vulnerable to geomagnetically induced currents.

A number of other train systems are also vulnerable to disruption from solar storms, he says, including transformers connected to overhead electric lines, the systems used to tilt trains as they round curves at high speed, radio communications and the satellite navigation systems used for purposes such as detecting the precise location of a train.

Patterson is now collaborating with Network Rail, the Rail Safety Standards Board and engineering companies in the UK to help them make systems more resilient. It was hard to get those conversations started, he says, but they are taking it seriously.

Magnus Wik at the Swedish Institute of Space Physics agrees that signalling anomalies due to solar storms may be going undetected.

"They may experience a short disturbance and then it is back to normal, and they don't know what caused it and [have] no evidence of it," he says.

Wik says Sweden modified its railway system in the 1950s after signals turned from red to green during geomagnetic storms in the 1930s. In the 1982 incident, it turned from green to red, he says, which is less serious.

"The Swedish Transport Administration probably don't know if this can occur again or if it has happened multiple times," he says. "We have discussed a possible study to check for past geomagnetic disturbances and compare with error logs, but this is not official." ▮

Physics

The secret reason why gold never loses its shine

Karmela Padavic-Callaghan

SILVER goes dull, copper turns green and iron rusts, but gold is always shiny. Why this is the case has remained a mystery, but researchers may have finally figured out what makes the valuable metal so resistant to change, and how to tarnish it.

Gold is chemically inert, meaning that it doesn't react with molecules from its surroundings, such as oxygen in the air. This is great news for jewellery, but it limits gold's usefulness in chemistry, where researchers think it could be a useful catalyst – if only it could be nudged out of its inertness.

Matthew Montemore and Santu Biswas at Tulane University in Louisiana investigated a phenomenon called reconstruction, which happens when a piece of gold is cut, creating a new surface.

"The atoms just hate being on a surface so much that they completely rearrange," says Montemore. Often, they rearrange into a pattern resembling repeating hexagons, then don't shuffle further because their energy is low in this arrangement.

Gold always gleams – and the arrangement of its atoms is key

LI ZHIHUA/CHINA NEWS SERVICE/VCG VIA GETTY IMAGES

Reconstruction isn't common among metals, so the researchers wondered whether it contributes to gold's inertness.

They used a supercomputer to simulate the quantum states of atoms for several different rearrangements that can happen during reconstruction, and to analyse their interactions with oxygen. For a reconstructed gold surface to lose some of its lustre, a molecule of oxygen would have to first split in two upon hitting it.

The researchers' simulations revealed that such splitting requires a lot of energy for atoms in a hexagonal pattern, which makes tarnishing very unlikely, but a lot less energy when their arrangement is rectangular (*Physical Review Letters*, doi.org/hb4573).

Because the hexagonal pattern is more common, gold tends to stay shiny. Biswas says that this connection between atoms' geometry, reconstruction and oxidation has never been considered before.

Understanding it could now help researchers make gold more useful as a catalyst, says Hongliang Xin at Virginia Tech. "The exciting takeaway is that gold's catalytic behaviour may be tuned by controlling surface reconstruction," he says. Montemore says that one way to control reconstruction, like nudging atoms into rectangular patterns that are less inert to oxygen, could be by placing a piece of gold in an electrical circuit and applying a voltage.

"[This work] is telling us something that perhaps hadn't been considered before. Definitely there's something here for experimentalists to go and look at," says Andrew Beale at University College London. ▮

New Scientist *Live*

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TV Presenter and YouTuber

LIVE SCIENCE SHOW

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First British astronaut

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Will lab-grown sperm let infertile men have children? A start-up claims it can grow sperm in the lab. But **Michael Le Page** thinks this will have to be combined with gene editing to be most helpful

Michael Le Page is a reporter at *New Scientist* specialising in genetics, biomedicine and the environment

Michael's week

What I'm reading
This Is How You Lose the Time War *by Amal El-Mohtar and Max Gladstone*

What I'm watching
Secret Garden*, the David Attenborough series that takes big liberties with the definition of a garden*

What I'm working on
A piece about the huge losses in food production and resulting economic impacts that will get worse as the world warms

INFERTILITY isn't something men like to talk about, but it's very common. Around 1 in 10 couples will have problems with conception, and in half of cases it is wholly or partly to do with sperm. In many cases, existing treatments can't help – but a US start-up called Paterna Biosciences thinks it can change this.

There are a huge range of reasons why men may struggle to father a child. They may have a low sperm count, their sperm may lack the ability to enter the egg, and so on. In these cases, injecting a sperm directly into an egg as part of IVF treatment usually works.

Around 1 in 100 men don't have any sperm at all in their semen. This lack of sperm can be because some kind of obstruction is preventing the sperm from reaching the prostate. In these cases, it is usually possible to remove the obstruction or take sperm directly from testes.

But in most cases where there are no sperm in semen, it is because very few or none are being produced in the testes. That's where Paterna Biosciences comes in. Paterna's co-founder and head Alex Pastuszak says the company can take small pieces of tissue from testes and generate "high-

"The company says the sperm it derived were able to fertilise human eggs, which developed into early embryos"

single-digit to tens of thousands of sperm" from each piece.

Paterna's team is able to do this because it has identified the signals that tell sperm stem cells to start forming sperm, says Pastuszak. The process takes around a month in the lab.

Paterna has provided no evidence to back its claim yet,

PDC/SCIENCE PHOTO LIBRARY

Some men may have a low sperm count, while others don't produce any sperm at all

and Pastuszak says this is about protecting intellectual property.

The company says the sperm it derived were able to fertilise human eggs, which developed into early embryos. If Paterna has done what it claims, the next question is whether it's safe.

Sperm are formed from stem cells in the testes. When these stem cells divide in two, one cell remains a stem cell. The other divides to form four sperm via a process called meiosis, during which chromosomes swap bits of DNA.

"That's a very dangerous situation," says Miles Wilkinson at the University of California, San Diego, who studies sperm stem cells. When DNA is broken, there is a risk of it not being put back together right, so it is really important meiosis isn't disrupted.

Pastuszak says the lab-grown sperm appear normal. "We've shown that the sperm that we're creating in vitro look molecularly exactly like the sperm that are made [in the testes]," he says.

Assuming Paterna's technique is safe, the next big question is what proportion of infertile men it could help. A few men who don't produce sperm lack sperm stem cells altogether, and this certainly won't work for them. Others have sperm stem cells that fail to turn into sperm, and mutations are probably to blame in a lot of cases.

If a mutation is blocking meiosis in the testes, it's also likely to block it in the lab, says Geert Hamer at the Amsterdam Reproduction & Development research institute in the Netherlands.

But Pastuszak claims his team has been able to derive sperm in the lab from men who don't produce any sperm in their testes. This is because they have mutations that stop support cells from triggering meiosis, he says, so providing the right signals allows sperm to form.

Again, we have no evidence to back this up. I'm sceptical that this applies in most cases, as Pastuszak claims, but I hope he is right, because a lot of couples might benefit if he is.

But what if Paterna is wrong? Well, there is a potential solution – using CRISPR gene editing to correct the mutation causing infertility in the sperm stem cells, making it possible for them to turn into sperm and resulting in the birth of gene-edited children who lack the harmful mutation.

This isn't as easy as it sounds, because in most cases we don't have a clear idea of what mutation might be to blame, just some rather tentative associations.

Even so, in my view, in cases where we can pin down the exact mutation, the use of germline gene editing for this purpose would be justified. In fact, it's the only compelling case for its use that I know of.

Paterna isn't ruling it out. "I'm not going to take that off the table, because I think science and technology are going to continue to advance, and the goal here is to help a lot of people," says Pastuszak.

Q-Day could destroy bitcoin – and our retirement savings Even if you've never bought any cryptocurrency, its vulnerability to quantum computers could affect your money, finds **Karmela Padavic-Callaghan**

Karmela Padavic-Callaghan is a reporter at *New Scientist*, specialising in physics and quantum technology. Karmela earned a PhD in theoretical condensed matter physics and atomic, molecular and optical physics from the University of Illinois Urbana-Champaign. Their physics memoir *Entangled States* is out now

Karmela's week

What I'm reading
On Eating: The making and unmaking of my appetites *by Alicia Kennedy*

What I'm watching
Foundation *on Apple TV+*

What I'm working on
A short talk on quantum theory and queerness for an upcoming lecture series in New York

MY FIRST exposure to bitcoin was unglamorous. It was the early 2010s, and I heard about it through the chatter of students in my college maths classes. Bitcoin's siren song rang loudly for some of my peers, but I was striving towards some romanticised idea of being an old-school theoretical physicist, and something like "mining for crypto" just didn't seem to be a part of that. Recently, however, I have learned that I may have been naïve, as the issue of bitcoin and its safety became relevant to my work as a physics reporter – and also to my savings.

This change in perspective started a couple of months ago when researchers at Google, the Ethereum Foundation (a non-profit that supports the eponymous cryptocurrency) and a couple of universities published a 57-page paper on the threat quantum computers represent to the safety of various cryptocurrencies. I saw the paper while I was eating breakfast in my dining room in Queens, New York, and by the time I made it to *New Scientist*'s Manhattan office about an hour and a half later, I knew it would overtake my life for the next day.

The whirlwind feeling of breaking news whipped up as a second paper by researchers at the quantum computing start-up Oratomic appeared online. It didn't just echo the imminent threat quantum computers posed to cryptocurrency, but reinforced it with an even more aggressive timeline for when we might see it become real. The key metric in either paper was the number of quantum bits – or qubits, which are the building blocks of any quantum computer – that a device would need to break one very commonly used form of encryption. Google's team put the number at 500,000 qubits, while the researchers at Oratomic argued for 10,000. This is shockingly close to the largest qubit array that already exists, which counts 6100 qubits.

These qubits have not been used in a computation yet, but it is increasingly feeling like we are nearing a cryptography crisis – so-called Q-Day, when quantum computers render most codes currently safeguarding our digital communications and transactions ineffective. Accordingly, Google has been urging everyone to move to post-quantum cryptography (PQC), which would prevent Q-Day, by 2029.

I called everyone I could and did my best to figure out how much of a threat quantum computers are to encryption in general. But researchers kept bringing up bitcoin.

The type of encryption bitcoin uses is built around what's called the elliptic curve discrete logarithm problem (ECDLP). The idea is simple: this is a mathematical problem that is incredibly hard to solve for conventional computers, so if cracking encryption can be reduced to solving ECDLP, then that encryption should be incredibly safe. Because of this, ECDLP-based encryption is widely used. For instance, it protects many internet communications like bank transactions, and it is also used for securing nearly every major cryptocurrency.

A recipe for chaos

But for almost three decades researchers have also understood, with a high degree of certainty, that a powerful-enough quantum computer could easily break all that. They even have a mathematical recipe for how to do so – the famous Shor's algorithm.

Turning Shor's into a program that could be run on a real machine, however, has proved troublesome. First and foremost, a large and error-proof quantum computer didn't exist in the 1990s, or the 2000s, or the 2010s – and it still really doesn't in the 2020s. But quantum computers keep getting bigger. And alarmingly, the estimates of how big a quantum computer needs to be to break ECDLP-based encryption with Shor's algorithm keep decreasing. In 2019, researchers were debating about tens of millions of qubits; now, Oratomic was putting forward a much less intimidating 10,000.

Moreover, Google's researchers say that the first sign that quantum computers have lived up to their promise as dangerous decryption machines may appear on the blockchain, the technology that underpins how cryptocurrencies work. Specifically, researchers

MICHAEL NAGLE/BLOOMBERG VIA GETTY IMAGES

Threats to bitcoin could have a knock-on effect on global financial markets

identified a way in which a quantum computer could perform an "on-spend" attack, stealing the currency being transferred during the roughly 10-minute window it takes to make a bitcoin transaction.

Reading between the lines of the paper, it was clear to me that it was meant to make bitcoin users take PQC more seriously. That's necessary because bitcoin has a decentralised governance structure, which means any changes to its protocol require consensus among users.

"I'm very worried, and I very much agree with what Google is saying," cryptocurrency pioneer Eli Ben-Sasson at StarkWare told me a few weeks later. "I'm very disappointed by the ossification of bitcoin development."

JP Aumasson, a cryptographer who worked on one of the signature PQC algorithms, echoed the sentiment. "I'm really not impressed by what they [the bitcoin community] have been doing in terms of post-quantum transition," he plainly told me.

The worlds of technology, finance and nearly everyone else who worries about information security are now considering changing all of their encryption to quantum-safe algorithms and protocols by the end of the decade. Aumasson predicts we have until 2036, rather than 2029, to make the switch, a less hurried timeline. But he says that bitcoin users ought to be an exception. "When I see the decision-making process of the bitcoin community and how fast, or maybe how slow, they move, I think they better hurry up," he says.

Perception matters

One particularly worrisome aspect of the threat facing Bitcoin is that the safety of currencies – crypto or otherwise – relies not just on technology but also on perception. "It might be sufficient to just spread the rumour [that bitcoin is vulnerable]... then the market will panic," says Aumasson. The financial losses would be enormous.

Several proposals for how to make bitcoin quantum-safe through a software update already exist, but putting them into action would require the disparate and wide bitcoin community to reach consensus on whether, how and when to do so. It's been roughly half a decade since bitcoin's last such effort and Ben-Sasson says that, in recent years, any issue concerning changes to bitcoin's infrastructure has attracted controversy and conflict. "We're in this very sad state where everyone, I think, understands what is needed and knows that it's not a big deal, but everyone's sort of afraid of even talking about it, because who knows when anonymous, crazy crypto mobs are going to attack you," he says.

Avihu Levy, one of Ben-Sasson's colleagues at StarkWare, recently developed a way to make bitcoin quantum-safe without a software update, but the amount of computational power that this would require for every new, safe transaction would be so great that it would increase the cost of doing business more than 200 times.

The trouble at hand is a diabolical intertwining of emerging technology, advanced mathematics and plain old follies of human nature. But, as someone who has more or less successfully tuned out any noise about bitcoin for nearly a decade, I found myself wondering: do I, too, have to care about this now? Or could my refusal to participate in anything blockchain-related protect me from bitcoin's messy clash with quantum technology? To my horror, the answer to the latter question turned out to almost certainly be a resounding "no."

This is because I, like many workers in the US, have a retirement account. In June of 2025, *New York Times* finance columnist Jeff Sommer reported on uncovering unexpected bitcoin in his own retirement account. It snuck in because his account was connected to an index fund that included stock from a company known as Strategy, whose primary asset is bitcoin. As I am writing this in May 2026, Bitcoin Treasuries, a website that tracks digital assets, has Strategy firmly at number one when it comes to public companies that own bitcoin. As Sommer's reporting made clear, investment funds run by all the prominent companies in that space, such as Fidelity, Vanguard, BlackRock and Morgan Stanley, include shares of Strategy.

"No simple solution is in sight, other than rooting for cooperation among people invested in bitcoin's future"

My own retirement account is run by Fidelity, so chances are that if the price of bitcoin were to fluctuate wildly – for instance, because of a quantum panic – there would be a ripple effect that runs from bitcoin to Strategy to Fidelity to my ability to retire. Several US states, including California, North Carolina, Texas and Louisiana, hold shares of Strategy in retirement funds they have set up, for instance, for state employees and public school teachers. Recently, the administration of President Donald Trump indicated that it wanted to make it easier to fold cryptocurrency directly into retirement accounts – for instance, by rescinding past guidance against it. While definitive regulatory changes haven't happened yet, some in the cryptocurrency community see them on the horizon.

No simple solution seems to be in sight, other than rooting for and encouraging cooperation among people invested in bitcoin's future. Futuristic technologies such as quantum computing and the blockchain should not give us a blanket permission to forget that consensus is one of the oldest and most important enabling technologies. Government regulations could also go a long way.

While the current administration in the US seems to be leaning away from regulating cryptocurrency, this could change following elections in the next few years, if the voting public demands it. And though it is a fool's errand for a journalist to try to predict the future, I am keeping my fingers crossed for my retirement. ▮

Why your brain needs 'Aha!' moments In the age of AI and instant answers to our questions, **Helen Thomson** discovers that figuring things out for yourself can boost brain health

LAST week, my editor, Chelsea, said something that stopped me in my tracks. She was worried about AI, but not for the normal journalistic reasons: job losses, plagiarism, dull prose, etc. It was the possibility that by using AI, she might be missing one of life's most reliable pleasures – the daily joy she gets from having an "Aha!" moment. "For me," she says, "it's almost a physical feeling, something spreading across my brain."

It turns out that Chelsea's description wasn't far off. "Although it does feel like you get a jolt of dopamine, we can't say that every insight produces a dopamine hit," says Carola Salvi at the Catholic University of the Sacred Heart in Italy. However, several lines of research strongly suggest the dopamine system is involved when you have those mini-epiphanies.

For instance, in 2018, Martin Tik at the Medical University of Vienna in Austria and his colleagues found that when people solved problems designed to elicit a eureka moment while undergoing functional magnetic resonance imaging, their brain scans showed small changes in activity in midbrain structures involved in releasing dopamine.

We all enjoy the satisfaction of a "light bulb moment"

But "Aha!" moments don't just feel good. There is increasing evidence that they also have cognitive benefits for learning and memory, says Salvi. She believes that they function as a kind of internal "selection signal".

By this she means that when a solution pops into our head, the accompanying feeling of accuracy and satisfaction helps capture our attention. The brain, perhaps with the help of the dopamine system, flags the idea as important. According to Salvi's models, this helps us prioritise certain ideas for learning and future use.

"From an evolutionary perspective, this makes sense," says Salvi. "If the brain suddenly discovers a useful new pattern or solution, it would be adaptive for that information to become especially memorable."

Which brings us back to AI. If we increasingly turn to large language models for ideas and solutions to even our smallest problems, are we depriving ourselves of an opportunity to learn, remember or perhaps something greater still?

For this, I turned to Hannah Critchlow, a neuroscientist at the University of Cambridge and author of *The 21st Century Brain: How to future-proof your mind in the age of AI*.

She pointed me to a small but fascinating study published last year that compared the neural activity of 18 people who wrote essays either using brain power alone, with the help of a search engine or with ChatGPT. Those who used AI showed consistently lower brain activity than those who used Google or brain power alone.

So, aside from deleting AI from our lives, how do we defend against this? Critchlow draws attention to a separate body of research showing that when people discuss ideas together, in a manner that's not competitive, their brainwaves start to synchronise with each other.

She says that how well your brain synchronises with others can be used to predict how healthy your brain will be in later life. "It seems to be potentially protective against dementia and is one of the most significant predictive factors for whether a teenager is going to flourish during adolescent periods – whether they are going to be able to form bonds with others and learn from them," says Critchlow.

So, for anyone who shares Chelsea's concerns, there may be a simple lesson here. While it may be tempting to turn to LLMs for instant insights, exercising your own mental muscle to get to the answer yourself, whenever possible, may be the better path to take – not only for your own quick dopamine hit, but for long-term learning and brain health, too. ▮

AMY SMIRK/ALAMY

Helen Thomson is the author of books including *Unthinkable: An extraordinary journey through the world's strangest brains* and *This Book Could Fix Your Life*. She was previously head of features at *New Scientist*

Helen's week

What I'm reading
The Wedding People *by Alison Espach – a great poolside read as I'm on holiday this week*

What I'm watching
Rivals *on Disney+*

What I'm working on
Our new podcast, Change Your Mind *– delivering the no-nonsense neuroscience behind the latest brain-boosting claims*

NOT ANOTHER ONE.

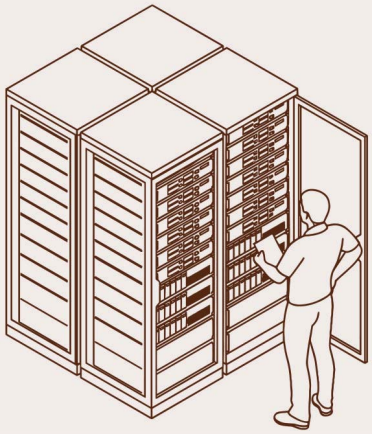
Find out more.

Break the cycle of energy crises. Build a more resilient energy system.

Britain can build a stronger, cleaner and more secure energy system by making use of the heat we already produce. Large-scale heat networks can capture wasted heat from industry, data centres and other local and ambient sources, alongside heat from excess renewable electricity, and deliver it to homes, businesses and public buildings.

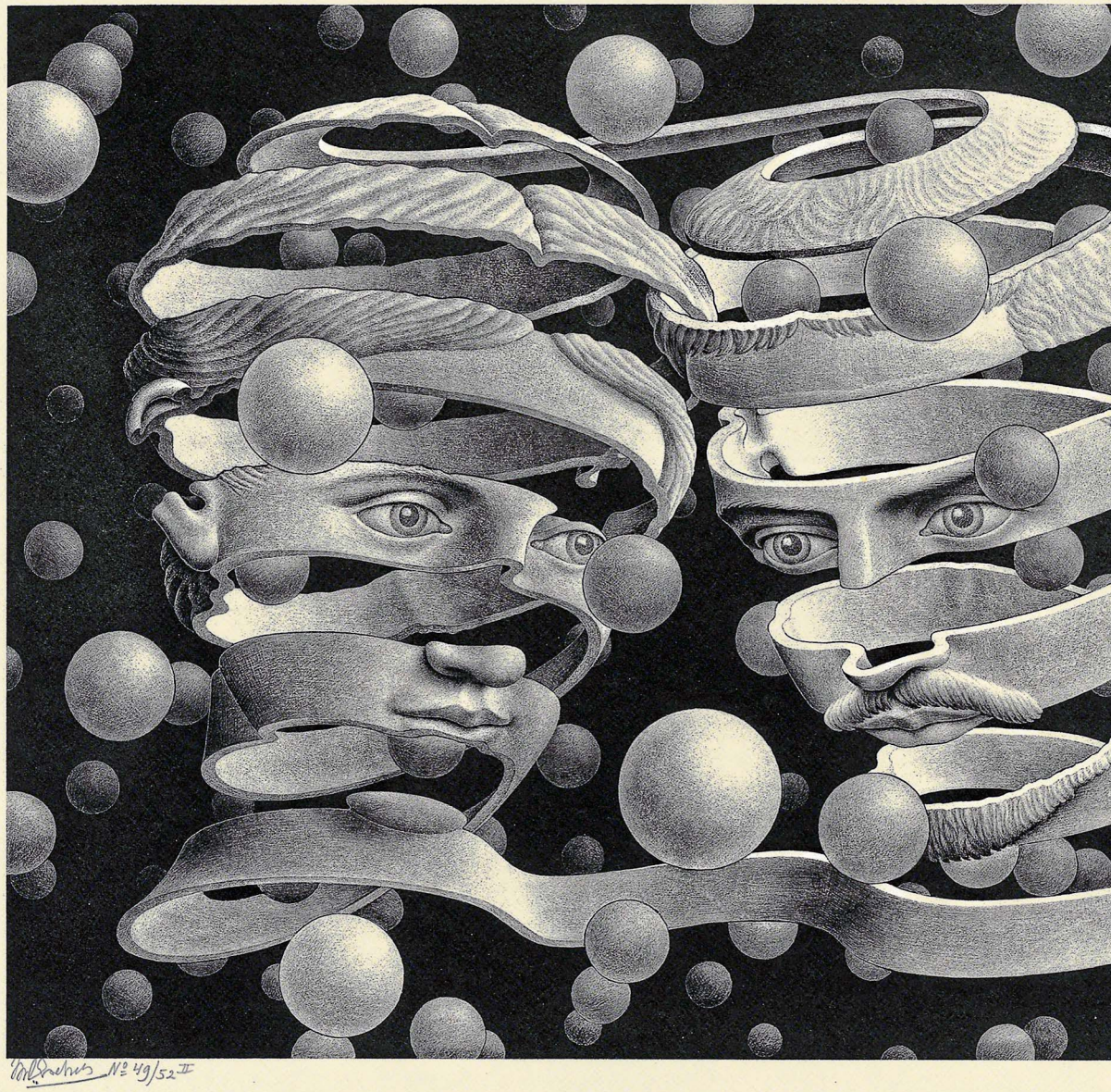
This is a practical national infrastructure plan that can cut waste, reduce gas dependence, protect billpayers from global shocks and keep more of Britain's energy value here at home. Britain has made a system-wide energy shift before, when it moved from town gas to natural gas. Denmark and Sweden made the same kind of strategic choice in the 1970s: when fuel shocks hit, they changed course — expanding heat networks, capturing waste heat and building more resilient, integrated energy systems that were less exposed to future crises.

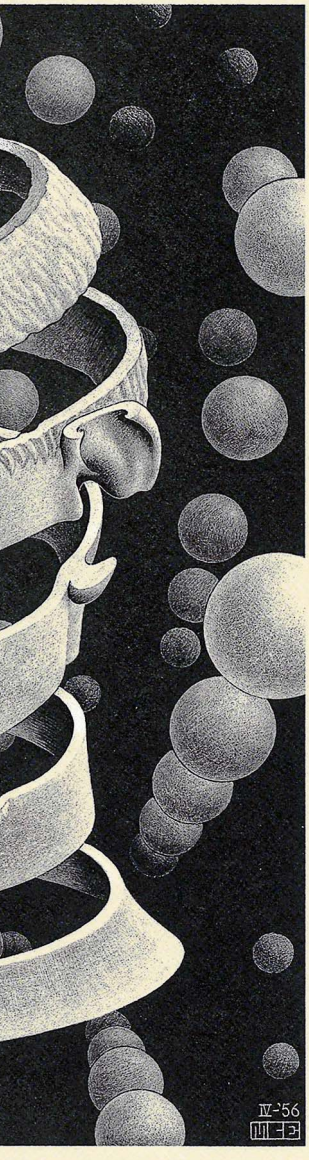
These shocks will keep coming for as long as Britain remains reliant on gas and on prices it cannot control.

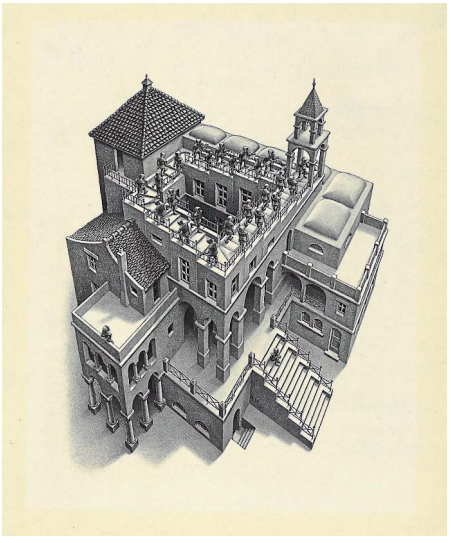


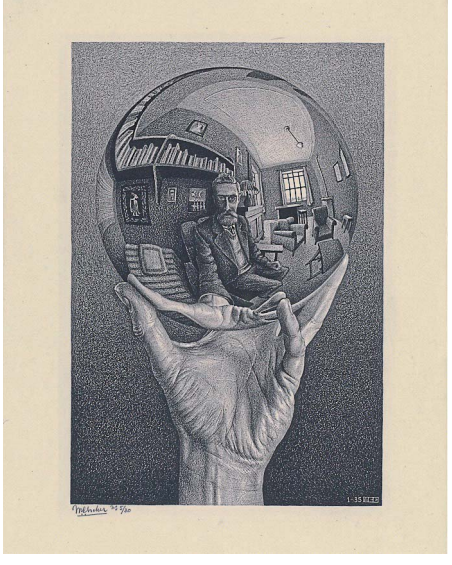
By 2035, waste heat from data centres could heat 3.5 to 6.3 million homes - but only if we build the networks to capture and move it to where it is needed.

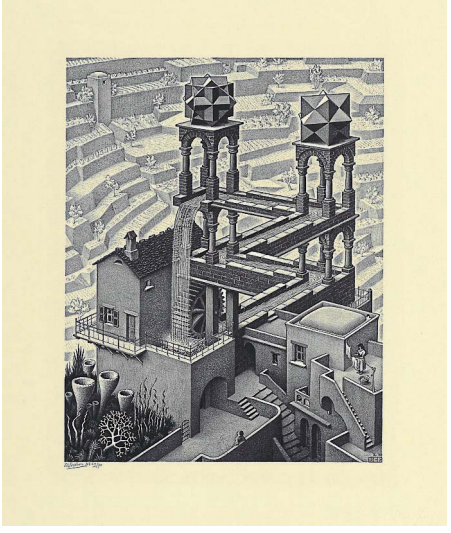
EnergiRaven











Impossible art

2026 The M.C. Escher Heritage Somerset House

IN 1954, a young Roger Penrose came across the works of artist and print-maker Maurits Cornelis Escher, which draw heavily on mathematical concepts like infinity and paradox. He was immediately "spellbound" by their mathematical beauty.

Penrose and his father, the psychiatrist Lionel Penrose, then came up with impossible designs of their own, like paradoxical triangles and staircases, publishing their ideas in the *British Journal of Psychology*. This article inspired Escher himself to produce at least two works: *Waterfall* (near-left, bottom), in which flowing water follows an impossible route, just like Penrose's triangle, and *Ascending and Descending* (near-left, top), the image of a never-ending staircase inspired by the Penrose stairs.

These prints, together with more than 150 other works, will feature in the major retrospective "M.C. Escher: The Exhibition" at Somerset House in London from 6 June until 6 September.

The ease with which Escher worked with mathematical concepts in his art was impressive, says Federico Giudiceandrea, president of the M.C. Escher Foundation, given his lack of formal maths education.

"He had a huge mathematical intuition," says Giudiceandrea. "I always am amazed and, really, astonished to see how deeply and precisely he transformed these mathematical ideas into artworks."

In the main drawing, *Bond of Union*, a single strip of paper twists to form two heads. The near-left, middle image is a self-portrait from 1935, called *Hand with Reflecting Sphere*.

Alex Wilkins

Insides out

Giulia Enders made her name with *Gut*, a deep dive into our intestines. Now, she's listening to what our other organs are telling us. **Carissa Wong** explores

Book
Organ Speak
Giulia Enders
(Illustrated by Jill Enders, and translated by Jamie Bulloch)
Hachette (UK); HarperCollins (US)

WORK, home, politics, TV sagas, juicy celebrity gossip – who doesn't get caught up in the drama of everyday life?

But there may be an equally compelling and fascinating story unfolding every second of every day inside the squishy bodies doing all that living.

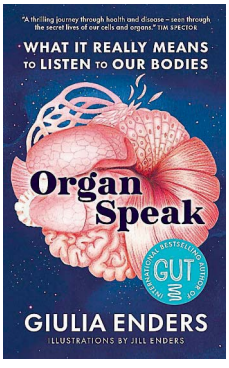
There, our organs do the quiet yet incredible work of providing the oxygen, energy and resilience we need to experience the joys and navigate the hardships of life.

By gaining deeper appreciation of our intricate machinery, honed over millennia of human evolution, we can find fresh inspiration to lead healthier, more meaningful lives, argues Giulia Enders in her new book *Organ Speak*: *What it really means to listen to our bodies*.

Enders, who is also a medical doctor and a researcher specialising in the digestive system, is best known for her bestselling book, *Gut*. This is an amusing account of the intestines – her favourite organ – covering nitty-gritty topics like what happens when we fart and what is the best position for defecating.

In her latest book, she extols the marvels of five other areas: the lungs, immune system, skin, muscles and, last but not least, the brain. In some ways, the new book is another tour de force. Enders explains complex biology with clarity, great enthusiasm and sometimes a dose of humour, making a strong case for paying more attention to what lies inside the working parts within us.

The book shows her fascination with how organs function and what we can do to keep them in good shape. Enders dedicates a chapter to each organ, drawing on the latest scientific research, and weaving in stories from her personal life to map her experiences onto the organ or system. For example, at one point, she describes how her late grandmother's best friend



constantly helped people around him respond to unexpected life events, acting almost like an immune system in human form.

"Our organs also have a substantial say in what it means to be ourselves. They're involved in key questions such as: what do we really need? How do we deal with threats? How do we want to treat each other?" she writes. "If we can better understand the answers from our body, we could lead a more harmonious life."

She starts with the lungs. These soft and flexible balloons in our chest bear the impressions of our ribs, heart and oesophagus as they inflate and shrink some 20,000 times a day. This delicacy helps them make the most of the air we inhale, which is almost never at the perfect temperature or humidity for our lungs, and contains damaging particles such as dirt or pollutants.

Enders also explores obscure, and problematic, breathing habits like "email apnoea" – where people hold their breath as they open their inboxes – and excessive mouth breathing. Both of these can lead to tiredness, neck tension and shortness of breath. As you might hope, she offers solutions, such as exercises where you briefly hold your breath after exhaling to soothe your nervous system.

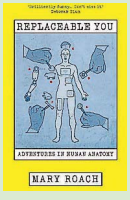
Next up is the immune system. Enders shows how it protects us from bacteria and viruses, before explaining why we feel so ill when we catch a nasty infection. She amusingly frames a runny nose as "nose diarrhoea" because, much like diarrhoea, it also helps to flush out pathogens.

Allergies and autoimmune conditions, she explains, happen when the immune system mistakes a harmless substance for a threat – and that can be anything from peanut protein to healthy tissue – causing it to release inflammatory molecules. These produce unpleasant symptoms like rashes or painful joints.

Luckily, there are some ways to help keep your immune cells happy: sleep, eat and exercise well – and get vaccinated, she writes. The latter will help to protect you against viral infections, such as flu or covid-19, which can impair the immune system for weeks or even months after the virus has gone, through what is known as post-viral syndrome.

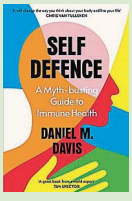
As for the skin, Enders peels back its complex layers before explaining things like why wrinkles form and the benefits of being

Three more great books on the human body



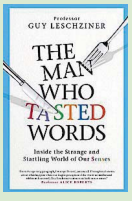
Replaceable You by Mary Roach

When our body parts fail or get a bit rusty, medicine offers a slew of solutions. Mary Roach takes a look at the most innovative attempts to repair, replace or enhance, with a daring dose of self-experimentation in the mix.



Self-Defence: A myth-busting guide to immune health by Daniel Davis

We constantly hear about ways to boost our immune system, but what if these claims are wrong? From taking vitamin C to eating turmeric, Daniel Davis takes a forensic look at what really helps us look after our immune system.



The Man Who Tasted Words by Guy Leschziner

Neurologist Guy Leschziner uses fascinating (or disturbing) real accounts to explore how our senses make (or unmake) our private worlds. We meet the man who "tastes" words but also one who doesn't feel pain.

CHRIS COOPER-SMITH/ALAMY

***Hymn*, a Damien Hirst sculpture, reveals layers of our organs**

touched. In pre-term babies, for instance, skin contact in early life may improve sleep, cognitive development and resistance to stress years later, she explains. In adults, it seems to lower blood pressure, reduce anxiety and can even bring pain relief.

To slow skin ageing, the science suggests we wear moisturising creams containing vitamin C in the evenings and vitamin A-infused moisturisers, in combination with sunscreen, in the mornings. This is because such creams help capture damaging free radical particles when applied in that way: vitamin C degrades in sunlight. while vitamin A, in the absence of sunscreen, can generate radicals in sunlight.

And if you've ever wondered how muscles "muscle", Enders has the subject covered. Among a tranche of medium to less well-known facts, she explains what would happen if you could stay in bed for a fortnight without moving at all. It turns out that your body would lose a staggering tenth of its muscle mass, similar to the loss that occurs over 30 years of normal ageing.

As you might expect, Enders lays out the evidence on why we should exercise: reduced anxiety, a stronger heart and new brain cells – things the health-conscious among us may already know.

But how exactly your muscles respond to exercise partly depends on your genetics. Some people are better suited to long-distance running, while others are built to excel at strength training. So, rather than comparing your athletic prowess with other people's, you're better off finding the kind of workout that suits your body best – and you'll probably find it more enjoyable too.

The book ends with the brain. Enders digs into what happens when we're sleep deprived and what drives substance addictions, and she offers tips for snoozing better. Basically, she says, avoid bright lights or caffeine before bed, and don't bother with melatonin because most people won't benefit much from the hormone.

All in all, *Organ Speak* probably won't offer *New Scientist* readers many health tips you've not heard before. I also found some passages hard to read, where Enders speaks of organs as wise gurus from which we can learn deep life lessons. These didn't work for me: for instance, I am pretty sure thinking of my skin won't help me to cope better with grief or heartbreak, as she suggests.

The book also takes unnecessary detours. Take the lung chapter: Enders describes the evolution of Earth's air, when a narrower focus on the lungs themselves would have been more engaging.

Despite these issues, *Organ Speak* is probably worth picking up if you're curious about your inner workings – and it just might remind you to take better care of them. I will certainly try an extended exhale when I next open my more worrying emails! ▮

New Scientist *recommends*

Chelsea Whyte
Senior editor
Portland, Oregon

If you've ever suspected that everything to do with cryptocurrencies is a scam, the documentary **Everyone is Lying to You for Money** will fully convince you.

The film is a project from Ben McKenzie (above), an actor with an economics degree whose breakout hit was the teen drama *The O.C.*, and who is now one of the foremost voices speaking out about the grifters of the cryptocurrency world.

It sees him document the rise of crypto over the past decade, and his bafflement at the excitement and increasing appetite for what seems to him to be, plainly, a total scam. It's an entertaining watch, one he narrates with a light-hearted tone and a streak of charming self-deprecation.

Even though I've followed the headline news of crypto scandals for years, I was still shocked to find out what some of the industry's biggest figures thought they could get away with.

The documentary is on limited release in the US, and is coming to the UK later this year.

VICTOR PENA/2026 EASY MONEY PRODUCTIONS, INC

The human paradox

Why do we have big brains? Or walk on two legs? Biological anthropologist and broadcaster **Alice Roberts** talks human exceptionalism with Michael Marshall

PHYSICALLY, *Homo sapiens* is not that special in the animal world. But the species has discovered ways of finding food and beating the odds of survival in every habitat from jungle to Arctic wasteland.

It has also come to obsess Alice Roberts, who started off in medicine, becoming a surgeon and an anatomist. She was captivated by the evolutionary story of the ape that walked and talked, and is now professor of public engagement in science at the University of Birmingham, UK. Her expertise spans anthropology, archaeology and palaeopathology.

She also has a huge track record of TV shows, from *Digging for Britain* and *The Lost Scrolls of Pompeii* to *Witches of Essex*, and a growing pile of books. Roberts was editor-in-chief of the latest, *Humans: The evolution of a species*, which tells the story of human evolution with illustrations and contributions from an international team, including Michael Marshall, who quizzed her about her latest work.

Michael Marshall: What's the big idea in this latest part of your journey into the human past?
Alice Roberts: When I was working at the University of Bristol, something happened that was really important to how I think about humans. When I was a young surgeon, teaching anatomy to students, we built a dissection room in the vet school. I was roped in to teach there and remember looking at a lamb's heart.

It was the first time I properly understood the way the heart changes from the fetus to the heart in a baby and an adult. I was thrown into a bigger department where I was forced to see humans as another mammal. And that is what we are. It really changed the way I look at us all.

How should we think about our bodies as products of evolution, about our history being written in our skeletons and our organs?
There's biochemistry going on in our cells that goes back to these earliest single-celled creatures living in the ancient oceans. If we look at our arms and legs, they go back about 360 million years, when the first amphibians crawl onto land, and fins have become limbs. We can see that change, map the bones of our arm, and see where they've come from in evolutionary terms. You can do that with every bit of the body.

"I laid out the skeleton of *Homo floresiensis* and it sent shivers down my spine... it was so human and yet not"

Can you give me some examples?
I've always said I could put the humerus of a female chimp in a medical students' exam and they wouldn't notice the difference – the bone is about the same size and shape; all the features are there. The more you look, the more similarities you start to see. Hands are really interesting: so similar and, at the same time, subtly different. The human thumb is longer and really chunky compared with the chimp thumb.

I'm always struck when palaeoanthropologists compare ape and human hands and confidently say, "obviously that one is *Homo habilis*". It's not obvious to me...
Exactly. Because if we're saying chimp hands are quite similar to human hands, if you're looking at other hominins, [then] they fit into the gap between the two. It's difficult when the fossil record is fragmentary as well. I'm quite nervous about some classification. It makes me feel uncomfortable – as somebody from a medical background who likes a lot of data.

Humans do seem to have one exceptional thing – our brain. How much difference does this make?
I think it's the biggest thing. If I characterise humans in as few words as possible, it is: walks on two legs, small teeth, big brains. Big brains are connected with walking on two legs, but I'm not sure how.

There are lots of theories linking that [bigger brains] to bipedalism: the two are happening at the same time, or bipedalism is happening and then brains are growing. People have said, it frees your hands so you can use tools and that drives brain expansion. Or you're able to move in different ways and maybe cover greater distances, so you've got larger social networks. Maybe that's driving brain expansion.

We have similar-sized bodies to other apes, yet the human brain isn't just bigger, it's got more folds – packing in an awful lot of cortex into an already massive brain. We tend to say, humans are over here and the rest of the natural world is over there. It totally influences the way we deal with it.

The number of human species that coexisted before us and alongside us really stands out now. How has that changed our understanding?
The first other humans we knew about were Neanderthals. We

DAVE STOCK

"We are fundamentally, at the end of the day, animals," says Alice Roberts

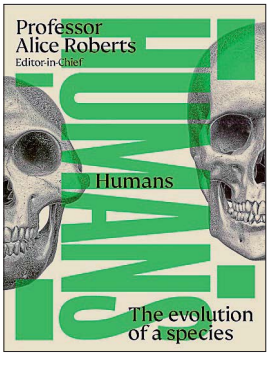
understand now there's an overlap, that they weren't a human ancestor that developed into modern humans. We've got about 20 different hominin species now, and more every year.

In 2008, I was making *The Incredible Human Journey*, my first landmark series for the BBC. In Jakarta, Indonesia, I went to the museum and introduced myself as a biological anthropologist, and they said, great, in that cupboard is *Homo floresiensis* [LB1], you can lay out this fossil. I was blown away. There I was with LB1 and the table with bubble wrap on it.

"The hobbit" – the original *Homo floresiensis*!

The original *H. floresiensis*! I laid out the skeleton and it sent shivers down my spine because it was so human and yet not, especially the skull. It has a tiny skull and a tiny brain. And yet, we know it is anatomically human. We know they were making stone tools. That was a big revelation. In the archaeological record, we've got brains getting bigger and stone tools appearing – we just assumed the two went together. Then you find tiny-brained individuals making stone tools on Flores.

I love it when new discoveries throw big spanners in the works. It did change my concept of what it was to be human. It's a paradox that I hold in my head continually. I will rail against human exceptionalism while saying humans are exceptional. If we look at our culture and our tech, we are utterly exceptional. If you're looking at individual bits of us, you can see where it has come from; it hasn't just exploded into being. We are fundamentally, at the end of the day, animals.



Still primates. But eventually the Neanderthals, the Denisovans, they all disappeared. Why is our species left?

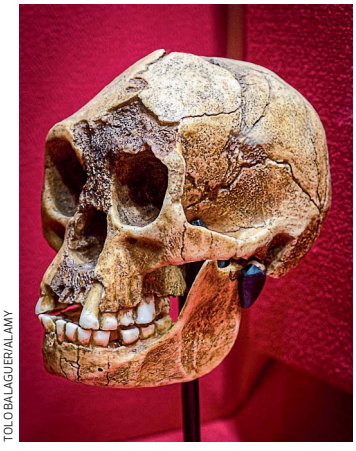
It's a very hard question. You're pushing tens of thousands of years, if not hundreds of thousands, of evolution into one question and one answer. One hypothesis, which is hard to test but it has the best evidence – and I'm cautious because I don't think it's one thing – is about the social networks modern humans had. The evidence is extraordinary. It seems raw material is travelling further in human networks. If you try to work out why, you're talking about groups of people who are connected and exchange objects, raw materials and artefacts.

So you think, OK, you've got small bands of people, but they know others. Maybe if you fall on hard times and you aren't managing to get enough food for your tribe, there are other people you can call on.

Like the rest of the natural world, we are evolving. Will we change over the next few hundred years?

Not much. When we see evolution happening rapidly, it's usually because something awful has happened – a population has been reduced to just a few. Then you get profound effects based on that selection of genetic diversity.

If we remain a big global species, I think most change will be the change we've been able to detect in the immune system, that kind of thing. We're not going to grow extra arms and legs, certainly not in the next 100 years.


TOLO BALAGUER/ALAMY

Homo floresiensis had a tiny skull (above) and a tiny brain – yet made stone tools

One really interesting and very scary thing on the horizon is the ability for us to change DNA. I don't know how that will play out. That's a big ethical question.

"It's a paradox I hold in my head. I will rail against human exceptionalism while saying we are exceptional"

Is your work feeding into the fiction you are writing?

I've written two children's books set in the ice age. I was imagining what it was like when modern humans first met Neanderthals. I wanted to bring it alive as a story.

Then my first novel for adults is out in September, *The Goddess Queen*, the story of Cleopatra and Mark Antony. When we talk about Cleopatra, we talk about her love affairs, but politically she's incredible. What intrigued me was the potential for things to have played out differently: there's a lot of chance and contingency in human history, just as in evolutionary history. Different books, but with the same themes and ideas.

Overall, where is our relationship with nature? What should that be?

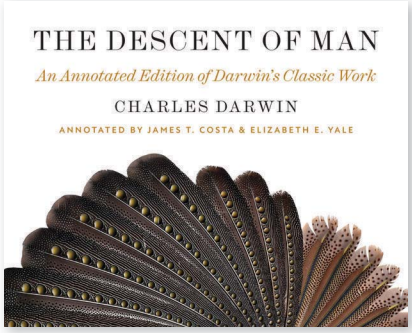
There are billions of us. Our culture is exceptional. But by taking this evolutionary approach, you've got less of a hard line between the rest of the natural world and us, you can see where this culture has actually come from, even if it makes us feel completely separate.

Today, it's important to remember we're not separate. I don't believe in any supernatural phenomena. I don't believe in any divinity. Another way of framing that is, I think nature is enough, and for me as a humanist, I draw quite a strong moral lesson from the knowledge that I am part of the natural world, that all those other species out there are close cousins, that what evolution has conferred on us is this incredible intelligence and understanding.

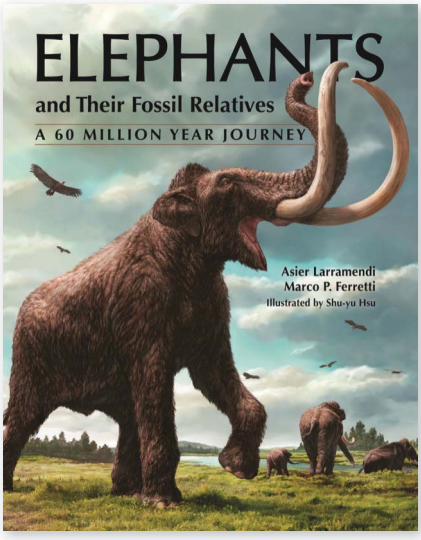
We understand the impacts we're having. When we have a deleterious impact – even if it's not happening immediately – we understand that by virtue of the lifestyles we're living, we are impacting negatively on biodiversity. Morally, we need to limit that impact. Because however insulated we feel from the natural world, we're part of it. If that disappears, we're not going to be here very long. ▮

This is an edited version of a *New Scientist* video interview that will be available at youtube.com/NewScientist from 10 June. Michael Marshall is a writer based in Devon, UK

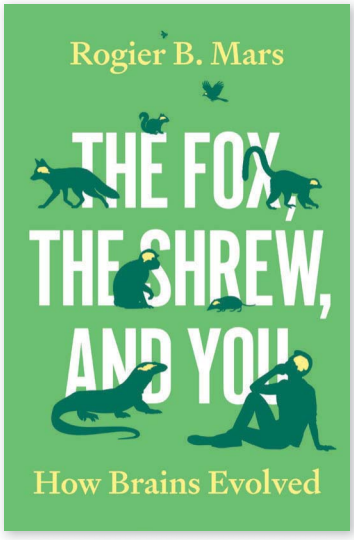
New from Princeton University Press



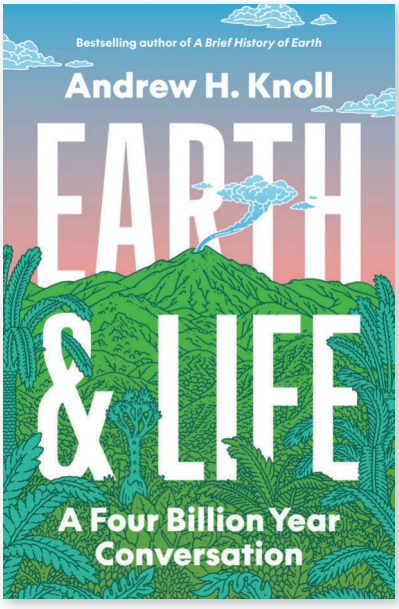
The first annotated edition of the book that shocked the Victorian world and continues to generate controversy today



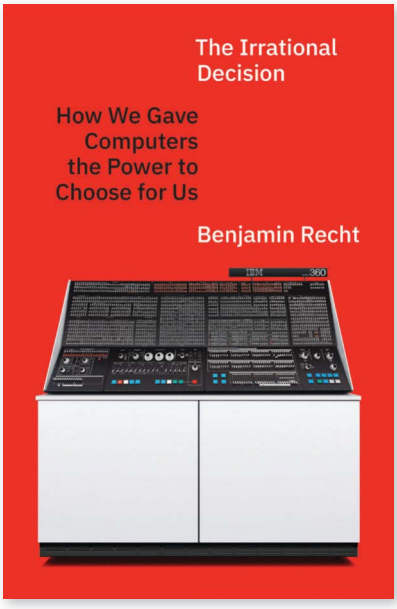
The ultimate illustrated guide to elephants and their prehistoric relatives



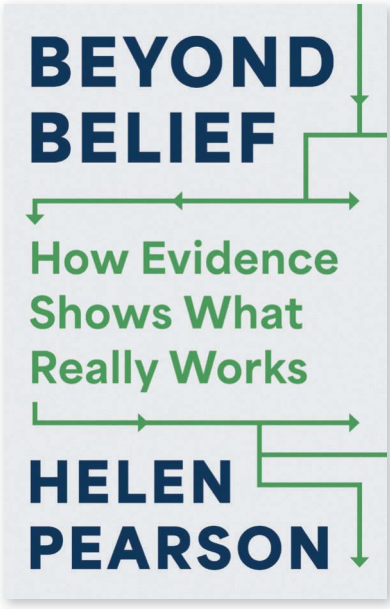
A leading neuroscientist describes the long evolutionary process that led to the human brain



From the world-renowned geobiologist and bestselling author of *A Brief History of Earth*, the epic story of a planetary conversation four billion years in the making



How the computer revolution shaped our conception of rationality—and why human problems require solutions rooted in human intuition, morality, and judgment



The remarkable story of the global movement championing the idea that evidence, not opinions, should guide our decisions

Editor's pick

Debating the laws of nature

16 May, p 30

From Vic West, Rochester, Kent, UK

In response to João Magueijo's article "Bringing chaos to order", the term "law of nature" is used to describe a process that has, since its identification, always been observed to be the case. However, a basic tenet in the philosophy of science is that one knows that the observation of the process describes only what has been the case up to this point, that a new observation is always possible and the description of the process (the law) would, in that case, need rephrasing.

So, one isn't committed to having to accept that anything one calls a law is "permanently so".

So no surprises or issues here, then – it isn't "backing every football team at random" – it is being able to accept that change can happen to one element and alter the fortunes of a club.

From Spencer Weart, Hastings-on-Hudson, New York, US

Magueijo's fascinating speculation about the evolution of the laws of physics from a chaotic initial state begs to be extended. He presumes initially random variations of laws and constants over time, but there would also have been random variations over space. Thus, it might be worth looking for inconsistencies not only as time passes, as he suggests, but also from one region of the visible universe to another.

From Nick Canning, Coleraine, Londonderry, UK

The notion that the "laws of nature", the term we use to give natural explanations rather than supernatural ones, may not have always existed, while intriguing, is also corrosive to rational thought, for without stable natural laws, the very notion of a natural explanation of phenomena loses all meaning. Such metaphysical conjectures are in danger of abandoning the realms of refutable hypotheses and testable deductions that Karl Popper placed at the heart of the scientific endeavour.

How long would it take to visit a distant star system?

23 May, p 36

From Paul Bowden, Nottingham, UK

Leah Crane writes a fascinating article about the TRAPPIST-1 star system, with its seven roughly Earth-sized planets. Just out of curiosity, I worked out how long it would take us to get there, as measured on board a ship. If a 1*g* ship accelerates for the first half of the journey, and decelerates for the second half, it would take roughly 7.5 years for the astronauts, because of relativistic time dilation, but just over 40 years as measured on Earth. All we need is that spaceship!

Which came first: the bird or the dinosaur?

2 May, p 40

From Alex Bowman, Glasgow, UK

In your interview with Dave Hone, he says that "birds are literally dinosaurs". It is likely that the physical characteristics of birds that facilitate flying – lighter, stronger bones and more efficient lungs that have unidirectional air flow and sacs that act like bellows – are also characteristics that in dinosaurs led to huge sizes. Birds also have smaller, tighter neurons, which mean some birds are smart despite seemingly small brain capacity, and so perhaps dinosaurs were smart, too. It's often said that dinosaurs evolved into birds, but considering the above, perhaps dinosaurs evolved from an originally flying animal.

From Owen Wilby, Eye, Suffolk, UK

I greatly enjoyed Hone's interview, but think he greatly underestimates the importance of birds' legs. Not just useful for running and jumping into the air, they are also sophisticated at perching and catching prey of all kinds – both in the air and in water. Also, birds' wings can enable hovering and flying backwards, as well as effortless soaring. Could the pterosaurs do all that?

The important distinction between a cow and an ox

9 May, p 30

From Georgina Skipper, Weymouth, Dorset, UK

The story of the gradual decipherment of proto-Elamic script is fascinating and impressive. However, the reason "cow" doesn't appear with "plough" is probably because they used a different sign for "ox". An ox was a beast of burden and used for ploughing. A cow was for milk and calving. The fact that we modern English speakers retain the two words – despite not having used oxen since the industrial revolution – shows that the distinction was important.

Sorting objective from subjective reality

2 May, p 36

From Lawrence J. Ryan, Wilsonville, Oregon, US

It seems to me that "The essence of reality" confuses the objective and the subjective. "What could be more real than experience?" your author asks. A human observer with three distinct iodopsin molecules in three distinct retinal cones will experience the red tomato differently than people with zero, one or two cone types. So, their subjective reality differs – so what? A physicist should instead measure the distribution of reflected wavelengths and their intensities under a specified light source. That is the objective reality. The rest is just spinning philosophical wheels with no traction.

Humans and animals evolved senses and perception of those sensations to maximise survival and reproductive fitness. Does our inability to detect X-rays mean they don't exist? Obviously not. Did the world not exist before I was born? Well, it didn't for me, and won't after I die, but that doesn't mean reality didn't exist before me or won't continue to exist after me (at least I hope not; that would be too great a burden).

The philosophy that science can't do without

16 May, p 3

From James Hardy, Belfast, UK

Your leader article "Asking the big questions" must draw us to René Descartes: "I think, therefore I am."

Can science exist without three domains of philosophy: personhood, thought, existence?

An evolutionary view on the meaning of love

23 May, p 10

From Neil Stuart, Keswick, Cumbria, UK

In her piece about the mystery of love, Carissa Wong doesn't mention evolution. She refers to the initial honeymoon stage filled with intense desire. In the normal course of events this is likely to produce offspring. This period will, therefore, have served its evolutionary purpose.

For the record

Global sea-level has risen by more than 0.2 metres over the past 150 years as a result of global warming (16 May, p 4).

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A revolution in maths

The stunning progress AI is making in maths is leaving some questioning whether there will still be room for humans, discovers **Alex Wilkins**

I AM attempting to solve a mathematical conundrum that has stumped many of humanity's greatest thinkers. I have zero mathematical training, apart from a distant undergraduate physics degree, which should put my odds of success at slim to none. But I also have a trick up my sleeve – a kind of mathematical genie that can conjure arcane secrets seemingly out of thin air. I make a short request concerning an esoteric conjecture in number theory, then cross my fingers.

Perhaps "genie" is a bit too strong – I'm simply using GPT 5.5 Pro, the latest iteration of OpenAI's flagship model. But for mathematicians, modern AI models appear to have a spark of magic. Even in an era of rapid progress, the growth in AI's mathematical ability is stunning. In just a few months, many prominent mathematicians have walked back previous scepticism and replaced it with sweeping predictions, whispering behind closed doors about job concerns and whether it is even worth embarking on a particular research project if AI might get there first.

In April, I visited San Francisco, where the future often seems to arrive fastest, to attend a hastily organised meeting between mathematicians and AI researchers. There was an air of excitement and curiosity in the room, but also an undeniable feeling of existential dread. If someone like me could produce mathematics at the press of a button, what would that mean for the professionals? Will we even need human mathematicians? And will the machines crack problems that no human could? The answers may have profound consequences for the millennia-old practice of mathematics, and it feels like mathematicians have only a brief window to prepare.

"I think AI is going to come in a big way, and it will significantly revolutionise the field," says Jacob Tsimerman at the University of Toronto, Canada, who helped organise the conference.

Opinions on the future are divided. "We are running out of places to hide," wrote Jeremy Avigad at Carnegie Mellon University in Pennsylvania in a recent essay. "We have to face up to the fact that AI will soon be able to prove theorems better than we can."

Some mathematicians are welcoming the mechanisation of mathematics. Terence Tao at the University of California, Los Angeles, has said the field is moving from an era of "proof scarcity" to one of abundance that could see many once-thorny problems fall to AI. Rather than focusing on being the first person to find a proof, mathematicians might instead race to be the first to understand it, he argues.

Artificial intelligence isn't terra incognita to mathematicians, but it is only in the past few years that it has started producing useful contributions. At first, these were artisan operations, using individually crafted neural networks to crack particular problems. These bespoke AI models proved difficult to apply across different mathematical disciplines, and remained of interest to only a tiny fraction of working mathematicians.

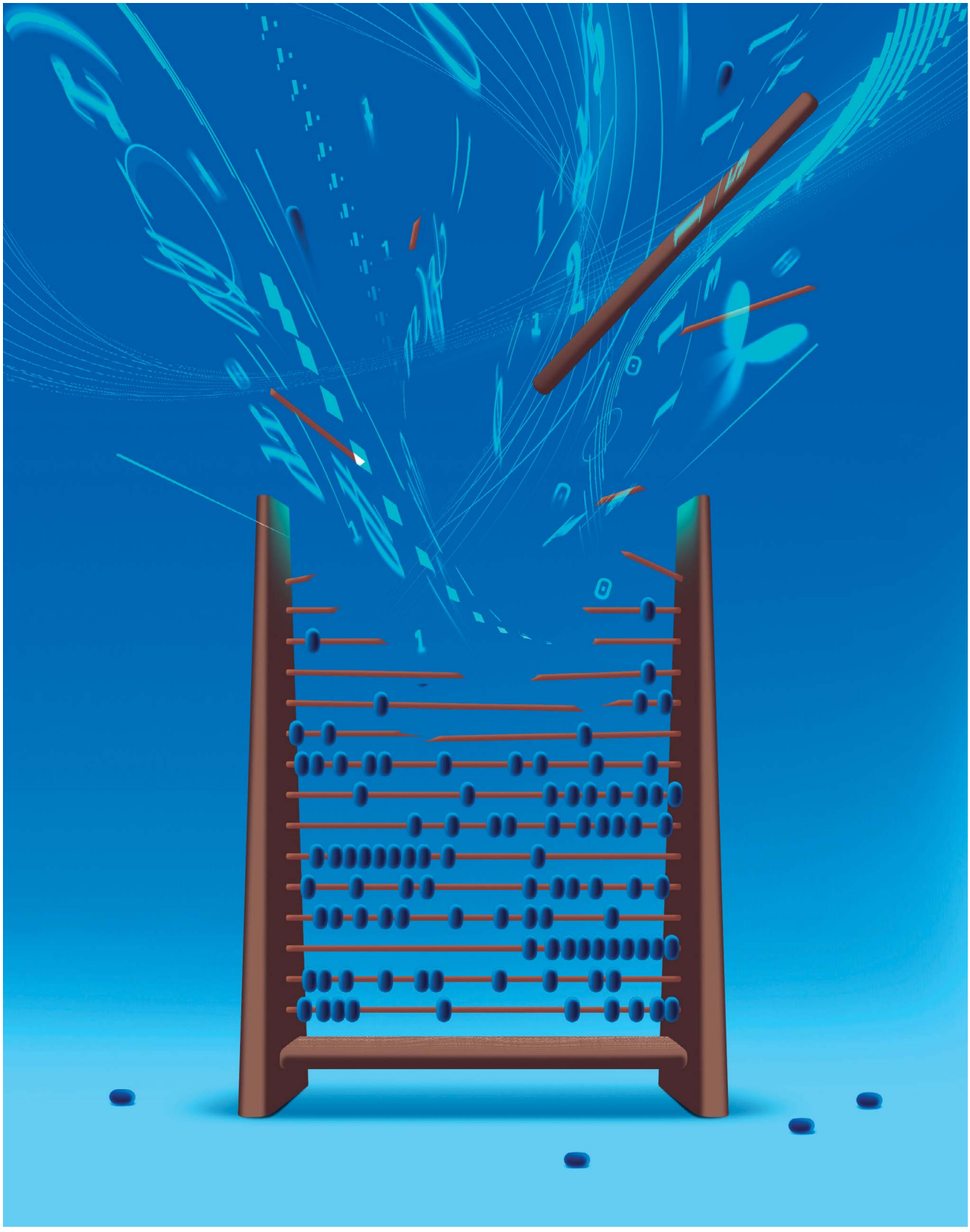
Even when ChatGPT launched in 2022, mathematicians remained unimpressed – large language models (LLMs) like GPT-3.5, which powered the first version of OpenAI's chatbot, struggled to perform even basic arithmetic and spouted confident nonsense when asked to solve research-level mathematical problems. But as LLMs scaled up and were trained on increasing amounts of mathematical data, they began to yield results.

The gold standard

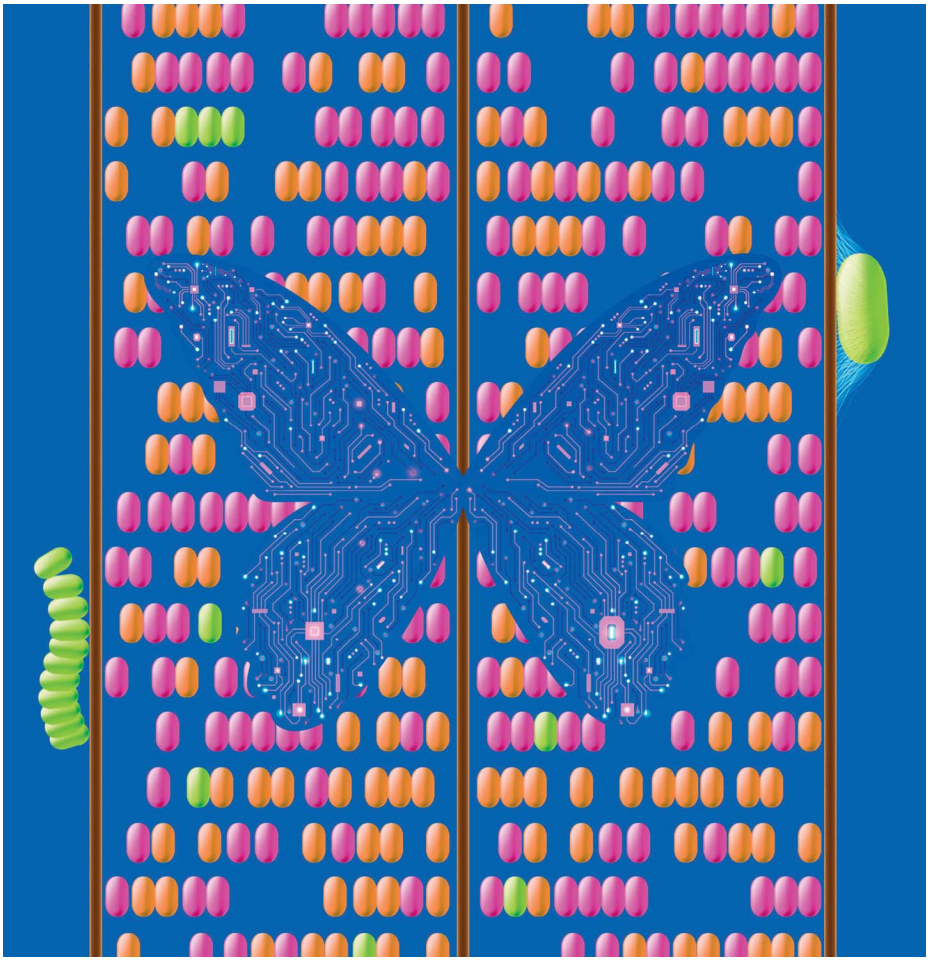
One of the first signals that AI was becoming more adept came when AI models were tasked with attempting the International Mathematical Olympiad (IMO), an elite test for high-school students consisting of just six questions of devilish difficulty. The mathematical intuition and range of disciplines required to succeed at the test meant many researchers saw it as a benchmark for mathematical AI, but thought it would take years, possibly a decade, for it to score highly.

They were wrong. In July 2024, Google DeepMind announced that its AlphaProof AI system could solve four out of six questions from that year's IMO, enough for a silver-level performance. This was impressive, but AlphaProof wasn't a strict LLM and had been fine-tuned for IMO-style questions, such as geometry, and it was unclear how much further it might go. But just a year later, Google and OpenAI announced they had achieved a gold-level performance, with OpenAI in particular using a less maths-focused model. The results made mathematicians sit up. "People's eyes really opened," says Ravi Vakil at Stanford University in California.

It wasn't long before these capabilities were made available to the public, where they quickly found use beyond high-school competitions and began encroaching on research-level mathematics. Thomas Bloom at the University of Manchester, UK, first noticed the impact of these newer models in the last months of 2025. He runs a website that tracks progress on a set of more than a thousand problems posed by the famous mathematician Paul Erdős. They tend to be simple to state, but range in complexity ›



ADRIA VOLTA



"We have to face up to the fact that AI will soon be able to prove theorems better than we can"

from relatively straightforward to very difficult, and many of them are seen as signposts for mathematical progress.

Bloom started getting comments on the site from people he didn't recognise. At first, they were just using GPT-5, then recently released, to dig out obscure references in the literature that might help with a particular problem. But in a matter of months, the release of more powerful models like GPT 5.2 Pro saw people posting full-blown solutions with AI assistance, some of which were verified by Bloom and his colleagues as correct. These solutions took "non-trivial effort", Bloom told me at the time. "It's incredible that AI is capable of that."

What's more, some of these solutions weren't coming from professional mathematicians, but amateurs and novices. Kevin Barreto, who is in his second year of an undergraduate mathematics degree at the University of Cambridge, has solved numerous Erdős problems using AI, frequently with his collaborator Liam Price, who has no maths degree or formal training.

Inspired by their success, I wanted to try autonomous mathematics for myself. While these tools can, in theory, be used by anyone, Barreto and Price seem to have a magic touch in prodding the genie to produce useful answers, so I asked for help. The trick isn't just asking the model to produce a proof, Barreto tells me, but bizarrely giving it a certain level of support, like "try your best" or "don't give up". "You try to encourage the model," he says. "You try to hint it into believing the problem is of an easier difficulty than it actually is."

Even so, success wasn't guaranteed. Solving certain problems has often taken Barreto numerous attempts, if he succeeds at all. "Coaxing the correct proof strategy out of it is essentially like trying to play the lottery," he says.

Still, I wanted to try my hand and spin the wheel in the mathematical proof casino. I chose an unsolved Erdős problem, number 710, which concerns a list of requirements that must be satisfied by a set of numbers, with the goal being to find a set with the smallest difference between the lowest and highest numbers. It is a bit like having a list of picky hotel guests, who insist on having a room with a bath or a sea view, for instance, and needing to find the shortest block of rooms that will satisfy them all.

Mindful that I needed to use the most powerful AI model available, I asked OpenAI for access to ChatGPT 5.5 Pro, which normally costs $200 a month but was provided for free for this article. Like Barreto suggested, my prompt for the AI hints that the solution is within reach and that "it just takes a few clever tricks".

As I left the AI crunching away, I turned to consider the most recent developments in this mathematical revolution. If solving Erdős problems is AI creeping up on the door of research-level mathematics, the past few months have seen it kicked down. A steady

stream of mathematical papers are claiming to solve real, cutting-edge problems.

In January, Vakil and his colleagues uploaded one such paper, noting that "the proof of this result was obtained in conjunction with Google Gemini and related tools". The proof focuses on a particularly thorny problem concerning how certain sphere-like shapes can be linked to other mathematical objects called flag spaces, which can be thought of as collections of nesting-doll-like objects. This would provide an important link between topology, which concerns the more general properties of shapes, and algebraic geometry, which deals with the precise shapes themselves. The task is made difficult by the multitude of ways in which the flag spaces and sphere-like shapes can correspond.

Taking a shortcut

Vakil and his colleagues first gave a simpler version of what they wanted to prove to a custom AI model from Google DeepMind. The model found a mathematical structure they hadn't previously seen, making it clear to them how to generalise and write the entire argument, which turned out to be simpler than it initially seemed.

"There's no way the AI could do it by itself because it wouldn't know the [correct] question. We absolutely told it what to do," says Vakil. At the same time, the AI provided a shortcut. "The paper might never have happened because we might never have had the time to get together and figure out the argument," he says. "It's more how things will happen. The future will be some combination of human and machine."

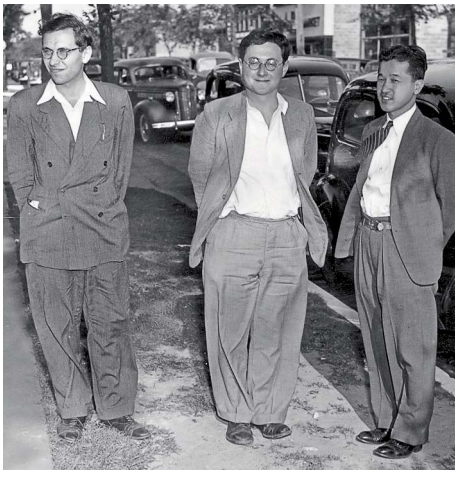
This line is already becoming increasingly blurry, however. The very same month as Vakil's paper, Tony Feng at the University of California, Berkeley, who also works with Google DeepMind, published a paper detailing how he had used Google's Aletheia AI to calculate a previously unknown collection of numbers that are vital for translating between two disparate mathematical disciplines, algebraic geometry and number theory. Building such bridges is an important goal in the Langlands programme, often seen as a grand unified theory of mathematics. According to Feng, the "core mathematical content" was generated entirely by Aletheia.

The biggest result yet in AI mathematics came just a few weeks ago, when OpenAI announced that it had used an unreleased model to solve an 80-year-old maths conjecture called the planar unit distance problem. The firm didn't provide full details of the model, other than to say it was a general-purpose AI, rather than one trained specifically to do mathematics. The reaction among mathematicians has been one of stunned disbelief.

It is becoming difficult to keep track of the torrent of mathematical research assisted by AI, not least for professional mathematicians, who are themselves busily attempting problems using AI that they may not have previously had time to do.

"It opens up a world of possibility," says Alex Kontorovich at Rutgers University in New Jersey. "I can imagine projects I could undertake this summer, things that I know would have taken me five years that I would never have even started."

Could those new possibilities even include a solution for the Riemann hypothesis, a deep question about the origin of prime numbers that is one of the Millennium Prize Problems, which are often seen as the greatest challenges in maths? Several mathematicians working for AI companies told me they thought we might see one of these problems fall in the next several years, while others cautioned that they are in a wildly different class of difficulty from those problems that had been solved so far.



NEW YORK DAILY NEWS ARCHIVE/NY DAILY NEWS VIA GETTY IMAGES

Mathematician Paul Erdős (left) posed hundreds of problems that AI is getting better at solving

The San Francisco conference I attended in April was an attempt to map these possible futures. It took place in a nondescript building owned by a venture capital firm, the only clue that it existed an unmarked pink door and a video doorbell. As I waited for the door to open, I was joined by a former maths professor who now works for a hedge fund, stepping out from a driverless car. Once inside, I found eminent mathematicians like Vakil and Kontorovich mingling with employees from companies like OpenAI and Google.

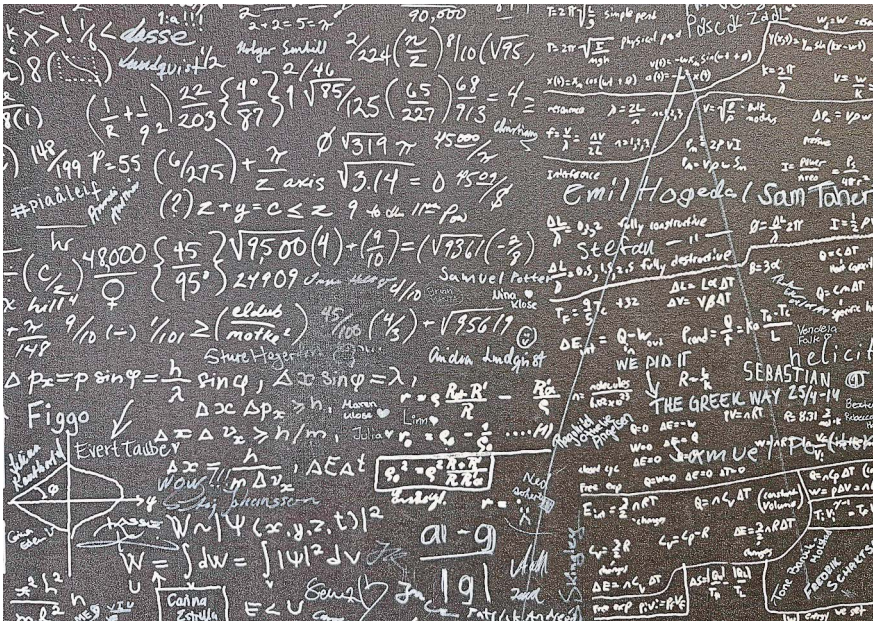
The ostensible goal of the meeting was to come up with a way to track AI's mathematical progress and where it might be headed. Attendees had their own personal priorities, however. "My hope was to understand a little bit more about where the models are and where they're going in terms of mathematical capability," says Daniel Litt, another conference organiser, also at the University of Toronto. "It's clear that the models are, in some sense, missing some capabilities that mathematicians have."

In the past, the most common way to test an AI model's mathematical ability was to run it on a benchmark, a collection of problems that typically require simple and easy-to-verify solutions, like a single number. This was convenient for AI companies, because they could present their models' progress as a clean, rising line on a graph. But many mathematical tasks aren't so neat and tidy, requiring proofs that need interpretation by an expert.

What's more, prowess in one area of maths doesn't imply a human-like mathematical ability in general, says Melanie Wood at Harvard University. "One big mistake that people make when they think about AI and math is to take the correlation of these skills in humans and think that it's going to match some correlation in AI."

Mathematicians at the conference worked in small groups to come up with a better way to track AI's mathematical ability and finished the week with a working draft. But boiling down all the things a working mathematician does into a short document wasn't easy, and there was still disagreement over the best way forward.

A large part of the conference consisted of free-flowing group discussions primarily ›



THOMAS T/UNSPLASH

Is the era of humans solving problems almost over?

between the mathematicians, hashing out the details of what an AI-led mathematics might look like. Would it be of humans and machines working in lockstep, like Vakil thought, or would it be more like a slot machine, pressing a button that sometimes produced an interesting result in full?

For Tsimerman, who grew up taking part in maths competitions like the IMO, the latter didn't have much appeal. "My experience of math is the act of solving problems, and if I don't do that anymore, I think I might prefer playing music or doing theatre or learning something else," he says.

At one point in a group discussion, Tsimerman asked people in the room to indicate whether, in his button-pushing vision of the future, they would want to continue being mathematicians. Only around half raised their hand.

Not everyone agreed that this was a useful exercise, however, or that solving problems was the most important mathematical activity. "What I actually care about is understanding things and figuring out what's true," says Litt. "One can do that by posing and proving a conjecture, but you can also do that by going over to your friend and asking them a question."

And even if these tools can solve difficult and thorny problems, many mathematicians remained adamant that it was only humans that could decide what was interesting to work on or what the important problems to tackle should be. Maths isn't about solving puzzles just for the sake of it, points out Wood, and mathematicians generally look for solutions that push the field forward. "Does it suggest a way to solve a lot of other problems, or is it only a solution for that particular problem?" she says.

Lateral 'thinking'

On the conference's third day, excited murmurs rippled among the attendees. Overnight, it appeared that another Erdős problem had been cracked, one that was qualitatively different from the others. Jared Lichtman at Stanford University, who happened to be at the conference, had spent a considerable portion of his PhD wrestling with a closely related problem, after many mathematicians had spent decades trying to solve it. "It was a problem I was already independently very passionate about," he says.

Price had elicited a solution to the problem, known as Erdős 1196, from a single request to ChatGPT 5.5 Pro. It concerns "primitive" sets of numbers that are similar to prime numbers, in that no number in the set can divide another. Erdős had come up with a number calculated from these sets that helped order them, and argued that the largest this number could be for any primitive set was 1.6. Lichtman had proved that Erdős was correct in this case, but wanted to do the same for a more restricted family of primitive sets. Erdős suspected the highest value this number could be was 1, but proving it remained a tougher nut to crack.

The AI took an entirely different approach, using a mathematical tool that all previous attempts had missed, called a Von Mangoldt function. "You can use the Von Mangoldt function to circumvent a lot of technical difficulties that all these previous approaches had used," says Lichtman.

Working with others, including Price, Barreto and Tao, he later adapted this technique to solve a related 60-year-old conjecture by Erdős. "This is perhaps one of the first examples of an AI-generated proof having downstream impacts, which we are still exploring," Lichtman said when posting about the work on social media.

Meanwhile, I was finally ready to explore my own AI-generated proof. After "thinking" for 22 minutes and 18 seconds, ChatGPT pinged me with a response. "Here is the clean proof," it wrote, followed by dozens of lines of impenetrable mathematics. I felt a jolt of excitement. Had I solved a decades-old problem, cementing my name in the mathematical history books?

I fed the answer back into ChatGPT, and soon received confirmation: "Yes – the main argument is correct." I was growing even more confident. I dashed off an email to Barreto, asking whether I might be on to something. But as quickly as my excitement had arrived, it vanished. "It doesn't look like it solves the problem," he replied. I had missed that the AI had actually proven something different from the formula Erdős had hoped for, which had already been discovered by Erdős himself years ago.

It was something that an expert mathematician might have quickly caught, but for me it was lost in the noise. Perhaps there is a future for mathematicians after all, even if only to help humans understand what an AI produces. "I still want to know what's going on," says Litt. "A model can't understand something for you." ▮

Alex Wilkins is a reporter at *New Scientist* focused on physics and technology

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Hearing aids

Hearing loss is bad for the whole body, but there are ways to safeguard this crucial sense, finds **Graham Lawton**

I'M SITTING in a soundproof booth at an audiologist's office, wearing headphones and straining to hear some faint electronic noises. When I think I've heard one, I press a button. It's really hard. Was that real or did I imagine it? Oh god, I'm going to fail...

I'm here because my partner thinks I'm losing my hearing. Apparently I'm always saying "Huh?" when she's talking to me. I wouldn't be surprised if I am. Deafness runs in my family and I have probably been to too many loud concerts and spent too much time listening to music via headphones.

If I am losing my hearing, I might well lose a lot more besides, including my mental health, my heart health and even my life. Once regarded as a mere inconvenience of getting older, hearing loss is now being recognised as a major public health issue, according to otologist Justin Golub at Columbia University in New York. It is strongly linked to issues from dementia to cardiovascular disease. Fortunately, there are ways to restore the hearing of those who are losing it. There are also promising new-generation drug therapies in the pipeline for a condition that, up till now, has had none. So, if you don't want to lose one of your most important faculties, listen up.

Hearing loss happens for many reasons, mainly the wear and tear of old age. Whatever the cause, the outcome is the same: a problem hearing very quiet sounds. When the quietest sound detectable is roughly 20 to 25 decibels – about as loud as a ticking watch – a diagnosis of hearing loss is in order.

The condition comes in three basic flavours. The plain variety is when sound waves can't reach the inner ear because of a blockage.

CARL COURT/AFP VIA GETTY IMAGES

Hearing loss has inspired art, such as John Baldessari's *Beethoven's Trumpet (With Ear)*

Earwax build-up and infections are the usual causes of this "conductive" hearing loss and can be cleared up relatively easily. More troublesome, and by far the most common, is sensorineural hearing loss (SNHL), which is caused by damage to the inner ear, either the snail-shaped cochlea or the nerve pathways from it to the brain. This is usually due to advancing age, genes, underlying diseases, noise damage or pharmaceuticals that are toxic to the inner ear, notably a class of antibiotics called aminoglycosides.

The third and most complex type is auditory neuropathy spectrum disorder (ANSD), in

which, for some reason, the way the brain processes sound goes awry. Both SNHL and ANSD are irreversible, but can be alleviated somewhat with technology or therapy.

Today, over 1.5 billion people – almost a fifth of the global population – are living with some form of hearing loss, according to the World Health Organization, making hearing loss one of the most common chronic conditions on the planet. Indeed, around half of people over 65 have some difficulty hearing, according to the WHO's first-ever *World Report on Hearing*, published in 2021. The prevalence doubles with every decade of life and, by age 70, about two-thirds of people can't hear as well as they used to.

The problem is only going to get worse. The WHO predicts that, by the end of this decade, 1.9 billion people will be hard of hearing, and by 2050, this will rise to 2.5 billion people: a quarter of the world's population. At least 700 million will be sufficiently affected to need a hearing aid, cochlear implant or some other form of intervention, such as learning sign language or lip-reading. The ramifications for worldwide well-being could be seismic.

Take the most obvious effect of losing your hearing: social isolation and loneliness. According to Julie Beadle at Simon Fraser University in Vancouver, Canada, even mild hearing loss can cause people to become socially disengaged. Multiple studies have shown this effect and a recent review found that "uncorrected hearing loss often leads to a significant withdrawal from social activities". It also makes it hard to work or study, lowers self-esteem and can be very tiring. The results are alarming. All told, social isolation and loneliness increase the risk of death from any cause by about a third.

Hear for your heart

If the isolation doesn't get you, maybe cardiovascular disease will. Evidence of an association has been building for some time, and earlier this year a team led by Iris Otero-Luis at the University of Castilla-La Mancha in Cuenca, Spain, reviewed all the research. The researchers concluded that many known risk factors for cardiovascular disease – obesity, type 2 diabetes, high blood pressure, imbalances in blood lipids and metabolic syndrome – are also risk factors for hearing loss.

According to a study led by Woei Shyang Loh at the National University Health System in Singapore, people with hearing loss have a 38 per cent higher risk of cardiovascular disease. The more severe the hearing loss, the higher the risk. One study in China, for example, found that participants with the worst hearing were 76 per cent more likely to have a stroke.

This isn't to say that hearing loss causes cardiovascular disease. The most likely explanation, says Otero-Luis, is that the two are consequences of the same underlying problem. Cardiovascular disease is often caused by damage to small blood vessels, and this may also disrupt the workings of the inner ear. Oxidative stress and inflammation may also be involved, she says, but as yet the mechanism remains unclear.

The idea that hearing loss and cardiovascular disease are two sides of the same coin may also explain why asymmetric hearing loss greatly increases stroke risk, as it can reflect localised damage to blood vessels in one side of the brain and inner ear. Paradoxically, this may be good news, according to Shaojie Li at Peking University in Beijing. Asymmetric hearing loss could be an early warning sign of cardiovascular trouble brewing, so allow for early intervention. Other troubling scourges linked with hearing loss include falling ›

over – a leading cause of injury and injury-related death worldwide – as well as mental health troubles like depression.

There is also a link between hearing loss and dementia. In 2024, the *Lancet* commission on dementia published a landmark report on the condition's prevention, intervention and care. It identified 14 known risk factors, one of which is hearing loss. In the past decade, five major studies have found a significant association between hearing loss in old age and subsequent dementia. The increased risk ranges from 28 per cent to a whopping 139 per cent. The most recent of these analyses found that each 10 decibels of hearing loss increases dementia risk by 16 per cent. The *Lancet* commission concluded that 7 out of 100 cases of dementia are caused by hearing loss and could be prevented.

Brain overload

But there are those who say the *Lancet* commission is over-egging it. Last year, a team led by Séverine Sabia at the research organisation INSERM and Paris City University in France published an analysis of existing data to see whether hearing loss around the relatively young age of 50 is an even bigger risk factor for dementia – as you might expect, given that these people will spend much longer being hard of hearing. But that isn't what the researchers found. "There is an association, but it's not as strong as previously thought," says team member Marcos Daniel Machado-Fragua, now at the Spanish National Centre for Cardiovascular Research in Madrid. This study put the increased risk at more like 10 per cent.

According to Sabia's INSERM colleague Archana Singh-Manoux, the reason why the *Lancet* commission found such large numbers is probably because the study populations were people in their 70s, who may have hearing loss as a result of the early stages of dementia. "Pre-clinical dementia causes changes in the central nervous system, it affects hearing, so those results are open to what we call reverse causation, which is the disease itself affecting what you think is a risk factor," she says.

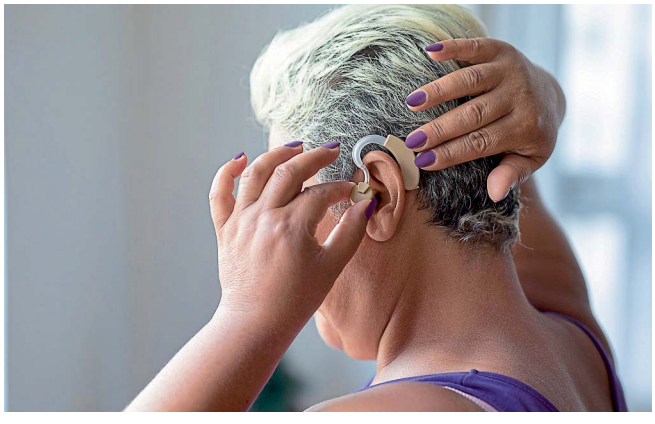
Nonetheless, a 10 per cent increased risk is not to be ignored. The reason for the link is debated. According to the *Lancet* commission, there are four main contenders. It could be because hearing loss leads to social isolation, loneliness and depression, which are dementia risk factors in their own right.

It could alternatively be that the brains of people with hearing impairments are chronically overloaded by the burden of processing sounds. Such high "cognitive load" would cause the brain to shrink and eventually lead to dementia. A third possibility is brain shrinkage caused by reduced sensory stimulation. Or perhaps hearing loss is just another symptom of dementia that can appear before cognitive deficits. Given the troublesome forecast of a global hearing-loss time bomb, rumbles of new-generation remedies are welcome.

"Hearing loss is strongly linked to issues from dementia to cardiovascular disease"

One future solution in the works is drugs that prevent or reverse hearing loss. At the moment, there are none, but plenty of people are working to change that. "New therapies have gotten a bit of a buzz recently," says Golub.

That is partly because the US Food and Drug Administration recently approved a treatment for a previously intractable form of congenital



BYMURATDENIZ/GETTY IMAGES

Wearing a hearing aid (right) may slow cognitive decline, and can help people socialise with friends

MARTIN PARR/MAGNUM PHOTOS

deafness called DFNB9. The treatment, Otarmeni, developed by Regeneron Pharmaceuticals in New York state, is a gene therapy that fixes a mutation responsible for profound hearing loss from birth. It won't directly help many people – just a few thousand worldwide have DFNB9 – but Otarmeni is proof of principle that gene therapies can be delivered to the correct part of the inner ear and restore hearing, says Golub. "It's exciting because we finally have an example of a biological treatment for hearing loss."

That is a boon to researchers and companies working on fixing the genetic basis of later-life hearing loss. One group, based at the University of New South Wales in Sydney, Australia, is currently developing a gene therapy to enhance the performance of cochlear implants. The genes are delivered during the installation of the implant and stimulate the production of two growth factors known to promote the survival of neurons, neurotrophin-3 and BDNF.

The therapy has successfully completed a phase II clinical trial and is moving into phase III. The results have yet to be published, but they are looking good, says chief investigator Gary Housley. "The regeneration occurs very rapidly," he says. "The results bode well for the use of this technology to achieve better hearing." The delivery system could eventually be used for standalone gene therapy without a cochlear implant, he says.

Another promising approach is using stem cells to regenerate the spiral ganglion, a clump of neurons that connects the cochlea to the auditory nerve. Degeneration of these neurons is a leading cause of SNHL, and while they don't regenerate of their own accord, they can be coaxed into doing so by implanting stem cells called otic neural progenitors. Earlier this year, a company called Rinri Pharmaceuticals based in Sheffield, UK, got clearance to run a clinical trial of such a therapy – again, delivered simultaneously with a cochlear implant – and a US rival, Lineage Cell Therapeutics in Carlsbad, California, has something similar in early-stage testing.

The third approach is chemical compounds that protect or regenerate the parts of the inner ear that break down in age-related hearing loss. Such drugs have been in development for some time and have a habit of failing: since 2023, three promising ones have been binned after failing to perform well enough in clinical trials. But hope springs eternal. One of the failures, from Audion Therapeutics, was a close-run thing, suggesting that the drug might get over the line if tweaked a little. And there are many others in development, two of which – Ebselen from Sound Pharmaceuticals in Seattle, Washington, and Paliroden from Cilcare in Montpellier, France – are in phase II clinical trials. "It's impossible to forecast when we'll actually have a drug but, yeah, I think there's potential," says Golub.

VECCHIO/THREE LIONS/GETTY IMAGES

CRO MAGNON/ALAMY

Left: Past aids to help those with hearing loss included ear trumpets

Above: Foods rich in omega-3 are protective of the inner ear

While we await hearing-saving drugs, there are already things you can swallow. Foods rich in antioxidants, vitamin B9 (folate), omega-3 fatty acids and magnesium have been found to be protective of the inner ear, and last year a team at Rush University in Chicago reported that people who eat healthily, particularly the DASH (dietary approaches to stop hypertension) diet, have a reduced risk of hearing loss and slower cognitive decline once it starts.

Can you say that again?

There may already be an off-the-shelf solution to many of these problems: hearing aids. Ten years ago, researchers at Johns Hopkins Bloomberg School of Public Health in Baltimore, Maryland, began the world's first clinical trial to see whether these devices can slow down or prevent cognitive decline and dementia in older adults with hearing loss. The results, published in 2023, indicated that they do, in some circumstances. The overall effect wasn't statistically significant, but among a subgroup of subjects – who were more susceptible to dementia because they were older, less educated, less wealthy and more likely to smoke, plus had more underlying health conditions – hearing aids substantially slowed cognitive decline.

There are dissenting voices, however. Sabia's team at Paris City University also analysed whether hearing aid use protected against dementia, finding that it didn't. "Wearing a hearing aid isn't going to mitigate the risk of dementia," says Singh-Manoux. But that isn't a reason not to wear one, she says. "Hearing aids are important for people to remain connected to life, to remain connected to friends, to remain connected in conversations, to manage their day-to-day life." Ditto cochlear implants, which can vastly improve the quality of life of people with severe or profound hearing loss, says Golub.

But the most important thing is to get your hearing tested, he says, especially if you suspect you are losing it. "My main advice would be, don't ignore it. Go and see an audiologist, find out exactly what your level of hearing loss is and then you can make a decision about what to do about it." Hearing test apps for smartphones are also available and increasingly good, he says.

My test revealed that I have very mild hearing loss at two middle frequencies in my left ear. It's clearly age-related, unfortunately, but also nothing to worry about – yet. I'll be keeping a close ear on it. ▮

Graham Lawton is a consultant for *New Scientist*. He is the author of *Mustn't Grumble: The surprising science of everyday ailments*

"I'm quite optimistic that in the next 10-plus years, we are going to break the standard model"

As the Large Hadron Collider nears a four-year shutdown for upgrades, **Mark Thomson**, director general of CERN, tells *New Scientist* what the collider could still teach us about the universe – and about the bold plans for the next super-sized particle accelerator

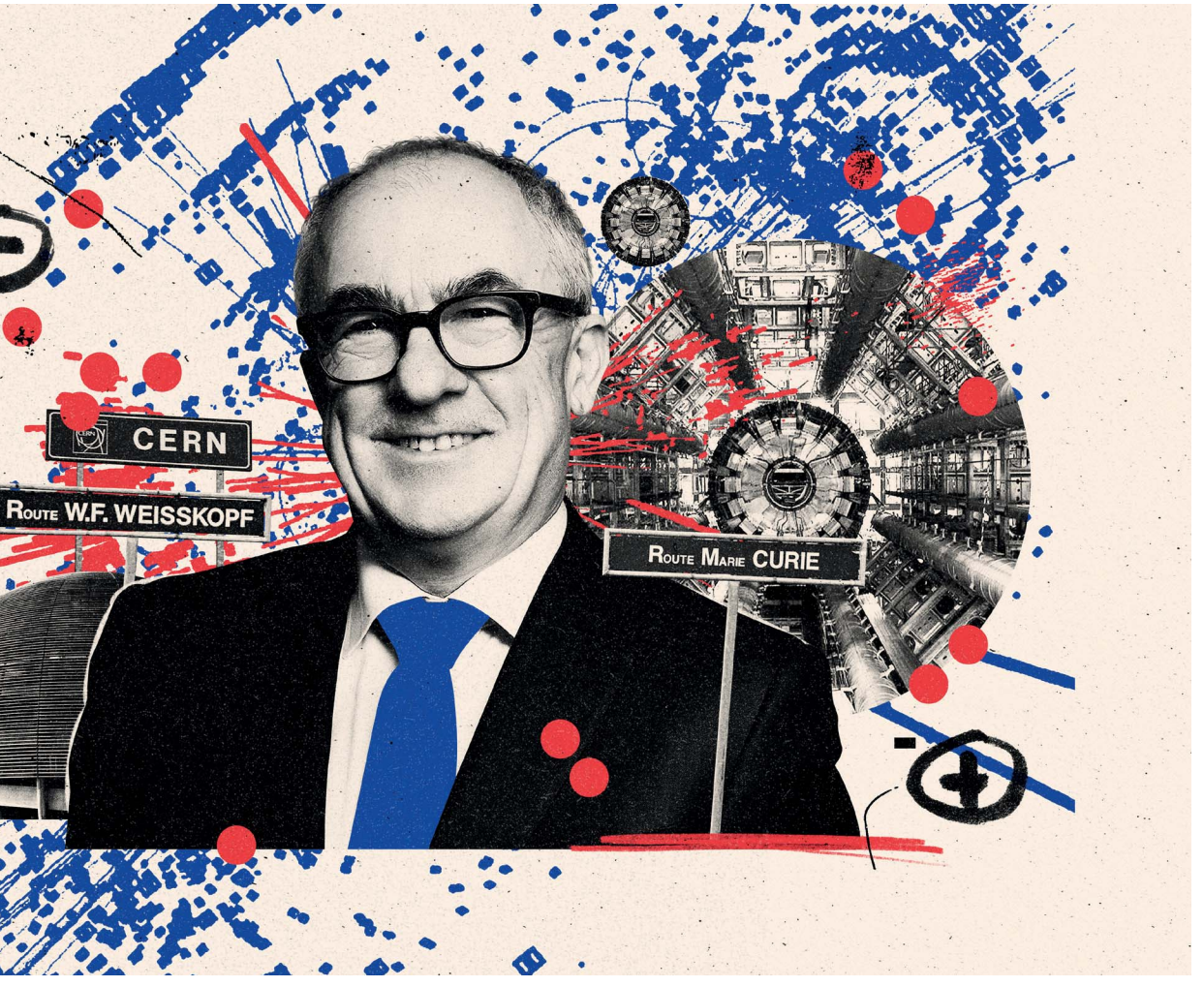
KLAWE RZECZY

WHEN Mark Thomson was 13, he read a book about the European Organization for Nuclear Research, better known as CERN, a particle physics lab whose remit was to interrogate the fabric of reality. The book left him both fascinated by how the universe worked and frustrated by its lack of detail. More than 40 years later, Thomson is CERN's director general, taking charge just as it shuts down the Large Hadron Collider (LHC) for upgrades and decides where to place its next multibillion-pound bet.

The goal of this gamble is to answer big, lingering questions we still have. In a sense, particle physics hasn't changed since Thomson was a boy: it is dazzling in its outline, but maddening in the details it cannot yet supply. The field's crown jewel, the standard model, describes the particles and forces that make up the visible universe with extraordinary precision. And in 2012, the discovery of the Higgs boson seemed to be the masterstroke that completed its picture of reality. But for all its success, the standard model says nothing about dark matter, an invisible substance thought to make up most of the cosmos, and it offers no deeper explanation for the masses of the particles it catalogues. It also cannot account for why the universe contains matter at all after the big bang.

With the LHC set to undergo major upgrades that will sharpen its search for rare phenomena, Thomson spoke to *New Scientist* about what answers the LHC may still yield, and why its physicists are going all in on a £13 billion collider as its successor.

Alex Wilkins: How much has changed since you first read about CERN as a teenager?
Mark Thomson: When I first read about CERN, we had three main fundamental forces, plus gravity. We knew about electromagnetism and knew about the particle that conveyed it [known as the photon], but we had never seen the particles associated with the weak force [known as the W and Z bosons]. Those were discovered at CERN in 1983. We also didn't know that fundamental particles called neutrinos had mass. Just over 25 years ago, we thought these particles were massless. And the real massive discovery, obviously,



was the discovery of the Higgs boson in 2012.

The Higgs boson is radically different to any other particle we know. It has no spin and no electric charge, only mass, which potentially connects it to several outstanding issues within the standard model of particle physics. It is one of a kind, at least as far as we know. It also has the very strange property that, in some sense, the quantum field associated with the Higgs boson is present everywhere in the universe. It is this property that gives all other particles their masses. Without the Higgs field, all known particles would be massless. Consequently, the Higgs field determines many properties of the universe, for example, the mass of the electron and, consequently, the size of atoms. There are also deep questions about the nature of the Higgs boson, such as whether it is a fundamental particle and is unique, or if there are other Higgs bosons.

How much is left to find?

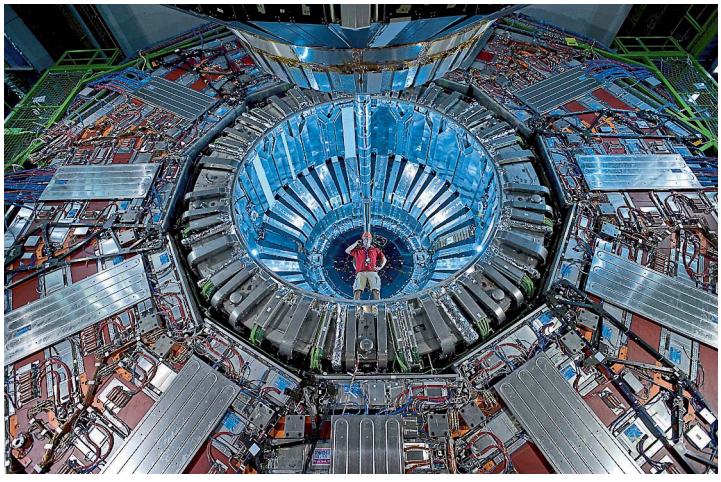
We've definitely not found everything. If you take a look back at the really big, game-changing discoveries – like neutrino mass, the Higgs boson, the discovery of gravitational waves, the discovery of dark energy – these things come along every five to 10 years. You don't get these game-changing discoveries all the time, and you shouldn't expect to. We're now at a point in time where we understand the universe really well, but we also understand there are so many questions that we don't understand, but we can start to answer. ›

"The upgraded LHC will produce an enormous number of Higgs bosons"

We know there's dark matter out there. At some point, we will discover what it is. We don't know when, but we will discover what it is.

We also know that the particles that make up the universe have a very strange pattern of masses. It looks semi-random, and we don't really understand whether there's something fundamental hidden in that pattern, but we know it has something to do with the Higgs boson. I would really love to know why particles' masses have that pattern.

We also don't know why there's any matter left in the universe after the big bang. In principle, in the big bang, you produce matter and anti-matter. At some point, they come together, and they annihilate and we get energy. That's not what happened [because we observe matter in the universe]. So, there are all these really big questions out there, and at some point, we need answers to them.



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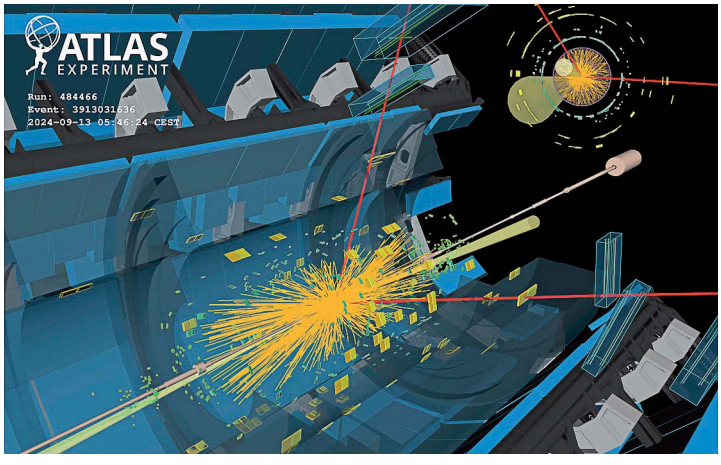


CERN

The Compact Muon Solenoid (top) and ATLAS experiment (above) are both getting an upgrade

The LHC will soon be shutting down for the high-luminosity upgrade. Can you tell us what will be done?

In the summer, on 29 June at 6am, we will switch off the LHC for four years. We're replacing about 1.2 kilometres of the 27-km ring with this very advanced technology. When the particles come around [the collider], we bend them towards each other. If you make the bunches of protons smaller and smaller, you get many, many more collisions. You concentrate everything in the same place. That's what these super-high-field magnets are doing.

We have this incredible superconducting cable that powers these magnets. Installing this is a massive task. It's by far the biggest thing that CERN has done for the last 20 years – and, at the same time, the big experimental collaborations, ATLAS and the Compact Muon Solenoid, which we sometimes call the general-purpose detectors, are upgrading their giant detectors. These are, again, the biggest projects that the experiments have done since building the detectors themselves.

The High-Luminosity LHC will produce an enormous number of Higgs bosons, which is necessary to measure, for the first time, key properties such as how it interacts with itself.

Particle physicists have now begun to look at the future beyond the LHC and to think about constructing an even more powerful collider, like the Future Circular Collider (FCC). Why?

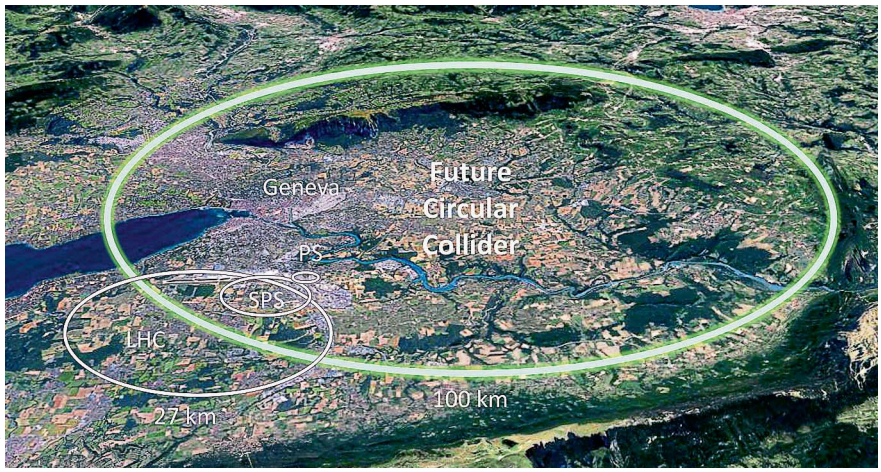
Occasionally, I write down my 10 big questions in particle physics, and half of them have something to do with the Higgs boson. Like, does the Higgs boson interact with dark matter? We know [dark matter] is there, but we don't know the answer to that question. Why does the Higgs boson have the properties that it does? Is the Higgs boson on its own, or are there multiple Higgs bosons?

The only way you can really start to address those questions is to make what we're calling a Higgs factory, producing many Higgs bosons in much cleaner environments, so we can then look at the properties of the Higgs boson. If we see deviations from the properties we expect, we might then learn something about the unknown universe.

From what we know today, there's a grouping of interesting physics at what we call the electroweak scale, which corresponds to energies that we think existed about a 100th of a nanosecond after the big bang. At this

time, elementary particles cease to be massless. The Higgs mechanism gives the W, Z and Higgs bosons clustered around the electroweak scale their mass. The top quark also has a similar mass. However, all the other fundamental particles have much smaller masses – which is perhaps more surprising.

Last year, across Europe, each individual scientific community came together and asked themselves the question: what should we do next at CERN? There was a massive consensus that the FCC is by far the best machine to do the science. That's because there's a huge gap in scientific sensitivity between this particular machine [and] the other things you could do. It's very unusual, even in a specific scientific community, to get such strong agreement. So we're convinced it's the best machine to do the science that we feel we need to do to continue our exploration of the universe.



CERN, PANAGIOTIS CHARITOS/SCIENCE PHOTO LIBRARY

The proposed Future Circular Collider (green) would dwarf the Large Hadron Collider (white)

Will there ever be a particle accelerator big enough? Is FCC the end of the line?

One of the advantages of something like the FCC is that it starts off being an electron-positron collider, but potentially in 30 or 40 years' time, our successors could say what we need now is a Hadron Collider like the LHC, but a bigger one. We would then have the tunnel. So, it paves the way to doing the next phase of our exploration.

Now, we're very focused on FCC; that's what we're going out to our member states to sell, but it does set the path, potentially, very, very long term. It would enable you to explore [physics at an energy] scale up to 100 times what we're looking at now. So, we're really exploring this whole electroweak scale, Higgs [and W and Z bosons]. If you don't see anything there, then I think you start asking that question [of whether we need a larger collider], but we're exploring the place where we think it feels like it's the right place to see something completely new.

I'm quite optimistic that at some stage in the next 10-plus years, we are going to break the standard model that we have. We are going to find a chink in its armour. It might not be where we expect it to be, but what we're doing with all of our big scientific problem projects is we're looking in the right place, or looking in the right places. We're asking the universe the right questions.

It's a very expensive project – £13 billion. Is it really the best use of money?

In any scientific ecosystem, you're going to have a range of experiments. You're going to do some small things at one end, but you have to have these really big bets and do the really ambitious science. The FCC is the one that's right out at the end. I don't believe it's stopping other science from happening. Medical research, for example, will continue regardless of the FCC.

We are seeing economic challenges across Europe. From the perspective of the FCC, we're not asking for money now. We'd actually be investing the money in the early 2030s, so we don't know what the economy will be like at that moment, but I do think it's our duty as CERN not just to make the scientific case, but to actually make that wider economic case. That case is there.

Sometimes the technologies we develop here at CERN, or in big science, do change the world, but they change the world 20 years down the line. If you didn't do the investment early on, there are things you just would not end up with. The World Wide Web was developed 500 metres away from where we are now, in a small office inside CERN, as a way of sharing data between physicists. That really has changed the way the world works. The accelerator technologies we develop are not only useful for things like advanced cancer therapy, which uses proton accelerators, for example, but they're also used in other fields of science. So, the economic benefits are huge, but sometimes they're very long-term. ▮

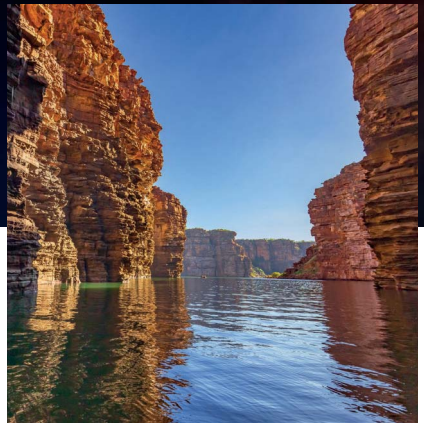
> "We are going to find a chink in the standard model's armour"

This is an edited version of a *New Scientist* video interview. Watch the full interview at youtube.com/NewScientist

Alex Wilkins is a reporter at *New Scientist*

New Scientist Discovery Tours

Three ways to experience the Great Australasian Eclipse in 2028



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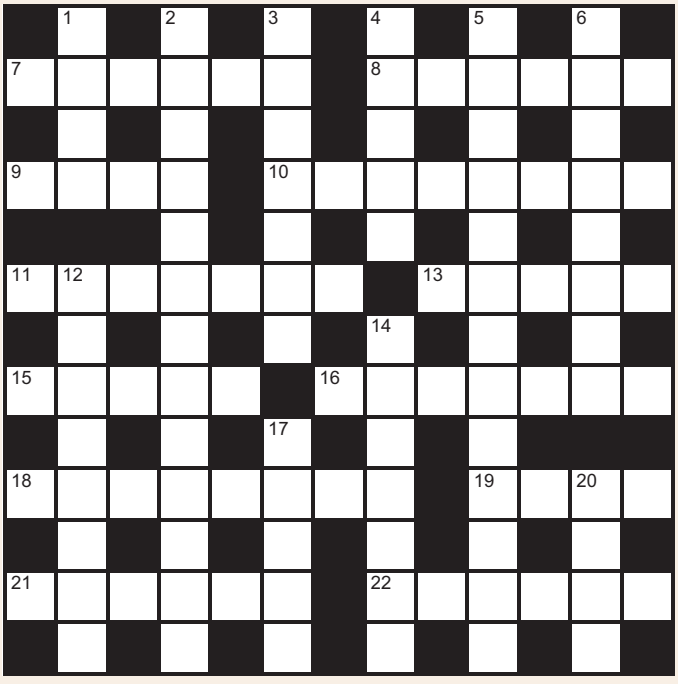
Cryptic crossword #189 *Set by Trurl*



Scribble zone

Quick crossword next week

ACROSS

7/20 DOWN Outspoken copper paired with Special Operations operative for so long (3,3,4)
8 Stimulating substances halved by an ex-president (6)
9 Drugs paraphernalia (4)
10 Fuel oil unwisely imbibed by Agnes, when drunk (8)
11 Dismiss puzzle as something for browsing (7)
13 Coil broken by electrical field – a sickener (1,4)
15 Might one that's seized during action ultimately require lubricator? (5)
16 Spooner's principal directed 21 movie (4,3)
18 Sci-fi monster inside of other object (3,5)
19 International experiment (4)
21 Rowing teams said to move effortlessly (6)
22 Song written by prisoner in cooler (3,3)

DOWN

1 Cries of volunteer that may be circulated online (4)
2 15 hospital getting rid (to recycle) after processing (13)
3 Second to encourage theatre star (7)
4 Perhaps Mach Three finally reachable now spaceships transcend beginnings (5)
5 Room for all to see stirring action on railway, as you might experience on trip (13)
6 Bush's sick lion adopted by Trumpist movement (8)
12 His other map incorporates temperature data (8)
14 Solo agent getting professional killer (7)
17 Something for your eggs? Er, TMI, gross! (5)
20 See 7 Across

Our games are now playable online
newscientist.com/games

Quick quiz #355
set by Michael Dalton

1 Which glacier in Antarctica has been dubbed the "doomsday glacier"?

2 Starship is the name of a rocket built by which company?

3 Which body of water separates Russia and Alaska?

4 In which country would you find the Plain of Jars?

5 The now-extinct moa was native to which country?

6 Which company claimed last year to have resurrected the dire wolf?

7 What was the name of the telescope launched by NASA in 2009 to search for exoplanets?

8 By which name is the European Organization for Nuclear Research better known?

9 *The Embedding* is a book by which science-fiction author?

10 Astronaut Scott Kelly has an identical twin brother, who is himself a former astronaut. What is his name?

Answers to this week's puzzles on page 47

ARTSIOM PETRUSHENKA/ALAMY

Antarctic glaciers are under threat – but which one is known as the "doomsday glacier"?

It's a trap

Why do Venus flytraps and pitcher plants trap and digest insects if they are fully capable of photosynthesis? If this is an adaptation to ensure there is always food, then why don't other plants do the same?

Mike Follows
Sutton Coldfield, West Midlands, UK
Carnivorous plants like the Venus flytrap (*Dionaea muscipula*) and tropical pitcher plants still get most of their energy from photosynthesis, just like other green plants. The insects they catch are mainly a source of nutrients rather than energy.

Although photosynthesis provides energy, plants also require essential nutrients – especially nitrogen and phosphorus – to build proteins, including enzymes, genetic material such as DNA, and new cells and tissues. These plants typically grow in habitats such as bogs, swamps and acidic wetlands where the soil is extremely poor in nutrients.

Their insect-catching adaptations help compensate for this deficiency. By trapping and digesting insects, the plants obtain nitrogen and other minerals that are scarce in the soil.

"By trapping and digesting insects, carnivorous plants obtain nitrogen and other minerals that are scarce in soil"

However, producing traps, digestive enzymes and highly specialised leaves requires substantial energy and resources. In nutrient-rich environments, ordinary leaves are generally more efficient for growth and survival. As a result, carnivorous plants are mostly confined to nutrient-poor habitats, where the benefit gained from capturing prey outweighs the cost of maintaining these specialised features.

Jonathan Wallace
Newcastle upon Tyne, UK
Photosynthesis is the process by which green plants use sunlight, water and carbon dioxide from the air to make carbohydrate. This provides the energy source needed to power the plant's metabolism as well as a key building block for its tissues to grow.

However, it doesn't supply all the necessary ingredients for the plant to survive and grow – also required are phosphorus, nitrogen and potassium, as well as a host of other elements in small quantities.

In most plants, these nutrients are obtained from the soil via the roots, but Venus flytraps, pitcher plants and other carnivorous plant species tend to grow in nutrient-poor wetland habitats where they aren't present in sufficient concentration to meet the plant's needs.

To compensate, the plants have evolved ways of catching and digesting insects to provide the necessary nutrients. Presumably, for plant species that usually grow in richer soils, there is little or no advantage to be gained from supplementing their nutrient input in this way.

MARTIN PARR/MAGNUM PHOTOS

What would happen if everyone decided to give up their mobile phones?

This week's new questions

Hang up **If everyone got rid of their mobile phones, what would happen?** ***Malcolm Thorpe****, Windsor, Berkshire, UK*

Planning ahead **Are there any plants and creatures that could be taken to the moon and that would survive, reproduce and be a viable food source in, say, 25 years' time?** ***Robert Watson****, Newcastle, New South Wales, Australia*

Shed light

If the speed of light were half its actual value, would the universe have developed very differently?

Ron Dippold
San Diego, California, US
Absolutely – because the speed of light isn't just the speed of light itself, it's also the fundamental speed limit of everything else, including the forces that hold atoms together. But let's ignore atoms ripping apart for now – stiff upper lip!

Because the apparent edge of the universe we can see is limited by how fast it is expanding and the speed of light, our visible universe would be half the radius it is now, which means one-eighth the volume. The "actual" universe would be the same size, we just couldn't see the rest of it because the light hasn't reached us yet. Because the speed of light is also the speed of gravity, galaxies would form a little differently. But at this point you could squint and it wouldn't look all that different.

However, then there's Albert Einstein's famous equation, $e = mc^2$, which says that an object's energy is equal to its mass times the square of the speed of light. If c is suddenly cut in half, the amount of energy you get from converting any given mass into energy is only a quarter as much! Since stars like our sun rely on nuclear fusion to keep from collapsing under their own gravity, they would have to burn four times as much gas, making them die much faster. So the universe would be colder and darker on average.

Physical constants relating to electricity, magnetism, the force holding atoms together and many other things are defined by the speed of light. If c is halved, the fine-structure constant holding atoms together doubles, which means any atoms heavier than barium become so unstable you won't see them outside of labs. Platinum, gold, silver, iridium, plutonium, uranium, lead – all gone! We would still have iron and tin, but some elements that weren't radioactive would now be radioactive.

Finally, we'll kill off all life as we know it – if the speed of light is cut in half, the magnetic constant and

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Tom Gauld
for New Scientist

the dielectric constant get cut significantly. If electrostatic forces weaken, atoms would balloon in size and the chemical bonds holding molecules together would weaken significantly. We would dissolve.

You can try to fix this with various patches like doubling the Planck constant to compensate for the half-speed light, but this makes atoms 64 times larger than they were before and the molecular binding force is still a quarter what it was before. Again, we dissolve. If you had a sufficiently large clump of sufficiently dense matter in this new universe, there might be enough gravity to hold things together enough to start new life with some radically different biochemistry.

Paw preferences

Do left- and right-handedness (or left- and right-leggedness) exist in animals? For instance, does a dog mostly lift its right or left hind leg to urinate, depending on its leggedness? (continued)

"The scientific literature on pawedness in cats, dogs and other animals is somewhat mixed"

Nina Dougall
Malmsbury, Victoria, Australia
"Almost the last word "is the first page I turn to when *New Scientist* arrives. Not owning a dog or cat, I cannot comment, but I do know horses.

Most horses lead off on the right. Our late draught horse always led with the right hoof. When playing "stomp and splash" in the dam on a summer day, he always used the right hoof. However, when being led and stopping to play the entertaining winter game of "stomp in the puddle and fill the boss's boots with muddy water", he always used the left – the closest to the boot.

Tobias Bast
University of Nottingham, UK
Based on observations in relatively small samples of cats, some readers have suggested that cats preferentially use their left paw, whereas others suggest that cats typically have a preferred paw, but left and right "pawedness" may be similarly prevalent. Similarly, the scientific literature on pawedness in cats and other animals, including dogs, rats and mice, is somewhat mixed, with individual studies based on relatively small sample sizes reporting different findings.

However, meta-analyses pooling and analysing the findings of many studies suggest that about 80 per cent of cats and about 70 per cent of dogs have a preferred paw, but that preference for the left and right paw is about equally common.

So, although most individuals of these species prefer one of their two front paws, there is no marked preference for one paw on the population level, contrasting with the strong population-level right-handedness in humans (about 90 per cent of us preferentially use our right hand). ▮

Answers

Quick quiz #355

1 Thwaites

2 SpaceX

3 The Bering Strait

4 Laos

5 New Zealand

6 Colossal Biosciences

7 Kepler

8 CERN

9 Ian Watson

10 Mark Kelly

Cryptic crossword #189

ACROSS 7/20 DOWN See you soon, **8** Reagan, **9** Gear, **10** Gasoline, **11** Firefox, **13** E coli, **15** Power, **16** *Rain Man*, **18** The Thing, **19** Test, **21** Cruise, **22** Air con

DOWN 1 Meme, **2** Hydroelectric, **3** Surgeon, **4** Ernst, **5** Hallucinatory, **6** Magnolia, **12** Isotherm, **14** Hangman, **17** Timer

Just a hallucination

The online encyclopedias are proliferating. While Wikipedia still dominates, there are plenty of others, like the spectacularly nerdy Memory Alpha, which contains all you could ever want to know about *Star Trek*. Elon Musk has Grokipedia, a partly AI-generated site that purports to correct Wikipedia's supposed biases, and in doing so is frequently incorrect.

Into this fray enters Halupedia. It is truly unique: it is 100 per cent AI-generated and all of the entries are hallucinations. If you request an article, the site will generate it and then store it indefinitely. Nothing on Halupedia is accurate, except by accident. Hence the site has a page for "The Great Pigeon Census of 1887", apparently "an ambitious, if ultimately misguided, undertaking by the Royal Society for Avian Enumeration (RSFE) to meticulously count every gold-crested rock dove within the administrative boundaries of the United Kingdom of Great Britain and Ireland".

Feedback was honestly intrigued by "The Society for the Prevention of Unnecessary Tuesdays", which aims "to eliminate the occurrence of superfluous Tuesdays, a phenomenon believed by its members to cause significant disruption to the global temporal flow and individual productivity". We don't like Tuesdays either: they are our deadline day.

Feedback went on the site and hit the "stumble" button, which creates new pages. The site offered us the "19nd Century", described as "a unique period in human history, marked by its distinct chronological anomaly". It "began precisely on the 15th of March, 1888, following the abrupt cessation of the 18nd Century" and ended as abruptly "on the 3rd of November, 1893".

This is all great fun, but we do want to issue a word of warning. The Halupedia AI appears to have very few guardrails, so some of the entries use extremely offensive language. For context, Feedback thought most of the torrential swearing in *The Thick Of It* was pretty funny, and we think some of these entries are over the line.

Curious to find out who created the site, we did some digging and found a Reddit account called baderbc, who claims to be the author. They offer this account of the site's origins: "Long story short: Was drunk with my friend and we built halupedia. Went viral, 150k+ users in a week." That is a bad way to launch an encyclopedia, but as a way to launch a parody site, it seems as good as any.

Twisteddoodles *for New Scientist*

Got a story for Feedback?
Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

Neologism ahoy

An opportunity has presented itself to add a word to the English language, and Feedback is inclined to take it. It comes from reader Neil McKay, who reports that it derives from "a conversation I had with a group of friends four years ago" and apologises for having been "so tardy, even dilatory, in sending it to Feedback".

Neil highlights the word "onomatopoeia" and its corresponding adjective "onomatopoeic", which cover words like "boom", "quack" and "zip" that sound like the thing they describe. But, he says, there is no opposite word. What about words "that sound very unlike the thing they reference"?

One such word, flagged by Neil, is "bucolic". It means "relating to the countryside" and has overtones of beauty and peace, but the actual sequence of syllables evokes a baby vomiting up milk. Feedback also suggests "pulchritudinous", which means "beautiful", but really doesn't sound like it.

Neil and his friends eventually alighted on "nonomatopoeic" for the adjective. "I believe this neologism deserves to enter the English language, so offer it here for wider dissemination," he writes.

To verify the originality of this idea, Feedback turned to some search engines. "Nonomatopoeic" returns very few results. Someone called Matt Ballantine coined it in 2016 to refer to "words that sound like they should be onomatopoeic but aren't", such as "fungible" – which isn't quite the same thing. On another blog, a user named patrickfrommemphis used it the way we are using it here, specifically to describe the word "refulgent", which "sounds nothing like radiance".

"Nonomatopoeia" is a little more common, with references in *The Atlantic*, the *Sydney Morning Herald* and an academic article asking if experimental novels like *Ulysses* can be properly experienced as audiobooks. However, these are still isolated instances, and they don't all use the word to mean the same thing.

Feedback therefore calls upon readers to use "nonomatopoeia" in conversation and writing, to drive this neologism forward until the *Oxford English Dictionary* has no choice but to take us seriously.

Chocolate 4.0

We continue our search for the theoretical fourth form of chocolate proposed by reader Toby Pereira (2 May). Unlike milk, white and dark chocolate, which have either cocoa powder or milk or both, this would have neither.

Retired chocolate scientist Peter Archibald writes in to say that a different fourth chocolate already exists. Chocolate company Barry Callebaut "got there before you", he says. "Ruby chocolate was invented in their laboratories more than 20 years ago... They described it as the fourth type of chocolate, using acidified non-fat cocoa solids from varieties of beans (fermented or not) that deliver a pink hue rather than the dark brown colours of traditional cocoas."

So, it turns out we are searching for the fifth chocolate.

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