

New Scientist

WEEKLY 10 October 2026

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OUR GALAXY

THE EXISTENTIAL BATTLE
OVER WHAT IS TRUE
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The floodgates are open

The AI age has unleashed a torrent of text – dealing with it won't be easy

GATEKEEPING is a dirty word. For decades, the internet has steadily eroded the power of gatekeepers and democratised access to information. Attempts to resist that are seen as censorship or elitism, neither of which anyone wants to be accused of.

But our new AI era may flip the script. Social media gives anyone a voice, breaking the old model of one-to-many broadcasting from institutions, but no one is forced to listen to this cacophony. Large language models that extrude text at speed are now changing this, with institutions under a many-to-one assault by information they must attend to.

This shows up in many forms – indeed, including in literal forms, as people use AI in their bureaucratic interactions with courts, schools, local officials and more.

These systems can't deal with the volume of information and are clogging up. The implicit gatekeepers that kept such submissions under control – time, ability, access – have fallen to AI.

The same thing is happening in science. Mathematicians are calling for more

"A kind of gatekeeping is the only way institutions can survive the AI era"

mathematicians in the face of an AI onslaught (see page 20). Meanwhile, the preprint server arXiv has seen submissions double in the past two years. Although preprints aren't formally peer-reviewed, arXiv's small team ensures minimum standards, and it is overwhelmed. In

response, it recently announced it would limit submissions to two per month – still remarkably high, with few scientists producing 24 papers a year of any quality.

This kind of gatekeeping is the only way institutions can survive the AI era, unless we want to fully hand over the reins to AI and let it handle inputs as well as outputs. But there are good reasons not to. As we report on page 4, tools for verifying mathematical conclusions are at risk from attack by AI, so keeping a human in the loop remains the only way for us to have a handle on the truth. That goes even more so for areas that are harder to verify than mathematics, which is essentially everything. So let's cheer on the gatekeepers – they are going to have a lot of work to do. ■

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The battle for mathematical truth

A key step for showing that claimed solutions for mathematical problems are correct could be at risk from hacking by artificial intelligence, reports **Matthew Sparkes**

AI HAS made staggering progress in mathematics in recent months, unearthing solutions to thorny puzzles that had evaded humans for decades. Key to technology firms being able to announce these complex new findings, confident in their correctness, is a niche field called formalisation.

But recently, the developers behind formalisation tools have realised that the AI models have the potential to cheat their way to success. Now, the battle is on to tighten up the tools and prevent that from happening.

Formalising mathematical theorems essentially turns them into code that allows computers to grapple with them, methodically working through the logic and exposing any flaws. The process is so thorough that if a theorem comes through intact, it is considered to have been proved beyond all reasonable doubt.

The leading software to do this, Lean, has risen to prominence as a convenient way for tech giants to quickly and decisively prove the output of their AI models. Without it, they would only be able to claim they had found a possible solution to the puzzles and then invite human mathematicians to assess the solutions – work that might take weeks or months.

Leonardo de Moura created Lean in the 2010s while working at Microsoft Research. He says that the software was initially a niche tool used only by human mathematicians, and that there were never any attempts at trickery or manipulation.

That all changed in July, when software engineer Ramana Kumar announced he had disproved the Collatz conjecture and published a Lean formalisation to back up his claim.

De Moura was surprised by the breakthrough, but it seemed

legitimate, not least because the code had been approved by both the standard Lean kernel – the tiny bit of code at the heart of Lean that actually checks the mathematics – and a separately developed one designed for Lean, called Nanoda. Lean allows for, and actively encourages, the creation of different kernels because variety equals safety; a specific bug that makes something true look false, or vice versa, in one kernel is vanishingly unlikely to appear in another. Formalised code checked by two kernels was as water-tight as things got.

But then it turned out that Kumar's disproof wasn't what

It's hard to be sure that AI has solved a mathematical conjecture

it seemed. He had used AI to discover and exploit two separate bugs in two separate kernels within the Lean code. "[The AI] managed to do something that we thought was impossible," says de Moura. "It found different bugs and managed to craft a problem that exploited both of them. After that, we were really worried. It was clear we had to improve."

Kumar told *New Scientist* that he thought the stunt would be "useful to throw some cold water on the hype" of formalisation. He didn't respond to follow-up questions on why he didn't then disclose the bugs he had found so that they could be fixed. In any case, a fix was published an hour after the bug was officially logged.

The experience concerned de Moura, the 20 or so full-time

developers working on Lean and mathematicians. They worried that AI might perform something similar unprompted. When faced with formalising a fiendishly difficult and complex piece of mathematics, AI might find it

"The AI found different bugs and managed to craft a problem that exploited both of them"

easier to hack Lean and give the appearance of success. This "reward hacking" can occur when an AI is given vague instructions, and researchers have already seen evidence of models trying to exploit Lean bugs rather than actually doing their homework.

The first thing Lean's developers did was to formalise their own kernel, using Lean to check the code at the heart of the software and verify there were no bugs that could be exploited. They then used AI to convert that kernel into a different programming language, and verified that second one as well. A third kernel written from scratch was also verified. This gave developers a greater sense of security, but it didn't necessarily mean that Lean was infallible.

Floris van Doorn at the University of Bonn in Germany says there was a vanishingly small chance that Lean had an unusual bug that caused it to report itself as error-free even when it wasn't. If so, the boot-strapping safety measures would have been meaningless. "That is completely possible, but in practice this would be very weird," says van Doorn.

To get around this issue, the Lean developers made a lot more kernels, as diverse as possible, built on all types of software and hardware, to increasingly lower the chances of finding a bug that worked universally. These kernels



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Live**

Hear mathematicians discuss the biggest unsolved problems in mathematics on 10 October
[newscientist.com/nslmag](https://www.newscientist.com/nslmag)

are tested head to head in a battle arena website where league tables record how well they have done on known true and false proofs, and unusual problems that have been shown to trip up kernels in the past.

The researchers are now also taking steps to push these kernels into wider use. Lean, which is open source, currently ships with just one, and it is on the user to check their code with others if they want more security. But because of the complexity of AI attacks, the next version will ship with four different kernels as standard.

Defensive moves

Developers now believe Kumar's approach would no longer succeed. "We want to get much closer to this idea of being bulletproof," says de Moura. "We don't believe the existing AI will be able to break all these layers of defence."

There are still risks, however. The diversity of kernels makes the chance of a universal bug that works on them all smaller, but not zero – and future AI models may become so capable that they can continue to find convoluted exploits that somehow work across the board on all kernels.

For instance, when working with engineers from OpenAI, the Lean team found a bug in the runtime of its program – the compiled code that is actually executed by a computer, created from the source code using a tool called a compiler. Exploiting this bug, they managed to incorrectly prove a conjecture that is false. The error cropped up because the compiler wasn't perfect, not because Lean's code had an error.

The ultimate aim is to show that one particular computer setup, with hardware and software of specified standards, is formalised, verified and guaranteed error-free.

AI solves yet another problem

While mathematicians attempt to make the formalisation process of mathematics AI-proof (see main story), AI continues to make breakthroughs.

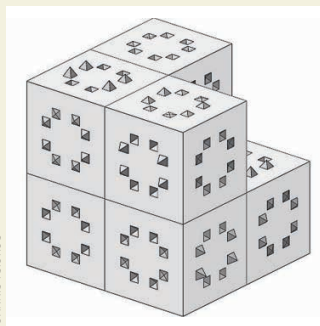
In 2023, after decades of searching, mathematicians discovered a shape called "the hat" that can tile a 2D surface without gaps and without ever creating a repeating pattern. Now, Ioannis Tsiokos, a software developer with no background in maths, has used AI to go one dimension better and discover a 3D shape that can do the same thing.

Tsiokos described the 2D problem to OpenAI's GPT-6 Astra model and asked it to find a similar result in three dimensions. He calls the 3D monotile Chair44 (arXiv, doi.org/rrqb).

"Astra found this, I didn't find the tile," says Tsiokos. "I gave Astra the theory, I gave it the laws, I gave it

the theorems, the Lean code, the papers, and I said: 'Here's the problem.' It's kind of cheeky: I've been in forums with other mathematicians, and [of] course they're all angry with me... because I don't have the background to land this result."

The Chair44 3D monotile fills all space with a never-repeating pattern



IOANNIS TSIOKOS

This would give Lean users the reassurance that it is totally trustworthy from top to bottom. "That's the dream," says de Moura.

There are other problems. Lean code is a programming language, so it can be crafted to do anything the user wants – including malicious trickery, says van Doorn. This could involve simply writing in the output file created by Lean that a theorem was correct, even if it was false, or changing the actual source code that makes up Lean itself to manipulate results, or report that every proof tried from them on was correct.

"You can redefine addition. And then you can prove Fermat's last theorem, which mentions addition, and you can say you've done it," says Kevin Buzzard at Imperial College London.

"But then when people actually look at what you've really done, you haven't done it."

These loopholes are also now being closed in Lean. Another effort involves Google DeepMind, which maintains a list of open mathematics problems that have been explicitly defined in Lean

"We don't believe the existing AI will be able to break all these layers of defence"

and then checked carefully by mathematicians. Anyone claiming to have solved one of these can take the appropriate definition off the shelf and use it in an unmodified form to test their proposed proof in Lean. Doing so would demonstrate that they

Tsiokos says he also used AI to write the paper describing the finding. But, as he suggests, not all mathematicians are impressed by the way the discovery has been disseminated.

Chaim Goodman-Strauss at the University of Arkansas says that while the result is valid, the paper does little to clarify or explain it. "Incontrovertibly, there's a very, very pretty result that emerges here," he says.

Goodman-Strauss has since published a paper clarifying Tsiokos's work.

Craig Kaplan at the University of Waterloo, Canada, was one of the researchers behind the 2D hat tile. He says the new paper has "all the usual deficiencies of AI-generated mathematics" in terms of readability and clarity, but that, despite this, the actual shape appears to be a valid solution.

aren't trying to cheat by subtly altering the definition of the problem to make it easier to solve.

When OpenAI solved the Navier-Stokes puzzle earlier this month, for example, we knew it was on stable ground because the statement provided to Lean was taken directly from the Formal Conjectures list.

But for some, none of these efforts will ever be enough. "You can find people that will never believe anything," says Buzzard. "You say 'I've checked it a million times' and they say 'well, what about gamma rays [flipping bits in memory], did you check for them?' There are some people that you can never convince." ■

For more on AI and maths, turn to page 20

Cut sugar to protect your microbiome

Antibiotics can reduce the diversity of microbes in your gut and lead to health problems, but changing what you eat can help, discovers **Chris Simms**

AVOIDING sugary foods while taking a course of antibiotics might help protect the diversity of your gut microbiome.

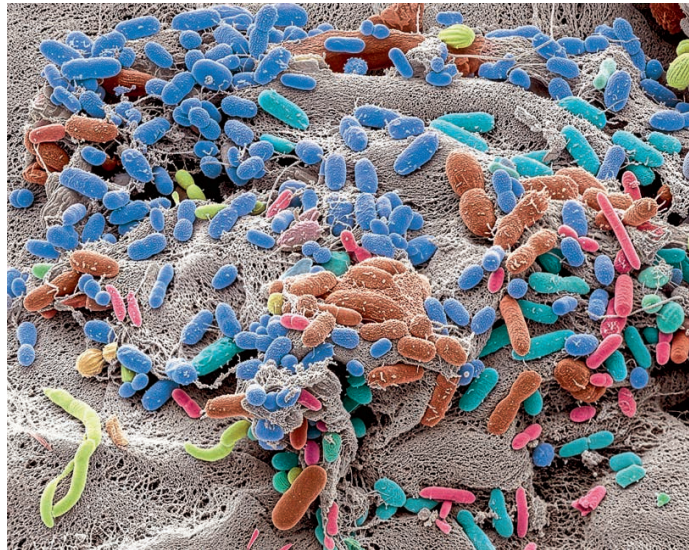
The array of bacteria in the gut plays a crucial role in supporting our digestion and our physical and mental health. But this diverse community can be disrupted by antibiotics, leading to digestive problems, fatigue and flare-ups of skin conditions. Stopping such disruption is particularly important for people with cancer, because greater gut microbiome diversity has been linked to better survival rates.

To dig into this issue, Jonathan Peled at the Memorial Sloan Kettering Cancer Center in New York and his colleagues studied 158 people with blood cancers. The participants were hospitalised for several weeks as they had chemotherapy to knock out their immune systems before an infusion of stem cells. To prevent potential infections, each person took at least one type of antibiotic.

The researchers monitored changes in the participants' gut microbiomes by analysing stool samples. Crucially, they also knew exactly what people had eaten and when they had eaten it. Each time a participant had a meal from the hospital kitchen, between 12 days before the stem-cell transplant and 49 days after, the food tray arrived with a questionnaire for recording the amount of each item they ate.

"We were able to collect these frequently and fill in the gaps," says Peled. "Suppose a patient ate half a lasagne. We know the recipe and the standard serving size and the nutritional information of each ingredient."

The researchers recorded more than 40,000 food items, creating a dataset with a level of detail that is rarely possible in nutrition



STEVE SCHMIDT/SCIENCE PHOTO LIBRARY

Our beneficial gut bacteria can be knocked out by antibiotics

research. When they scoured it for patterns, they found that people who consumed more high-sugar foods while taking antibiotics ended up with a less diverse microbiome (*Nature*, doi.org/rtrq3).

Having antibiotics in the 48 hours before the collection of a stool sample was linked to a drop in microbiome diversity. This varied from person to person,

"The remaining bacteria have survived the assault and then we are feeding them with rocket fuel"

but for every 100-gram increase in consumption of food or drink that was high in sugar during that time, the drop in total bacterial diversity was, on average, 24 per cent greater.

The combination of a sugary diet and antibiotic treatment also led to increased numbers of *Enterococcus faecium* bacteria, which can act as pathogens and cause severe

hospital-acquired infections.

The sugar in the gut exacerbates problems caused by the antibiotics, says team member Jonas Schluter at NYU Langone Health in New York. By wiping out many gut bacteria, the antibiotics disrupt the balance of the microbiome, leaving a few "last man standing" strains that aren't necessarily the most beneficial to our health. "They have survived the assault and then we are feeding them with rocket fuel."

"It makes sense that potential pathogens are boosted by sugar," says Nicola Segata at the University of Trento in Italy. This could directly favour pathogens that thrive on sugar but might not be able to break down fibre, and also boost them indirectly, because the beneficial bacteria they are competing with aren't getting the fibre they need to recover from the antibiotic assault, he says.

Experiments in mice backed up the idea that sugar was responsible for boosting potentially pathogenic bacteria. Mice given the antibiotic

biapenem while eating a high-sucrose diet had a 16.3-fold increase in the *Enterococcus* population in their guts by day three and a 33.4-fold boost by day six. Mice that ate the high-sugar diet without antibiotics kept their bacterial diversity.

Not so sweet

Peled says they saw similar effects when mice were fed on a commercial fruit smoothie, which contained high levels of the sugar fructose.

The work has implications for both inside and outside hospital. Doctors often recommend smoothies or milkshakes to people with cancer to boost nutritional intake. This recommendation might have to be re-evaluated if the individual is also taking antibiotics, says Peled.

Avoiding sugary foods while taking antibiotics could also be relevant to the wider world. "Many of us are motivated to find ways to protect the microbiome when we or our children are prescribed antibiotics. Limiting the intake of sugary foods offers a potential way to do that," says Peled. "It's very feasible, likely to be very low toxicity, very tolerable and very economical."

He points out that standard dietary recommendations involve avoiding excessive sugar intake, so it is something we should all be trying to do anyway.

A window opens for bacteria to recolonise your gut when antibiotics have disrupted the microbiome there, says Segata, who has shown that infants pick up new strains of bacteria faster after a course of antibiotics. To encourage the return of a wide array of beneficial bacteria, he recommends eating a high diversity of plant-based foods. ■

Archaeology

Anglo-Saxons held a privileged status in medieval Rome

James Woodford

A RARE collection of early-medieval coins found in Rome has provided a window into a time when English travellers and expats had special rights in the city and thrived in their own Anglo-Saxon quarter.

Historical records show that the English had their own area within the city, known as the Schola Saxonum. The newly uncovered hoard of coins, along with the remains of craft items such as leather, bone and metal, is the first material proof that the Anglo-Saxon quarter truly existed.

It also suggests that the English, unlike other foreign nationals, had the right to use their own currency in parts of Rome.

"The English quarter in Rome really was an interesting and vibrant place," says Rory Naismith at the University of Cambridge. "It might be compared with districts in modern major cities that house a specific community, like the

Chinatown areas of London, Melbourne, San Francisco and other cities."

Since 2020, researchers have been excavating the walled garden



CECILIA DE LEONE

Fused Anglo-Saxon coins found in Rome suggest English money was used as a part of local currency

of the Palazzo della Rovere near the Vatican. The site has yielded a total of 30 coins, 23 of which were minted in the 10th century, including 20 Anglo-Saxon pennies and one half-penny of the early to mid-10th century.

The team also found two Italian coins from the same era, along with six Roman or late antique bronze coins, and one unidentifiable

bronze coin that may be Roman.

Many of the coins have been fused together and are difficult to identify. Those that can still be read include specimens from several different parts of England: East Anglia, Kent, London and the West Midlands. Naismith and his colleagues have published their findings in a book, *Rome and the Others (300-1000): Foreigners in the city between conflicts and integration*.

Francesca Tinti at the University of the Basque Country, another member of the team, says the "shape, size and thickness" of the fused, unidentifiable coins are consistent with the clearly English ones. The non-English coins were found intermingled with the Anglo-Saxon currency, says Tinti.

"This seems to have been quite a busy, active area of the city, as the craft remains indicate," she says.

Naismith says it is exceptional

that most of these coins are English. Although many other English coins from the 10th century have been found in Rome, they have usually been regarded as religious donations, not as part of the regular currency of the city.

It was previously thought that the papacy banned the use of foreign currencies in Rome, but the new finds suggest that, in this part of the city, English

"The English quarter in Rome might be compared with the Chinatown areas of London and Melbourne"

coins were used as a major part of the local currency, alongside local Italian coins.

"This is highly unusual for the 10th century – the norm was to use the local coin of whatever jurisdiction you were in," says Naismith. ■

Palaeontology

Fossil mammal may have continuously replaced its teeth

A NEWLY discovered, semi-aquatic mammal had the streamlined look of a water rodent, feet like a platypus's and teeth that grew like a reptile's.

For more than a century, biology textbooks have identified that mammals replace some or all of their teeth just once during a lifetime, known as diphyodonty.

Now, a 120-million-year-old fossil unearthed in Liaoning, China, named *Dongoconodon platycauda* "challenges this long-standing view", says Shundong Bi at Yunnan University, China.

The fossil preserves evidence that incisors, canines, premolar-like teeth and molar-like teeth were replaced



DR. SHUNDONG BI ET AL. 2026

multiple times during the animal's life, known as polyphyodonty (*Nature Communications*, doi.org/rrwn).

"It is the only known mammal to exhibit polyphyodonty across all four tooth classes, a pattern previously associated with reptiles

rather than mammals," he says.

The specimen also has what Bi and his colleagues say is one of the most complete preserved middle-ear regions known from an Early Cretaceous mammal. This includes its Meckel's cartilage, a transient

Dongoconodon platycauda had an odd combination of traits

embryonic structure that temporarily connects the developing middle ear to the lower jaw in all mammals.

D. platycauda preserves an intermediate stage in which Meckel's cartilage maintained only slight contact with the jaw while remaining connected to the tiny ear bones.

"The discovery changes our picture of early mammalian evolution," says Bi.

Rather than changes to the teeth and ear bones evolving together as a tightly linked suite of characteristics, these important mammalian features evolved independently, producing diverse evolutionary experiments, he says. ■

JW

Animal behaviour

Elephants imitate each other's rumbling calls

Christa Lesté-Lasserre

ELEPHANTS appear to harmonise their vocal rumbles when they join together to form choruses, tuning their voices to sound more alike as the chorus unfolds.

The findings could offer new insights into how elephants communicate and navigate life within their complex societies, says Sara Keen at Earth Species Project, a US non-profit organisation that uses artificial intelligence

"It's like what humans do in conversation, where you start to adopt speaking patterns"

and machine learning to attempt to decode non-human animal communication.

"It's sort of like what humans do in conversation, where you almost start to adopt the speaking patterns or accents of whoever you're interacting with," says Keen.

Elephants communicate using a rich repertoire of body language, but also a wide range of sounds, including trumpet calls and throatier roars. The most common call is the rumble – so low-pitched it is often undetectable by humans – which can travel up to 10 kilometres, transmitting long-distance information.

Joyce Poole at Elephant Voices, a non-profit organisation based in Washington DC, says scientists have long been intrigued by the way elephants will rumble together in choruses. Studying those complex sounds, however, has proved difficult because it is hard to pick out any given rumbling elephant in the chorus – what researchers call "the cocktail party problem".

Poole, Keen and their colleagues turned to machine learning for help. They used a collection of 902 recordings of rumbles collected across four decades, emitted by wild female African savannah elephants from dozens of family groups in Kenya's Amboseli National Park. The calls were grouped according to six distinct social situations: staying in contact while separated; preparing to move; coordinating what to do next; comforting or reassuring calves; greeting close family members; and participating in large family reunions.

Machine analyses revealed that elephant choruses carry multiple layers of information at once, and vary in a way that suggests they encode information about what a family is doing together and what happens next, says Keen.

Tracking rumbles of individual elephants in the same chorus, the data showed

Elephants like to keep in touch with the family



ELEPHANT VOICES

that in some cases, the calls became more acoustically alike as the chorus progressed. This convergence occurred when they were staying in contact while separated, coordinating what to do next, and greeting after a separation (*Scientific Reports*, doi.org/hck8q9). This suggests that vocal convergence may play a role in helping elephant families build a plan of action, says Keen.

Combined with other communication tools, including body language, the rumbling calls seem to help facilitate complex social interactions. "They appear able to negotiate, agree and disagree – and make a plan of action," says Poole.

Because rumbles allow for long-distance communication, elephants' ability to unite through their voices is an exciting reflection of their advanced cognition and evolution in their environment, says Andrew McLean, a member of the International Union for the Conservation of Nature's Asian Elephant Specialist Group. ■

Geology

Earth's geographic poles wander more than we had thought

James Woodford

ANCIENT sea-level changes suggest that Earth's geographic poles – the points where the imaginary axis of the planet's rotation is located – may be far less immutable than previously known.

The geographic poles can move a little, through a phenomenon called true polar wander. This is driven by the way plate tectonics and mantle convection slowly redistribute mass in Earth's mantle and affect the planet's spin. When the spin is thrown out of whack, the solid outer layers of the globe begin to move in order to help Earth find a new stable spin equilibrium. This has the effect of moving the geographic poles.

Mathew Domeier at the University of Oslo in Norway and his team analysed the geological record of sea-level change, looking for distinctive signals that might be expected during a true polar-wander event.

As ocean water can more quickly adjust to the centrifugal potential changes than the rocky sea floor, these events are expected to leave a telltale pattern. Sea level will rise in one half of the northern hemisphere and fall in the other. This is reversed in the southern hemisphere: if it is the western side of the northern hemisphere that sees sea-level rise, it will be the eastern side of the southern hemisphere that does so. "This is a very strange pattern that is not caused by other Earth processes," says Domeier.

On the timescales we experience, the events would be unnoticeable. But over longer periods of geological time, a wandering pole changes the distribution of land and sea. Using this, Domeier and his colleagues found that the geographic poles moved dramatically, over periods of around 10 million years, four times in the geological past: at 20, 90, 140 and 190 million years ago (*Science*, doi.org/rrqq). ■

Most potent GLP-1 therapy yet

Combining drugs that target three different appetite-suppressing hormones had an “astonishing” effect on weight loss, finds **Carissa Wong**

THE strongest of the drugs currently approved for inducing weight loss has an even greater effect when combined with another hormone-targeting drug. The findings suggest combining the drugs could lead to more effective weight-loss therapies, an approach that could become available for wider use in the next few years.

“It’s a pretty astonishing degree of weight loss,” says David Preiss at the University of Oxford, who wasn’t involved in the latest research.

Tirzepatide, sold under the brand names Mounjaro and Zepbound, is the most potent approved weight-loss drug. Throughout the world, it is used to treat adults who have type 2 diabetes or obesity, or who are overweight and have at least one weight-related condition, such as high blood pressure. The drug is administered through weekly injections and mimics two appetite-suppressing hormones: GLP-1 and GIP.

Searching for an even stronger alternative, Dan Skovronsky at Eli Lilly in Indiana and his colleagues have now recruited 367 people from the US and Argentina who were overweight or who had obesity, all of whom had type 2 diabetes.

They randomly split the participants into groups, then gave some a high, 15-milligram dose of tirzepatide each week. Other groups received varying doses of tirzepatide in combination with eloralintide, a drug that targets a different appetite-suppressing hormone, amylin, and was delivered via a second weekly injection. The team named this duo approach EloraTZP. The remaining participants received placebo injections.



MOHAMMED ALJALAWY

New
Scientist
Live

Hear obesity expert Giles Yeo talk about whether GLP-1 drugs are the solution to obesity on 11 October
[newscientist.com/nsimag](https://www.newscientist.com/nsimag)

Eleven months later, participants receiving only the 15-milligram tirzepatide dose had lost 15.6 kilograms, or about 14.8 per cent of their body weight, on average. In contrast, those who got the highest dose of eloralintide and the 15-milligram dose of tirzepatide lost about 24.5 kg on average, equivalent to 23.3 per cent of their body weight. The placebo group lost just 3 per cent of their body weight, on average.

Regulating appetite

The findings were presented at the 62nd Annual Meeting of the European Association for the Study of Diabetes in Milan, Italy, on 30 September.

“Adding a drug acting like amylin [alongside tirzepatide] effectively brings a third appetite-regulating pathway into play, which may explain why the combination appears to deliver

substantially greater weight loss,” says Lora Heisler at the University of Aberdeen, UK, who also wasn’t involved in the work.

The tirzepatide group also experienced a 2.4 per cent reduction, on average, in their blood sugar levels. The same figure was 2.9 per cent in the high-dose EloraTZP group and 0.3 per cent among those on the placebo. “These are massive reductions [with EloraTZP],” says Preiss. “You would imagine that this [and the weight loss] would reduce the risk of cardiovascular complications, high blood pressure,” he says, although further studies exploring this are needed.

However, mild to moderate side effects, such as diarrhoea, nausea and vomiting, were more common in the EloraTZP groups than in those on tirzepatide alone or the placebo. This is probably why up to 27 per cent of those in the EloraTZP groups dropped out

GLP-1 injections mimic appetite-suppressing hormones

of the trial, whereas the dropout rate was just 3 per cent in the tirzepatide group and 17 per cent in the placebo group, says Preiss.

The increased risk of such side effects may put some people off the combined treatment approach, even if it carries the potential for greater weight loss, says Heisler. “They might find the combination more difficult to tolerate; if the patient’s already doing well on a drug like tirzepatide, then additional benefit may not outweigh the added treatment burden or side effects.”

What’s more, some people would only benefit from losing small or moderate amounts of body weight, and so EloraTZP may not be the right approach for them, says Preiss. Still, a larger trial of EloraTZP, delivered as a single weekly injection, is set to launch by the end of the year, the team wrote in a press release. If all goes smoothly, the US Food and Drug Administration could approve

23.3%
Proportion of body weight lost, on average, with the new therapy

the approach for wider use in the next few years, says Heisler.

Although the latest trial was based on people with type 2 diabetes, weight-loss drugs consistently have larger effects in people without the condition but have obesity or are overweight. It is unclear why this is the case, says Preiss, but it suggests the benefits of EloraTZP could be even greater for such people, although further trials are needed to verify this, he says. ■

First week may be key for allergy risk

The strength of immune response that newborns have could determine how their immune system develops, and the microbiome seems to play a role in this, finds **Carissa Wong**

BABIES who have a strong immune reaction in the first week of life appear to have triple the risk of developing an allergy or eczema by age 1, compared with those who don't. But the long-term impact of this early immune response, now defined for the first time, seems to be modulated by the microbiome and how babies are fed.

"If you ask 100 immunologists, they would say that immune development begins at birth and continuously develops over time, without discrete phases," says Petter Brodin at Imperial College London.

But at a talk at an immune conference in London last month, Brodin challenged this idea. He revealed that he and his colleagues have found that if a baby has a strong immune response in the first week of life, this seems to have an oversized impact on how the infant's immune system subsequently develops.

In ongoing research, Brodin and his colleagues have been studying nearly 600 babies in Sweden, collecting and analysing blood and stool samples from the infants throughout their first year. The analysis revealed that about half of them had what the researchers termed a strong "seeding" immune reaction during the first week of life, marked by high levels of inflammatory molecules such as interferon gamma, which activates immune cells. The remaining infants had lower levels of these inflammatory molecules during the first week, which the team called a weak seeding reaction.

Further analysis revealed that babies with a strong seeding reaction had substantially more *Bacteroides* bacteria in their gut than those who had a weak reaction. "A high abundance



ELISABETH SCHNEIDER CHARPENTIER/SCIENCE PHOTO LIBRARY

Immune reactions in the first week of life may have a lasting impact

of *Bacteroides* bacteria seems to drive seeding reactions to be very strong," says Brodin – although it is also possible that the variation in levels of the bacteria actually resulted from differences in the severity of the seeding reaction. Babies can pick up these bacteria via interactions with their mother and family members, he says.

The researchers think the effects of the seeding reaction last for only about a week at the beginning of life because that is when the gut is especially leaky, enabling bacteria like *Bacteroides* to enter the bloodstream and activate immune cells.

But the seeding reaction may have lasting effects: by sifting through the infants' medical records, the team found that 39 per cent of those with a strong seeding reaction developed either eczema or a food allergy by age 1. In contrast, just 12 per cent of infants with a weak seeding

reaction developed at least one of these conditions, which are caused by excessive inflammation. "What we ideally want is a weak seeding reaction," says Brodin.

Further analysis revealed that the infants with a strong reaction then followed one of three immune trajectories linked to two main factors: whether they were primarily fed breast or formula milk, and the abundance of bifidobacteria in their gut.

For instance, 50 per cent of babies who had a strong seeding reaction and were breastfed – but

"The discovery could reveal ways to develop personalised medicine for infants"

had low levels of bifidobacteria – developed eczema or food allergies. Breastfed infants who had a strong seeding reaction and had high bifidobacteria levels were less likely to develop eczema or food allergies, with 25 per cent of them doing so.

The researchers also found that 33 per cent of infants who had a

strong seeding reaction and were fed formula milk developed eczema or an allergy by age 1. In the work presented at the conference, the team didn't give details of bifidobacteria levels in the guts of these formula-fed babies.

Planting the seed

Brodin says the bifidobacteria may be important because they break down certain sugars in breast milk, known as human milk oligosaccharides (HMOs), to produce anti-inflammatory molecules called short-chain fatty acids. In turn, these can prevent the immune system from overreacting, he says.

"This is a really important piece of work. Only a few studies have looked at immune development during the first week after birth," says Lucy Crouch at the University of Birmingham in the UK. The research could reveal ways to develop personalised medicine for infants, she says.

For instance, you could imagine measuring whether a baby has a strong or weak seeding reaction, then, depending on whether they are breastfed or not and their levels of bifidobacteria, you could give them a probiotic that boosts these microbes to cut their allergy or eczema risk, she says.

But further research is needed to establish whether the seeding reaction has effects beyond the first year, says Crouch. Studies should also explore whether the links made in the study really are causal, she says.

For now, parents shouldn't alter how they feed or interact with their infants based on the results. "It is much too early to suggest that the findings should change advice to parents," says Lindsay Hall, also at the University of Birmingham. ■

Compressing bones releases molecules that ease traumatic brain injuries

Tosin Thompson

FIRMLY pressing down on shin bones for just a few minutes every day drastically improved movement and cognition in mice and pigs one week after they had a traumatic brain injury. The intervention stimulates bone cells that are sensitive to physical force, causing them to release substances that promote good brain health.

"This is big news to me, as it reveals a previously underappreciated bone-brain communication system, and could potentially lead to new therapeutic approaches in the future," says Kristian Franze at the Max Planck Center for Physics and Medicine in Germany, who wasn't involved in the work.

Traumatic brain injuries are usually caused by a forceful bump, blow or jolt to the head or body, such as during a fall. No approved drug restores lost brain function after a traumatic brain injury, and

physical rehabilitation to improve symptoms has limited benefits.

Xiaochun Bai at Southern Medical University in Guangzhou, China, and his colleagues have previously found that traumatic

"This reveals a previously underappreciated bone-brain communication system"

brain injuries can accelerate bone healing by releasing molecules that stimulate bone growth.

To see if this communication goes both ways, male mice were given moderate traumatic brain injuries while under anaesthesia.

The next day, their shins were compressed from knee to ankle using a mechanical loading device about 15 times their body weight. This was applied for 2.5 minutes per day over five days. The mice's motor and cognitive functions

were then tested one week and eight weeks after their injuries.

The team found that the treated mice descended a pole faster than untreated mice at weeks one and eight, with the former group's times being similar to those of mice without brain injuries. In a test where the mice learned to find a hidden platform in water, the treated mice crossed it nearly five times as often as the untreated mice one week after their injuries and about 1.5 times as often after eight weeks (*Nature Neuroscience*, doi.org/hckkwd).

Bone cells called osteocytes contain ion channels that open when they sense force. The team knocked out these Piezo1 channels in a different group of mice with traumatic brain injuries. Without Piezo1, bone compression had no impact on the mice's motor or memory functions.

Next, the team found serum –

the liquid portion of blood – from the treated mice had elevated levels of BDNF (which supports the survival, growth and maintenance of neurons), PF4 (which is involved in inflammation) and dopamine (involved in memory and movement). Injecting this serum into untreated mice seemed to transfer the benefits, without the need for compression.

The team repeated the experiment in male pigs, which improved cognition compared with untreated pigs. The treated pigs also had higher levels of the three molecules in their serum.

Medha Pathak at the University of California, Irvine, says the research needs to be repeated in female animals as "oestrogen regulates how bone responds to mechanical load". But if these results carry over to female animals and eventually people, the approach could be very helpful. ■

Technology

Ukraine thwarting drone attacks with razor fence

A NEW type of barrier developed in Ukraine defends against fibre-guided attack drones by literally cutting their communications.

Radio-frequency jamming stops most small drones. In response, drone designers have begun using fibre-optic cable instead of radio to communicate with the craft. The fibre-optic cable unspools as the drone flies, with 20-kilometre-range versions now common, and 50-km ones also appearing. Some 60 per cent of Russian first-person view attack drones are now fibre guided.

So far, the most reliable defence against these drones has been "passive barrier systems such as the



net tunnels installed over key roads", says Roy Gardiner, intel director at the group Defense Tech for Ukraine.

The Chaharnyk, developed by Logika Design Bureau in Kyiv, offers an alternative. An acoustic sensor detects drones and activates the

barrier: a motorised wire fence in which the wire moves like a conveyor belt with hooks to trap any cable laid over it. The hooks carry the fibre to a cutting block where it is severed.

Chaharnyk is supplied as two 50-metre sections, which can be

A motorised fence takes a drone's fibre-optic cable to a cutting point

set up in under an hour. It is battery-powered and waterproof, and can be turned on or off remotely. Barriers can be placed across known lines of approach used by drones, or as a perimeter to protect a location.

Breaking the cable generally disables a fibre drone, and the makers claim that Chaharnyk has a 95 per cent success rate in cutting the cable of drones flying over. But it only works if it detects the drone. Gardiner says the reliability of the acoustic detection system needs to be proven on the battlefield.

Logika Design Bureau didn't respond to a request for an interview. ■ David Hambling

Fieldnotes Kew Gardens, London

Urban trees can't cope with the changing climate In cities like London, trees are already struggling with hot and dry summers. **Madeleine Cuff** heads to Kew Gardens to hear about the impact



IT IS an unseasonably warm day in September, at the end of a very long, very hot summer. Kevin Martin is sitting in the passenger seat of a golf buggy, staring at a stand of withering beech trees in the middle of Kew Gardens in south-west London. Where there should be a show of dancing green leaves, there are only wisps of brown curls amid bare branches.

Martin is responsible for tending and curating the 11,000-strong tree collection at Kew. But successive heatwaves and a severe drought have been catastrophic for his wards this summer. Across Kew, branches stand bare against clear blue sky and leaves crunch under the feet of visitors, as the stressed trees shed their leaves early in an effort to survive the drought and heat.

Martin estimates that at least 400 trees, if not more, will have died this summer at Kew, equal to the record mortality seen in 2022. "It's disheartening and very distressing to see the amount of tree loss we're seeing and how the plants [and] trees are struggling," he says. "I'd be surprised if I've got any common beech left in this garden, because they are all very, very poorly. Because they can't deal with the heat."

It isn't just Kew Gardens where the trees are struggling. It is the same story across south-east England. Trees in urban

"Besides drought, city trees are affected by higher air temperatures, pollution and soil compaction"

areas are worst affected, because alongside the drought, they are battling higher air temperatures, pollution, soil compaction and other urban stressors. Mature city trees are more resilient, but younger specimens are in dire



HENRY NICHOLL/SAPPH VIA GETTY IMAGES

Trees and grass in London were affected by heat and drought this year

straits, threatening efforts to provide more shading and greenery in cities.

The charity Trees for Cities says half of the young saplings it has planted in London in the past year died over the course of this summer. Survival rates should normally hover around 80 to 90 per cent. "I've never seen anything like it," says Georgie Power from the charity. "I've walked around different sites, and you can see half the trees are dead and the other half are struggling. This summer has been very intense for the trees and very stressful for our team."

The loss of trees in parks and streets doesn't just mean a loss of beauty. London's trees help to cool the city by up to 5°C, research from environmental charity Friends of the Earth shows, and provide vital shading for humans and wildlife on hot days.

Things will only get worse for city trees as summers become hotter and drier. England's climate is shifting rapidly, and the south-east is moving from a moist, temperate climate to a semi-arid one, says Martin. Summers will become hotter, but rainfall levels will flatline. "The plants need more water to deal with the heat, but there isn't any more water coming," he says.

The root of the problem

Although temperatures will also increase in the north and west of the UK, rainfall will keep pace, maintaining the temperate conditions native trees are used to. "We have to get our mind set that, although we're a small island, we're going to have two very different ecosystems," says Martin.

Victorian city planners lined London's main roads with limes and London plane trees, while species such as oaks, birch and ornamental cherries and

magnolias adorn parks, gardens and squares across the capital. These trees simply won't be able to cope with the looming transition. Research published by Martin's team in November 2025 reports that 73 per cent of London's public trees will die or struggle to thrive under the climate conditions forecast for the city in 2090, assuming continued high greenhouse gas emissions. Just 0.38 per cent of its current trees are considered highly suitable for such a future.

Over the coming decades, growing numbers of large specimens will succumb to the heat, says Martin. "I think we will see quite a few mature trees that will have a big impact on our landscapes disappear," he says. "Trees that we're used to seeing – like your birch, your oak and your beech, they're really struggling – we will see them gone from our landscapes."

Against that backdrop, maintaining London's current

canopy cover – let alone increasing it, as Mayor Sadiq Khan is targeting – looks like a Herculean task. A massive replanting programme will be required over the coming decades, says Martin, which should be staggered to prevent the disappearance of cooling and shading canopy all at once. “I do think we are going to have to accept that some of the older trees that are really sickly, we’d be better off moving them out, removing them proactively, then planting the next generation,” he says. “We are getting to the stage where we’re going to have to start seeing proactive management of treescapes because we need to phase in these plants that are going to be more suitable.”

Growing demand

South-east England will need trees that can cope with heavy autumn and winter rainfall and cold snaps, as well as prolonged heat and drought over the summer months. The team at Kew is turning to the forests of the Eurasian steppe for answers,

This *Aesculus sylvatica* in Kew has lost its leaves much earlier than normal



MADÉLINE CLIFF

collecting seeds from the lime, hornbeam and beech growing there to assess their suitability for the future British climate.

The trees that thrive on the steppe are slow-growing and use water efficiently, says Martin. That might mean less “showy” displays of spring blossom on city streets,

“We will see quite a few mature trees that will have a big impact on our landscapes disappear”

with the focus shifting to species that conserve their energy to cope with drought stress. “Because our climate has shifted so fast and we’ve gone into this hot, dry summer with drying air, that’s why we have to look at these more boring plants that are more invested in their water safety,” he says. But these tougher varieties will still provide the shading, cooling and habitat services we demand from urban trees, he points out.

Power says Trees for Cities is changing the species mix it plants to include more drought-tolerant trees, such as ginkgo or the European nettle tree.

Finding the right trees is only part of the challenge. Ensuring that young saplings planted today survive into adulthood is becoming tougher every year. Trees for Cities is increasing its aftercare and watering regimes to help saplings through their first few summers. But local authorities need more funding and support to do the same, says Kenton Rogers at UK-based urban forestry firm Treeconomics. “There’s always capital funding, so you can buy the trees, but you can’t necessarily pay to maintain them,” he says. “Maybe we could be better at planting fewer trees, but looking after them.” ■

Neuroscience

Newly found brain cells may be key for pregnancy success

Alice Klein

A TINY region deep inside the brain is fundamental to viable pregnancies in mice. These neurons are also present in human female brains and could provide clues about unexplained recurrent miscarriages and IVF difficulties.

Nirao Shah at Stanford University, California, and his colleagues discovered the neurons while looking for gene expression changes in different parts of the female mouse brain during pregnancy. They observed a small population of neurons that completely transformed.

The levels of gene expression in these neurons changed over 30-fold when mice became pregnant for the first time, converting them to a new class of neurons that functioned in a completely different way by mid-gestation. “This cell type is exclusive to pregnancy,” the researchers write.

The previously unknown set of neurons is in an area called the preoptic hypothalamus, which is also involved in sexual and parental behaviours. The cells have receptors for pregnancy-related hormones like progesterone, which may switch the neurons on after the initial fertilisation of an egg.

Once activated, these neurons appear to coordinate the implantation of the embryo in the uterus and maintain the ongoing pregnancy. When Shah’s team created female mice without this special type of neuron, the mice were able to mate and become pregnant, but their pregnancies all ended at an early stage. This was because their embryos couldn’t implant in the lining of the uterus (bioRxiv, doi.org/rrpr).

“Certainly, the fact that when you get rid of these neurons,



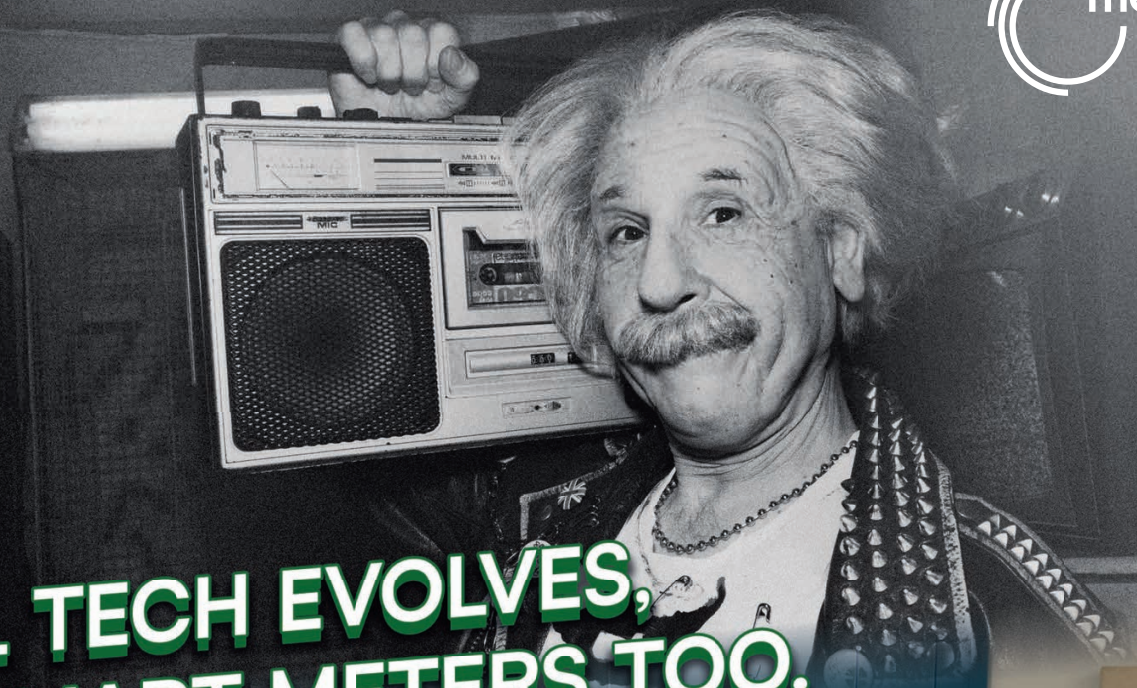
ALEXANDARNIK/GETTY IMAGES

When active, the cells may help embryos implant in the uterus

you lose these pregnancies, is really suggestive,” says Jennifer O’Chan at the Icahn School of Medicine at Mount Sinai, New York. However, further research will be required to investigate how these neurons actually do this, such as how the cells communicate with the uterus, says O’Chan.

Shah’s team also analysed an existing atlas of gene expression in the human brain and found that women have the same special set of neurons in their preoptic hypothalamus, hinting these neurons may play a similar role in human pregnancies.

Roughly half of miscarriages can’t be explained. For example, some people who conceive naturally have recurrent early pregnancy losses for no clear reason. According to Shah and his colleagues, these challenges may relate to the neurons they discovered, potentially paving the way for new treatments. “We speculate that a subset of such events reflects failure of particular neural circuits to recognize, monitor, or adapt to gestation,” they write. ■

A black and white photograph of Albert Einstein, smiling and holding a boombox. He is wearing a studded collar and a necklace. The boombox has a cassette tape inserted and a speaker visible.

ALL TECH EVOLVES, SMART METERS TOO.

Energy suppliers are switching up older smart meter hardware for new kit so you can keep getting accurate bills and access to flexible schemes and tariffs.

A woman with long blonde hair and bangs, wearing a blue denim shirt, is smiling and holding a small white smart meter component to her ear. She is in a kitchen setting. On the counter in front of her is a yellow bowl of fruit (oranges and grapes), two silver thermoses, and a green toaster. A smart meter is also visible on the counter.

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Rocket shortage is creating a crisis

SpaceX's changing priorities, the war in Ukraine and a lack of competitors has brought the future of rocket launches to a crunch point, reports **Jonathan O'Callaghan**

SATELLITE operators are facing a launch crisis as the number of available rockets diminishes, a situation that could last years and prevent new satellites reaching space.

Last year, wait times for a rocket launch were 12 months or so, says Anatolii Papulov, founder and CEO of UK space-tech firm NewOrbit, but the situation has now changed dramatically. "The lead times to launch right now are basically 30 to 36 months," he says. "This will definitely impact a lot of start-ups."

There "absolutely is a launch crisis at the moment", says Caleb Henry, a senior analyst for US company Quilty Space, which is being caused by a number of factors. The first is that Elon Musk's firm SpaceX is said to be sunsetting one of the most widely used rockets in the world, the Falcon 9. This reusable rocket, which debuted in 2010, transformed the launch industry and ushered in a new age of commercial space flight.

There were 165 Falcon 9 launches in 2025, the most of any rocket in the world and five times more than every other US rocket combined. While two-thirds of these were Starlink launches for the company's space internet constellation, the others were a mix of government and commercial projects, including ride-share missions where companies can hitch a ride to space with others at a cost as low as \$3000 per kilogram.

SpaceX, however, is reportedly no longer taking bookings on Falcon 9 beyond 2028. That is because it is transitioning to its much larger rocket, Starship, which reached orbit for the first time on 28 September. But it is unclear how available Starship will be for commercial launches, with SpaceX potentially focusing on more profitable areas like its

own Starlink constellation – which generated \$11.4 billion in revenue in 2025 – or its planned orbital AI data centre satellites.

Matt Hausman at the University of Illinois Urbana-Champaign, a former engineer at SpaceX, says the launch-capacity crunch is "a little bit of a result of SpaceX's success". The firm has lowered launch costs by 10 times or more, making it "a lot easier for smaller players to get involved in the space industry", he says. Ending Falcon 9 leaves many of those players without a route to space, says Hausman.

Starship, which NASA is hoping will return humans to the moon, may still offer ride-share missions. But the rocket is designed with flat Starlink satellites in mind,

SpaceX is reportedly retiring the world's most used rocket, the Falcon 9

deploying them through a slot in the side like a candy dispenser. This design might not support bulkier satellites from other companies, although some versions of Starship might have a more traditional satellite-deployment mechanism.

"The worst case is Starship is not available, Falcon 9 is gone and no one has an alternative route to space"

The war in Ukraine is also having an impact. Prior to Russia's 2022 invasion, about a fifth of global launch capacity, including many commercial launches, was handled by Russian rockets such as Soyuz, says Henry. Since the war began, that route to space has ended.

Another issue is the lack of commercial rivals to SpaceX. Its next-closest competitor is US company Rocket Lab, which launched 18 of its smaller

Electron rockets to orbit in 2025, but has yet to launch its new, larger Neutron rocket. Many other firms are developing new rockets, but these haven't started flying regularly. Another competitor, the New Glenn rocket from Jeff Bezos's company Blue Origin, is grounded after exploding in May. Other rockets, such as Europe's Ariane rockets, meanwhile, launch only a few times a year.

Much of global launch capacity was already taken up by another of Bezos's companies, Amazon, before SpaceX reportedly ended bookings on Falcon 9. In 2022, the firm ordered 83 launches for its own space internet constellation, Amazon Leo, of which only 14 have launched so far.

Uncertain ground

NewOrbit did manage to book a launch to space on an undisclosed rocket in 2028, but the process was "very hard", says Papulov.

China has also begun operating more commercial rockets, but US and most European satellites are barred from launching on these rockets because of US regulations. "Even if you have a satellite built in Europe, if it has a component from America, it cannot fly on a Chinese rocket," says Henry.

That leaves the global launch industry in very uncertain territory. SpaceX could still make Starship widely available and the crisis would dissipate, or other launch companies "could come in and fill the void left by Falcon 9", says Henry.

At the moment, though, we "don't know what 2029 or 2030 will look like yet", he says. "The worst-case scenario is Starship is not available, Falcon 9 is gone and no one has replaced that pathway to space. In that scenario, a lot of businesses will struggle." ■

MANUEL MAZZANTINI/PHOTO VIA GETTY IMAGES



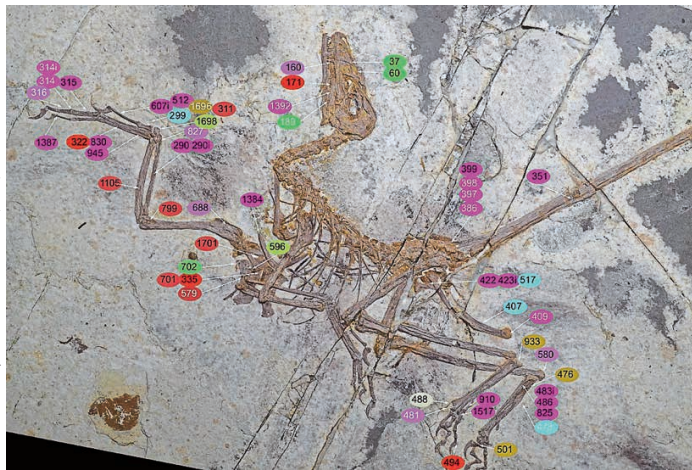
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Palaeontology

Bird-like dinosaur was unrelated to birds

James Woodford



ANDREA CAU ET AL., NATURE COMMUNICATIONS (2026)

A REMARKABLE and near-complete feathered dinosaur fossil discovered in China has many of the same adaptations for flight found in birds, but probably evolved them independently.

Ji Qiang at Hebei GEO University and his colleagues examined the 57-centimetre-long fossil, complete with plumage, teeth, wings and articulated spine. The specimen, found in Liaoning, China, is between 100 million and 145 million years old.

The researchers determined that the dinosaur was a new species, which they named *Norellraptor barsboldi*. It belongs to a group of small dinosaurs with both feathers and wings known as microraptorines.

Ji and his colleagues think the specimen was a young adult, aged at least 3 years old when it died, and that its feathers may have been associated with flight.

It also had a long tail like *Archaeopteryx*, the Jurassic dinosaur regarded as an early representative of the lineage that gave rise to birds.

While birds and microraptorines share several flight-related adaptations, such as shortened and fused wing bones, the team

The microraptorine fossil is 100 million to 145 million years old

think that these weren't inherited from a common ancestor.

Based on evolutionary relationships, the team found that around 30 per cent of anatomical changes in microraptorines also evolved in the bird lineage, but in a different order, suggesting that the two groups evolved flight separately and for different reasons (*Nature Communications*, doi.org/hckxvq).

Jacqueline Nguyen at the Australian Museum in Sydney says that while the new bird-like dinosaur shares many anatomical similarities with birds, there are also important differences. "Its forelimb growth pattern is quite different from that of living birds."

Analyses of *N. barsboldi* show that the evolutionary sequences leading to flight adaptations in living birds and in bird-like dinosaurs were quite different, says Nguyen. "This is interesting, because it shows that the evolutionary path to flight was not just a linear one, but that these evolutionary innovations appeared independently." ■

Health

Placenta hastens erection recovery after prostate surgery

Alice Klein

ERECTILE dysfunction is common after prostate cancer surgery, but wrapping thin sheets of dried placenta around exposed nerves during the procedure may allow faster recovery.

The amniotic membrane is the innermost, fetus-facing layer of the placenta, and is packed with growth factors and immune-modulating proteins that promote healing. Some companies peel the amniotic membrane off donated placentas, then dry, sterilise and package it in standard-sized sheets.

Between 2014 and 2024, Sanjay Razdan at HCA Florida Kendall Hospital used dried sheets of human amniotic membrane to wrap nerves near the prostate during 2560 radical prostatectomies, surgeries that remove the entire prostate gland to treat cancer.

He placed these thin sheets, each measuring 4 by 6 centimetres, on bundles of nerves called cavernous nerves that run along both sides of the prostate. He then wet them with saline to make them cling around the nerves.

Surgeons try to preserve the cavernous nerves when they take out the prostate because they signal for muscles in the penis to relax, so blood can rush in and produce erections. Robotic equipment is commonly used to improve precision, but "even when you do the most beautiful nerve-sparing surgery, there is usually still some damage to the nerves", says study co-author Shirin Razdan, also at HCA Florida Kendall Hospital.

This is because the nerves get stretched and heated by the surgical tools, and general inflammation tends to arise in the area. As a result, it is often

difficult to have erections after prostate removal.

But applying the amniotic membrane sheets appeared to help. In the 2560 men who received them, the average time to first erection post-surgery was seven days. By comparison, in 1495 men who didn't receive them, the average time was 14 days. These men were also operated on by Sanjay Razdan, but before 2014.

Three months after surgery, 75 per cent of the men who received the amniotic membranes were able to have erections "sufficient for penetration", compared with 60 per cent for those who didn't receive them (Research Square, doi.org/rrm3).

One risk of applying amniotic membranes to an area that has been affected by cancer is that they might spur further cancer growth, since they are rich in

7 days

The average time the wrap sped up erection recovery by

growth factors. However, the study didn't find any differences in cancer outcomes between the two groups after an average eight-year follow up.

However, the study is a retrospective review of procedures by a single surgeon, rather than a clinical trial. As such, Arthur Burnett at Johns Hopkins Medicine in Maryland says randomised clinical trials will be required to confirm that amniotic membrane nerve wraps do indeed assist erectile function. "I'm pleased to see that they're trying to think outside the box here, but nobody else is doing this routinely yet. It still needs to be further investigated." ■

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Hack your productivity

An endless stream of distractions in our busy world can make focus slip away, so **Helen Thomson** went hunting for neuroscience-backed ways to boost your productivity



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

Time of the Child by Niall Williams, a story recommended to me for its beautiful demonstration of kindness

What I'm watching

Celebrity Traitors – like the rest of the UK!

What I'm working on

The fascinating world of microchimerism and how it affects the brain

TO SAY I was busy this month would be an understatement. Two big projects, a book to write, a podcast to host, editing responsibilities, several freelance assignments and this column meant I was overworked and exhausted. With multiple deadlines converging, I needed a serious productivity boost.

Obviously, instead of getting on with the work, I started researching how to become more productive. Could I boost my attention, time my work to align with my body clock or somehow coax my brain into an ultra-productive state?

What I found was a myriad of myths, some intriguing science and some very counterintuitive results.

"We've got a productivity crisis," says Christian Poensgen, scientist-turned-entrepreneur and co-author of *Ultraproductive: The 90-minute method for more focus, better sleep and less stress*. "We treat ourselves like machines, constantly multitasking, never truly unplugging – this relentless hustle is backfiring [because] this idea of productivity, of doing more, is making us less effective and more exhausted."

Our attention at work certainly seems increasingly fragmented. In 2004, Gloria Mark at the University of California, Irvine, and her colleagues found that people spent just over 2 minutes on screen-based or paper tasks before switching to a different activity. Between 2016 and 2020, her data showed this had dropped to around 47 seconds.

WhatsApp messages and emails are my personal Achilles heel, so my first instinct was to turn off those notifications.

Post-lunch naps can boost performance for 2 hours afterwards

Interestingly, that might not necessarily increase how much work I produce.

In a 2008 experiment, Mark and her colleagues asked 48 people to do an HR email task three times, once without any interruptions and twice while interrupting them every few minutes. Participants actually

"Multitasking is a myth. You're actually just switching tasks really quickly. This makes us less productive"

finished their work faster and without any more mistakes when they were interrupted compared with when they were left alone.

However, the catch was that they experienced more stress, frustration and perceived effort. It seems we can compensate for interruptions by speeding up in the short term – but at a psychological cost.

Interruptions are one thing, but what about purposefully juggling more than one task at once? Multitasking is a skill I tend to consider useful for my productivity.

"Multitasking is a myth," Poensgen tells me. "You're actually just switching tasks really, really quickly. There's a lot of research that [shows] this makes us less productive."

When we jump from one task to another, leaving the first unfinished, part of our attention remains on it, creating what Sophie Leroy at the University of Washington Bothell calls "attention residue", which can impair performance on whatever we do next.

I've often read that it takes 23 minutes and 15 seconds to regain focus after you switch tasks – it's a stat that gets rolled out any time multitasking or distractions are mentioned on social media. Happily, the reality isn't so dire.

It comes from misinterpretations of an experiment by Mark and her colleagues, who studied 24 workers across 700 hours, noting when they chose to swap to a new activity, leaving their initial work unfinished, or were interrupted by emails, phone calls or colleagues.

It found that these workers tended to do more than two new activities after being interrupted and took, on average, 25 minutes and 26 seconds to return to their initial task (this stat was later misreported as 23 minutes, 15 seconds by Mark herself in an interview). Importantly, this was how long the distractions lasted – it wasn't measuring how long it took their brains to refocus once they returned to their task. Also, sometimes those distractions were activities directly related or helpful to the initial task.

In reality, lab studies suggest our performance recovers around 15 seconds after resuming our original task. Unsurprisingly, "nested interruptions" – where you get distracted by one task, then another – increase the time it



DAN QUET LIFE/ALAMY

takes to return to our original task.

So, notifications are off, as is trying to juggle more than one piece of work at once.

Needless to say, getting a good night's sleep is an unglamorous but effective productivity tool. A review of 61 studies found that even short-term sleep restriction impairs our attention and decreases executive function – our ability to plan, hold information in mind and resist distractions, or, in other words, many of the abilities that help make us productive.

Go with the flow

Poensgen also recommends what he calls “ultra-focus” – one 60-to-90-minute protected session of deep concentration each day, which he says can “double what you can get done every day without working a minute longer”.

He argues that if we push through the uncomfortable first few minutes, we can enter into what psychologists call a “flow state”, becoming so absorbed in a task that time and space fall away and effort seems minimal.

It can take a few minutes to enter a flow state because distractions are generally useful; they alert us to potential danger, among other things. Getting the brain to filter these out seems to involve the slow increase of chemicals such as dopamine, noradrenaline and acetylcholine, which are involved in motivation, focus and attention. After 90 minutes, you will be amazed by what you've done, says Poensgen. “Being productive doesn't feel good at the beginning, but it feels great later.”

Recent studies suggest the experience of flow may relate to activity in the locus coeruleus, an area in the brainstem that is widely connected to other brain regions and produces



KUAN CHANG CHEN/MILLENNIUM IMAGES, UK

noradrenaline, or norepinephrine, a hormone that helps us stay alert and focused.

Researchers argue that when we have just the right amount of activity in this area, our alertness and attention is raised so we can respond quickly to incoming data, but not so much so that we become overwhelmed and overstimulated. This sweet spot of focus appears to help the brain become more efficient – and help us be more productive.

How much more productive, though, is less clear. One widely quoted claim is that people become five times more productive in a flow state. It comes from research by McKinsey & Company, which asked more than 5000 executives, surveyed over roughly a decade, to estimate how productive they were during this state. Five times was a common estimate, but it wasn't an objective measure of their output.

Timing may matter too. Our alertness changes across the day

thanks to circadian rhythms, while our chronotype – whether we are a night owl or a morning lark – also affects when we tend to feel naturally most able to work.

Again, though, there are few neat rules about how to use this to improve our productivity.

A 2019 review concluded that, in general, our attention seems to be relatively poor in the morning,

“When we jump from one task to another, leaving the first unfinished, part of our attention stays on it”

improves towards midday, declines after lunch, then improves again towards late afternoon and early evening.

A 2025 review of 65 studies from 18 countries also found some evidence that people performed better on tasks when tested at a time that suited their chronotype. But the effect

Distractions might not affect your output at work, but they can make you feel stressed

was far from universal.

One daily fluctuation may be worth paying attention to, however: the post-lunch dip. Poensgen says that taking a 15-to-30-minute nap, doing a guided meditation or just resting during this time can be really effective for increasing productivity in the afternoon. Post-lunch naps have helped volleyball players improve their performance, first-year doctors reduce mistakes and working-age adults gain small improvements in cognitive performance and alertness for 2 hours afterwards.

One result I particularly like came from surgeons. In a randomised trial of 51 complex operations, surgeons who took a 5-minute break every 25 minutes were considered to be more productive than surgeons who didn't take any breaks, completing the surgery in the same amount of time with slightly better performance. Their cortisol levels were also around 22 per cent lower, suggesting they were less stressed.

So, where does that leave me and my work? Mostly with advice that is less exciting than the internet would have you believe. Sleep properly, switch tasks less. I've taken on board the regular breaks and post-lunch nap with exuberance, and am finding that protecting 90 minutes a day for getting into the flow offers real benefit.

I'm not convinced there is a one-size-fits-all solution, or that you can quantify the increase in productivity from any particular hack – neuroscience suggests our brains aren't that predictable. But something must be working, as, for once, I've finished my column with a little time to spare. ■

AI refuseniks There is no question that AI has transformed mathematics in recent months. **Jacob Aron** wonders if it will soon be impossible to reject AI and continue working in the field



Jacob Aron is a senior editor at *New Scientist*, writing about maths, physics and technology

Jacob's week

What I'm reading

Play Nice: The rise, fall, and future of Blizzard Entertainment by Jason Schreier, a history of the video game developer

What I'm watching

The new series of *Celebrity Traitors* on the BBC

What I'm working on

AI, AI, AI...

I HAVE been writing about mathematics for almost 20 years, and in that period, I don't think there has ever been a time quite like today. For most of my career, landing a big maths story – one that is both interesting and explainable to a general audience – was something that happened perhaps every few months at most. That all changed as artificial intelligence became shockingly capable at mathematics, a story we have been covering in detail for the past year or so.

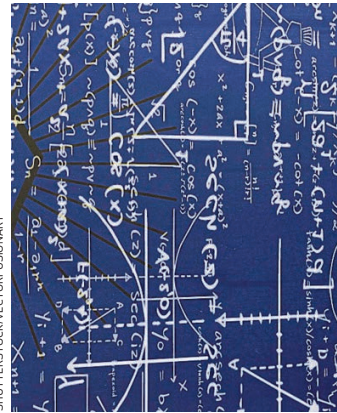
According to one analysis, 25 per cent of mathematical papers published on the arXiv preprint server in August acknowledge some use of AI, up from just 1 per cent the year before. Mathematicians are still reeling from the changes we are seeing, and it has left me – and them – wondering whether it will even be possible to do mathematics without AI in the near future.

One analogy that springs to mind is chess, for which we have had superhuman AI players for decades. People didn't stop playing chess – instead, chess AIs can inspire and train new players. Where the analogy falls down is that one game of chess doesn't build on every other game of chess that comes before it. In a way, mathematics is more like one big multiplayer

“Mathematics is like one big multiplayer puzzle, and once AI has joined the game, it is impossible to ignore”

puzzle, and once AI has joined the game, it is impossible to ignore.

Mathematical proofs are, by definition, true forever, which makes it impossible to unknow a result proven by AI. That is even the case for a proof written in such a way that humans don't understand it, because its veracity can be verified via the programming language



The number of new maths papers acknowledging some use of AI has skyrocketed this year

Lean, which breaks a proof down into elemental logical statements that can be checked by a computer.

The potential for a gap to open up between truth and understanding is concerning. Mathematician Terence Tao at the University of California, Los Angeles, argues that, while there are theoretically an infinite number of problems for mathematicians to work on, identifying problems that will lead to the discovery of new mathematical techniques is a key part of mathematical research. “The indiscriminate use of powerful solution-extraction tools can achieve the immediate short-term goal of solving problems at hand, but at the cost of sustaining the ecosystem for the next wave of progress, or in understanding the progress already obtained,” said Tao in a recent social media post.

One solution he suggests is that classes of problems should be ringfenced as deserving full analysis and understanding, not merely solving. I think this is probably impossible, as Tao essentially admits himself. It just takes one person to solve a problem using AI, and then it has been solved by AI forever.

So, could AI-free mathematicians, rather than AI-free maths problems,

work instead? “I don't think it's ideal if all mathematicians on the planet use the same technology as an inescapable interface between themselves and their discipline,” says Alessandro Della Corte at the University of Camerino, Italy. “I think it's better if a small minority, say 5 to 10 per cent, remains AI-free, while the bulk of the community engages with the tools, hopefully critically and within academia.”

Della Corte has set up an online declaration for mathematicians to sign and join him in eschewing AI in their own work, but he agrees that it won't be possible to ignore the spectre of AI completely. He says that if he encounters a result that would be useful for his work that was obtained using AI, he wouldn't pretend it doesn't exist.

Some mathematicians are more positive about the impact of AI. Daniel Litt at the University of Toronto has written that the profession is entering a new era. “I think we are at the beginning of an incredible, wonderful explosion of mathematics, and if we value human understanding, there will be more need for human mathematicians than ever before,” he writes – but what mathematicians do will have to change, with less of a focus on creating mere proofs and more on understanding and communication.

This feels like the most realistic scenario to me. I don't see how mathematicians can ignore AI-generated mathematics once it enters the literature. As Litt puts it, it is now “impossible to stop people, amateur or professional, from pushing a button to produce mathematics”. As an outside observer, it is fascinating to watch mathematicians as they try to adapt to this new reality. I'm also very glad that I don't have to be the one to develop new rules for the great mathematical puzzle, now that AI looks set to dominate the game. ■

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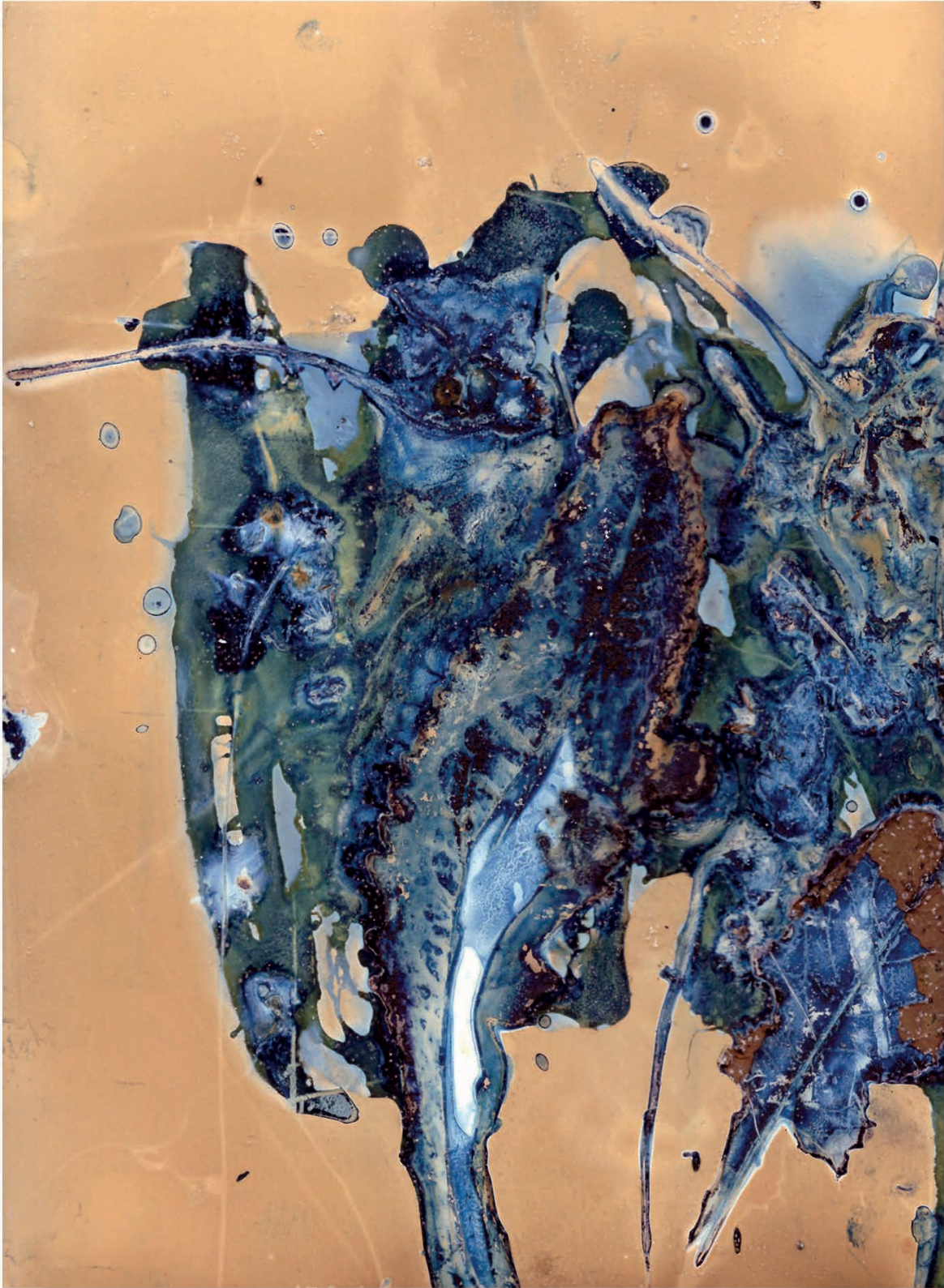
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Pond life



Andreas Scholz
Photoworks Festival

FOR Andreas Scholz, there is a contradiction at the heart of environmental photography. Photos of landscapes “can sometimes aestheticise environmental damage while remaining materially distant and separate from it”, he says, while photography itself consumes water and produces waste.

“I do not want to make work about ecological responsibility while pretending that the photographic printing process is somehow outside that problem,” says Scholz.

His latest project tackles this contradiction head on through the medium of cameraless photography. *The Most Beautiful Anthropocene #53* (left) was made while Scholz was at an artist residency in France. Using 19th-century lumen and cyanotype printing techniques, he took already-exposed photographic dark-room paper, water from a nearby pond and plants from a local flower meadow to create the piece.

“What you are looking at is the physical trace of plants and environmental conditions acting directly on a photographic material,” says Scholz.

The piece is part of an exhibition bringing together two of his bodies of work, *And So I Watch You From Afar* and *The Most Beautiful Anthropocene*, at the Brighton Museum & Art Gallery, UK, until 18 January 2027.

Part of this year’s Photoworks Festival, the installation sees Scholz explore how cameraless photography can provide a record of environmental change, from plant life to coastal edges, focusing on environments affected by humans. ■

Alison Flood

The art of eating well

A refreshingly different take on how to think about food and nutrition has some real lessons to offer, finds **Graham Lawton**



Book
Food Sense
Christopher Gardner

Allen & Unwin (UK), 15 October
Simon Element (US), 13 October

IF YOU are one of the tens of millions of people who watched the award-winning Netflix documentary series *You Are What You Eat*, you're already somewhat familiar with Christopher Gardner's work. The show followed four pairs of identical twins as they participated in an experiment – a real one, not a TV one – to test the health effects of switching from a standard US diet to a vegan one. Unsurprisingly, the twins who went vegan for eight weeks saw health improvements across the board.

So far, so vanilla. That's what nutrition scientists do – they run experiments on the health benefits (or otherwise) of diets, foods and individual nutrients. But Gardner isn't a cookie-cutter nutrition scientist. Yes, he is a distinguished researcher at Stanford University in California,

which certainly qualifies him to write a book like *Food Sense*. But he brings other things to the table, too. He started his academic life as a philosophy major, worked in restaurants for six years and is an accomplished chef. This peripatetic CV gives him a refreshingly different take on the question in the subtitle of his book: What to eat and why.

If you're expecting a prescriptive answer to that question, you won't find it here.

“Gardner found that food-adjacent issues were actually strong motivators of positive dietary change”

Gardner's stated aim is to teach us how to think about food, not tell us what to eat. That obviously includes understanding which foods and diets are healthy, but also the other factors that drive our food choices: pleasure, values and culture. The result is a holistic picture that goes above and beyond the narrow questions that dominate nutrition science.

Out of methodological necessity, scientists ask constrained questions such as “does consuming X at a dose of Y for a duration Z help this specific population to improve A or B?” X might be a nutrient such as sugar, or a specific food such as red meat.

But that isn't how humans eat in the real world. We don't just consume nutrients and specific foods in isolation; we eat meals and snacks, and choose what to eat and what not to eat for a variety of shifting reasons. We indulge sometimes, and generally find it hard to stick to diets.

In any case, people's food choices are rarely dictated by discoveries about health harms or benefits. Gardner recounts in his book how, early in his career, he took the orthodox approach to nutrition science, studying single nutrients, foodstuffs and diets and the health effects of eating them. He dutifully published his findings in journals and presented them at conferences, but the real-world impact of his discoveries was negligible. Almost nobody – not even the people involved in the study – changed their dietary



habits as a result of his work.

What was he doing wrong? In 2004, he accidentally discovered the answer. He and a colleague started teaching a class at Stanford focusing on food-adjacent issues such as the environment, animal welfare and social justice. He found these were much stronger motivators of positive dietary change than any amount of health-oriented nutritional advice.

Students who didn't care about the negative health impacts of, say, red meat, often decided to cut down on beef or give it up entirely for other reasons, such as its impact on the environment, its poor animal-welfare record or the working conditions on farms and in slaughterhouses. The fact that these values-driven changes also align with healthier choices is just a happy accident. Gardner calls this “stealth nutrition”.

That's not to say that there is no

Three more great reads on how to eat healthily



In Defense of Food:
An eater's
manifesto by
Michael Pollan

A classic from 2008 in which journalist and activist Pollan cuts through the crap of what he calls “nutritionism” to deliver a simple and oft-cited rule of thumb for a healthy diet: “Eat food. Not too much. Mostly plants.”



Fed Up: What evolution reveals about food, diet, health and eating well by Daniel Lieberman

Lieberman, an evolutionary biologist, examines popular diets and concludes that there is no such thing as a universal optimal eating pattern, apart from the four pillars of good nutrition, as Gardner writes (see main review).



The Salad Bowl
by Nicola Graimes

This is a recipe book, not a science book, but I recommend it to anyone who wants to eat more delicious, nutritious whole foods. As Gardner says in his book, salad is a meal!



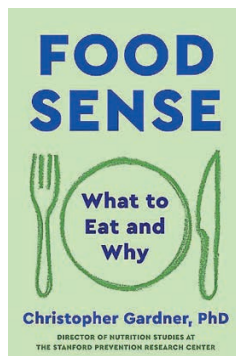
JOHNER IMAGES/LAMY

useful health advice in the book. Gardner explains that, despite the impression of endless controversies and U-turns, there is actually a high level of consensus in nutrition science about what constitutes an optimal diet. He boils this down to the “big four” and the “solid six”. The four are near-universally agreed principles for healthy eating: include vegetables and whole foods in your diet, and limit or avoid added sugars and refined grains (such as white rice and products made with white flour). The solid six are food groups that a large majority of nutrition scientists agree are key to healthy eating, though all have a handful of detractors: legumes, fruits, nuts, eggs, fish and yogurt.

In the second part of the book, Gardner sets the record straight on 11 nutrients and foods that are currently rife with confusion, hype

and mis- or disinformation. These include protein, cholesterol, seed oils, plant-based meats, sugar and ultra-processed foods. On protein, for example, he says you are almost certainly getting more than enough even if an influencer is telling you to eat more. I didn't expect to learn a lot here, but I did.

For his final act, Gardner serves up a recipe for what he calls “the



There is now a high level of consensus about what makes an optimal diet

philosopher-scientist's kitchen”. It's essentially a cookbook explaining how to apply the lessons of the preceding chapters. Everything sounds tasty, especially his guide to turning salad into a meal. Take a leafy green base and add crunchy vegetables, pulses, nuts, olives, avocado and a dressing. As he says, “unapologetically delicious, and infinitely variable”. There is also a helpful appendix explaining the various scientific methodologies employed by nutrition scientists. Mission accomplished: this is how to think about food and nutrition.

Another new big-picture take on the matter is provided by Dariush Mozaffarian, director of the Food is Medicine Institute at Tufts University in Massachusetts. In *Food Is Medicine: Healing our bodies, nourishing our minds and transforming our food system* Mozaffarian similarly argues that we have fundamentally misunderstood what healthy eating is. The food system has spent decades striving to make unhealthy processed food slightly less unhealthy, when it should, he writes, have focused on making minimally processed and nutrient-rich food the easiest, cheapest and most desirable choice. It's a somewhat predictable conclusion, but the book's strength is explaining how we painted ourselves into this corner, and how to get out of it.

Both of these books will change how you think about what you buy, cook and eat, and liberate you to enjoy a rich, healthy and delicious future. ■

Graham Lawton is a former New Scientist staff writer

New Scientist recommends

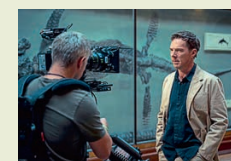


Alec Luhn
Reporter
London

How to Live on Earth, a new nature documentary hosted by Benedict Cumberbatch, starts with bizarre footage of farmers in China tickling pear trees with giant feather dusters. Because pesticides have killed off the bees, farmers must pollinate pear blossoms themselves. It shows how we are destroying the ecosystems that we depend on.

Producer Jonnie Hughes has worked on projects with David Attenborough, including *A Life on Our Planet*. While the cinematography in the new documentary is stunning, it isn't a masterpiece like that film.

But it does discuss the idea of a natural asset company, which



would allow investors to buy equity in an ecosystem. “If we start working with nature rather than against it... it's for the betterment of ourselves,” Cumberbatch told me in an interview.

So if you want to think about how we might start halting the biodiversity crisis that Attenborough helped reveal, this is a good place to begin.

On board the AI rollercoaster

Despite disagreeing over when (or if) AI will achieve human-level intelligence, **Jacob Aron** thoroughly recommends this primer to a fast-moving field



Book **The AGI Chronicles**

Kevin Roose

Simon & Schuster (UK)

Farrar, Straus and Giroux (US)

I THINK about AI almost every day. Part of this is a hazard of being a science journalist, while part is simply that I think large language models (LLMs), the technical juice behind products like ChatGPT, are fascinating in both their flaws and successes. Even if you aren't as AI-preoccupied as I am, you probably find it a tricky topic to escape, not least because we seem to get daily hysterical warnings about a coming AI apocalypse. But what is incredible is that the current AI era only really kicked off with the launch of ChatGPT in 2022.

Sure, researchers had been tinkering with LLMs long before they became products, and many other forms of AI had previously taken the world by storm, such as IBM's Watson in 2011 or DeepMind's AlphaGo in 2016. What made 2022 different is that it was the year that anyone with an internet connection could easily start talking to a computer and get something reasonably comprehensible back.

Since then, the progress of AI has felt like a rollercoaster the world can't get off. It is easy to forget how we got here after just a few years, which is why *The AGI Chronicles* by Kevin Roose is a very welcome read, documenting the past decade from the founding of OpenAI to the present day. It is a story that involves names you are probably familiar with – Sam Altman, Elon Musk and Demis

Hassabis – and many more that you aren't, but who have played an equally important role in getting to where we are today.

Roose's argument is that the race to build artificial general intelligence (AGI) is the 21st-century equivalent of the Manhattan Project to build a nuclear weapon during the second world war. One key difference between then and now is that much of the work today is being done by private companies, not government scientists, potentially making it much harder to document. Thankfully, Roose says he interviewed more than 150 insiders at OpenAI, Anthropic and Google DeepMind, and it shows – the access here is excellent.

One important thing to know is that Roose is self-declared "AGI-pilled", Silicon Valley lingo meaning he believes that AI will achieve general, human-level intelligence in the near future. This AGI-is-coming lens warps his view of recent history and aligns him with internal AI company narratives more than I would like. In fact, his epilogue reveals that he thinks AGI is essentially already

here, as long as you downgrade your expectations of what AGI means, which feels slightly pointless to me.

Despite this, *The AGI Chronicles* is an excellent historical read. It details how OpenAI was created by Altman, Musk and others out of fears that DeepMind would get to AGI first, how fallings-out led

"Roose's argument is that the race to build AGI is the 21st-century equivalent of the Manhattan Project"

to Musk leaving and, separately, how Anthropic was created as an apparently more safety-first AI company.

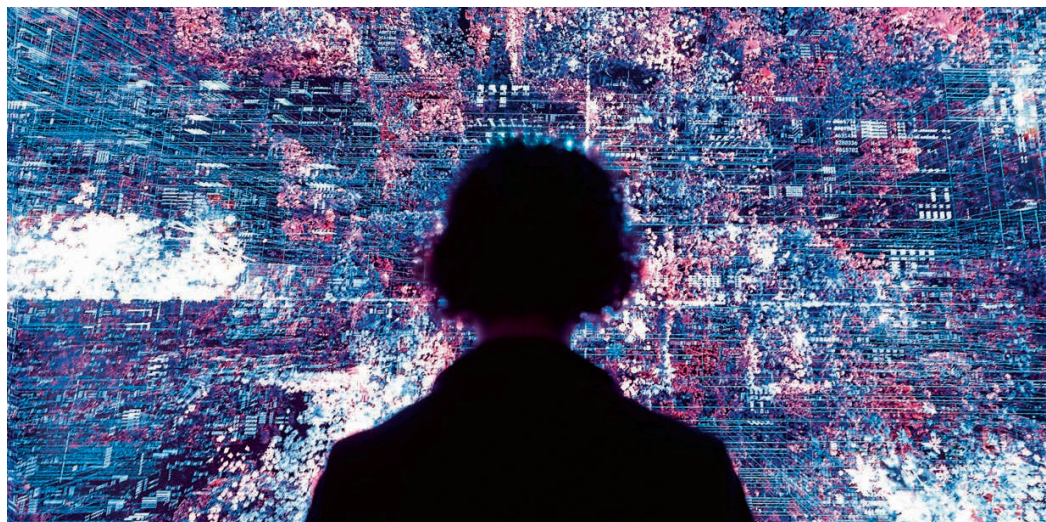
His dive into the history of the AI safety movement and its various factions also helps explain why AI executives can warn about AI destroying humanity at the same time as asking for billions of dollars to build it. There is some overlap with *Supremacy* by Parmy Olson, but her history goes deeper and her analysis is more sceptical, while Roose's access is better,

so it is worth reading both books.

Roose's book is also an excellent technical read, explaining the mechanics behind LLMs, some of the crucial discoveries of the past decade and how the companies overcame various technical hurdles along the way. These two strands, historical and technical, give you a full primer on modern AI while never falling into textbook mode.

Roose has done an impressive job of covering an incredibly fast-moving field. *Supremacy* suffered in its final section, which was essentially just a rapid summary of everything Olson could squeeze in before her press deadline, but Roose has pushed right up to the limit and covered the "agentic" developments of early 2026, when AI tools were increasingly writing computer code and becoming more powerful. The only events he misses are the emergence of AI as a maths powerhouse earlier this year, and the Hugging Face hacking incident revealed in July. Both of these will be an important part of future AI histories, but the present moves too fast for publishing house speed. ■

The current AI craze didn't really kick off until 2022



Save the cheerleader, save the world Sci-fi show *Heroes*, about ordinary people with extraordinary genes, first aired 20 years ago. Its first season is almost perfect, a combination of compelling characters, imagery and music, says **Bethan Ackerley**



Bethan Ackerley is a subeditor at *New Scientist*. She loves sci-fi, sitcoms and anything spooky. Follow her on X @inklerley



TV
Heroes
Tim Kring

Bethan also recommends...

TV
FlashForward

*This is another series in the mould of *Lost*, and it was even less successful than *Heroes*, lasting just one season. But I was fond of its premise – a mysterious event causes everyone on Earth to black out and witness their lives six months in the future, if they are alive at all.*



CINEMATICALAMY

YOU rarely appreciate the significance of a moment while you are still living through it. But that is exactly what happened to me, 20 years ago last month, when a show called *Heroes* first aired.

As you may have gathered from the title, it followed ordinary people whose genes have blessed (or cursed) them with extraordinary abilities, from time travel to telepathy. Made in the wake of the Human Genome Project, it was an elaborately plotted mystery, blending comic book aesthetics with a glancing interest in evolution. And for the past two decades, it has had the dubious honour of becoming a byword for failure: after a stellar first season, *Heroes* limped its way through three more outings of questionable quality.

The minute I saw *Heroes*, I knew I was changed. It was the first TV series to set a fire in my head, at age 10. If I wasn't watching it, I was talking about it; if I wasn't talking about it, I was thinking about it. But the extent of my obsession, combined with that drop-off in quality, has stopped me from rewatching it or its spin-off, *Heroes Reborn*, in the years since.

That changed in August with

the sad news that Hayden Panettiere, who played the show's most iconic character, Claire Bennet, had died. Since then, I have been revisiting that almost-perfect first season – and you should do the same.

Even before its narrative spiralled out of control, *Heroes* had a sprawling ensemble of leads. Claire, a 16-year-old cheerleader living in Texas, was the most consequential. Her body rapidly

“The minute I saw *Heroes*, I knew I was changed. It was the first TV series to set a fire in my head”

regenerates its cells when injured, making her practically indestructible – and attracting the attention of Sylar, a superpowered serial killer. Meanwhile, geneticist Mohinder Suresh seeks to complete his late father's work by contacting similarly gifted individuals, such as Peter Petrelli, a hospice nurse who dreams of flying, and Isaac Mendez, who can paint the future when under the influence of heroin.

Heroes, like Isaac, had a knack

Hayden Panettiere in her iconic role as a self-regenerating cheerleader

for striking images. Its first season is full of them: a cracked pair of horn-rimmed glasses; an office worker from Tokyo teleporting to Times Square in New York; a nuclear blast that Claire, somehow, can help prevent. “Save the cheerleader, save the world,” time traveller Hiro Nakamura tells Peter. This uncanny ability to distil essence and theme into potent symbols or phrases was the series' own superpower. Not to mention the music: a whirling updraft of drones and chimes, featuring ethereal vocals from L. Shankar, it became a landmark score in television history.

It's easy to dismiss *Heroes* as a *Lost*-like: it was perhaps the best in a flurry of shows trying to emulate that legendary series. But like *Lost*, *Heroes* explains a lot about what high-concept TV has become today – and has admirable qualities that its successors are thoroughly lacking.

It is a wholly original idea from creator Tim Kring, albeit one inflected with the tropes of classic comics. It is stuffed with action – certain plotlines, like psychic cop Matt Parkman's collaboration with the FBI in the hunt for Sylar, could have been a show all on their own. And it proves that a show that captures true brilliance, however infrequently, will always be worth watching.

So I implore you to watch (or rewatch) the first season of *Heroes*. You may be averse to starting a series known to nosedive, but it is worth the hurt. On rewatching as an adult, I have appreciated just how special Panettiere was as Claire. Her performance deserves to be remembered as one of the best of the 2000s. ■

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Editor's pick

Would a simulated world need such sophistication?

26 September, p 40

From Alain Williams,
Watford, Hertfordshire, UK

Astronomer Royal for Scotland Catherine Heymans has been considering the question of whether we are living in a sophisticated simulation. If that is the case, then why did the simulator make physics so complicated?

The subatomic standard model has equations that are notoriously hard to solve, for example. The more complex the rules of our universe are, the more computing power is needed to run the program. It also raises the question: what is the purpose of the simulation? "Set up a scenario and see how it evolves" seems to me to be a good guess. Wouldn't simpler rules of physics allow the same questions to be asked?

If we aren't in a simulation, then the need to be fast and efficient isn't a requirement.

There could be another way to improve lung function

12 September, p 12

From Mike Bradberry, Central Coast, New South Wales, Australia
Your article on laughter therapy and its potential benefits for people with chronic lung disease prompted me to write in. I have been playing blues harmonica for about 40 years. This difficult instrument happens to be the only one that requires the player to make notes by both breathing out and drawing in. Some of these notes need to be bent in order to produce sharps and flats, and therefore considerable effort is required.

On more than one occasion, I have been informed how much good comes from the exercises regarding improvements in lung function. So, perhaps there is more than one way to get these benefits.

Pink noise may benefit those with Alzheimer's

19 September, p 8

From Bruce Denness,
Niton, Isle of Wight, UK
Carissa Wong reports research showing that pink noise, akin to gentle radio static, helps flush waste products from the brain while we sleep. One wonders whether the subconscious link could be similar to that behind the sound of trickling water triggering the urge to urinate.

Could it be that pink noise might help clear beta-amyloid plaques and tau tangles from the brains of people with Alzheimer's, and not only when they are asleep?

For more on how the brain clears waste, see page 30

We should absorb one key lesson from *Star Trek*

12 September, p 28

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK
I was pleased to be reminded of the advent of *Star Trek*, 60 years ago. One feature of the franchise not mentioned by Bethan Ackerley, but noticed by me from the beginning, was the lack of money or any other exchangeable tokens in their future societies. The only exception (as far as I recall) were the Ferengi, who were generally portrayed as rather shifty.

As for all the rest, their infrastructures provided them with everything they needed, and often everything they desired, in return for which everyone was expected to contribute their best efforts towards common purposes. In other words: "From each according to ability, to each according to need."

Pharmacies lend wellness fads undue legitimacy

19 September, p 36

From Peter Bickerton,
King's Lynn, Norfolk, UK
In Grace Wade's fantastic interview with Xand van Tulleken, he says "vitamin supplements don't work for healthy people". I have long shared this suspicion, although fortified cereals have had notable success in reducing vitamin deficiencies, so we must assume the baseline, in the UK at least, is that people are often unhealthy.

I wonder if a similar sentiment also applies to the vast array of anti-ageing moisturisers and their innumerable counterparts that litter the shelves of pharmacies. These places, where people go to pick up medical prescriptions, can lend legitimacy to potentially harmful wellness fads, as well as homeopathic treatments not backed by science, in some cases.

Now that, in the UK, we are told that pharmacies are to become our primary healthcare option in many instances, they will take on an even greater aura of healthfulness.

Nuclear reactor needs more safety measures

12 September, p 17

From Sam Edge,
Ringwood, Hampshire, UK
It is reckless hubris to think that small modular nuclear reactors, like the one proposed in Parsons, Kansas, won't need containment beyond what is provided by burying it a mile underground, whatever improvements in safety technology are made. Every single nuclear incident and spill, including Three Mile Island, Chernobyl and Fukushima, occurred in facilities

that the owners and regulators had declared were safe.

Stuffing a reactor without traditional radiation shielding down a borehole is also arrogant. As experiments with fracking have shown, the subsurface is a deeply interconnected structure. A seismic event or technical mistake could destroy the borehole and open up fissures, allowing radioisotopes to escape.

Many perspectives on time's place in reality

19 September, p 28

From Julian Higman,
Wantage, Oxfordshire, UK
Physicists are debating whether time is two-dimensional, not one-dimensional as long assumed. But I feel time is a tool we use to understand physics, not an aspect of reality, fundamental or otherwise.

We have rulers for making sense of space, whether infinite or just a small portion, and time does the same function for motion. Both rulers and time are constructs we made up. Rulers are easy to understand because they are physical things; time is harder because the connection with physicality is less obvious.

From Sophie Gillet,
Ann Arbor, Michigan, US
I am fully in sympathy with the proposal that there are two dimensions of time. On the other hand (or possibly the same one), ancient philosophers postulated that there is ordinary day-to-day time, which we experience as continuous change, but also eternity, where everything "happens" or "is" at once.

From Mark Cargill,
Alcester, Warwickshire, UK
I was finally getting my head around the weirdness of quantum theory, when along comes Itzhak Bars and his two dimensions of time, upending our ideas about relativity and gravity. I'm getting too old for this. ■

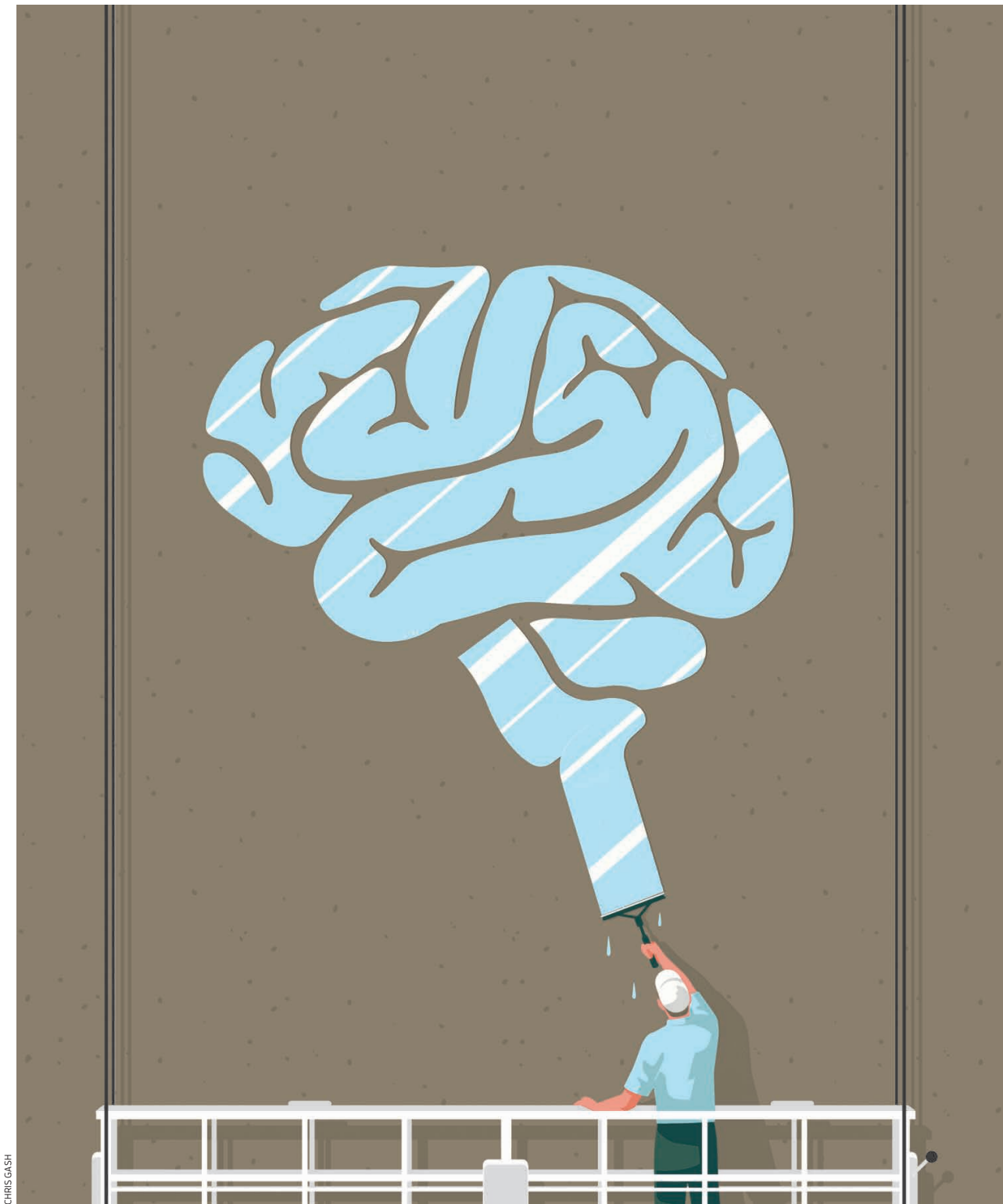


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CHRIS GASH

How to clean your brain

Boosting the brain's system for flushing out toxins could help protect your brain health – and possibly even prevent Alzheimer's, discovers **Michael Marshall**

WHEN you fall asleep, your brain doesn't just switch off. As the cognitive lights go out, housekeeping begins. Along the outer walls of blood vessels, microscopic currents flow, sweeping away waste that would otherwise cause harm.

This is the glymphatic system, a network of channels that helps the brain clear unwanted proteins and by-products of cellular metabolism. It may explain one of life's most familiar pleasures: feeling refreshed after a good night's sleep. Yet we only learned of its existence in 2012, and ever since, researchers have been scrambling to figure out exactly how it works.

Now, it seems this overlooked system may be crucial for our health – when clearance falters, it may contribute to Alzheimer's and Parkinson's disease, and possibly other hard-to-treat conditions, including migraine.

Doctors are eager to intervene, wondering whether boosting this nocturnal detox could slow or even prevent disease. "The field is filled with promise, and we're just starting to do the studies that will find out if it's going to make good on that promise," says neuroscientist Jeffrey Iliff at the University of Washington in Seattle.

Experiments range from using drugs and red-light therapy to inhaling bursts of carbon dioxide. There's also talk of improving brain clearance by changing how we exercise or breathe, or even the position in which we sleep. Meanwhile, emerging techniques hint that we might already be able to gauge

the health of our glymphatic system using a simple smartwatch.

Yet the young field has already been dogged by disputed methods, exaggerated headlines and the apparent detention of a key researcher. With so much at stake, it is vital to separate promise from hype, establishing what we can reliably measure, which interventions help clear the waste and whether doing so improves our health and prevents disease.

All our cells produce unwanted chemicals that become harmful if they build up. Luckily, we have an elaborate network of tubes called the lymphatic system that runs throughout the body, collecting fluid from cells, filtering it and sending it to the blood, with waste being expelled by the liver and kidneys.

The strange thing is that there are no lymph vessels in the brain. The implication was that the brain's waste molecules left passively, drifting through the extracellular fluid surrounding brain cells. But this never made much sense for such an energy-hungry – and therefore heavily waste-creating – organ.

A breakthrough came in 2012, when Iliff and his colleagues injected a fluorescent tracer into the brains of living mice. They targeted the subarachnoid space, a thin region between two of the membranes, or meninges, that encase the brain and spinal cord. The tracers rapidly moved from this space into the brain itself. But they didn't travel through tubes to do so. Instead, they moved along the outside of small arteries, later leaving the brain along the outer layers of small veins. The brain, it turned

out, had a waste-disposal system after all – but it was unlike anything we had seen before.

Closer inspection showed that brain cells called astrocytes, which have long, branch-like projections called endfeet, were wrapped around the blood vessels. The tracer chemicals were moving in the narrow space between the astrocyte endfeet and the outer walls of the blood vessels. Astrocytes belong to a larger group of brain cells called glial cells, inspiring the name glial lymphatic system, or glymphatic system for short.

Three years later, two groups discovered lymph vessels hidden in the meninges. Another part of the puzzle fell into place: the glymphatic system moves waste out of brain tissue, while the newly discovered lymph vessels take it away from there.

Mapping the glymphatic system was only the start, though: researchers also wanted to know what governs its flow. One vital clue came from the activity that occupies a third of our lives.

In 2013, Maiken Nedergaard at the University of Rochester in New York state and her team, which included Iliff, injected a green tracer into the cerebrospinal fluid of sleeping mice and watched it stream around the brain. After the mice were gently woken, this flow fell by about 95 per cent. The researchers also showed that beta-amyloid, a key waste product associated with Alzheimer's disease, was cleared roughly twice as fast when the mice were asleep.

Brain pump

Then last year, Natalie Hauglund, a sleep scientist now at the University of Oxford, and her colleagues helped identify a control mechanism. Studying mice, they showed that concentrations of the neurotransmitter noradrenaline rose and fell about every 50 seconds during non-REM sleep. This caused arteries in the brain to alternately swell and constrict, gently pumping the fluid along the outside.

That mechanism could be key to why glymphatic function declines with age. "As you get older, your arteries become stiffer," says Roslyn Bill at Aston University in Birmingham, UK. "So, I think that whole mechanism probably breaks down."

Crucially, Geir Ringstad and Per Kristian Eide at the University of Oslo in Norway showed that the glymphatic system also operates similarly in the human brain and that just ➤

one night without sleep is enough to reduce the removal of a tracer from people's brains.

This was one of the first hints that the glymphatic system can go wrong overnight, but what happens when the brain's housekeeping falters over months or years?

The strongest links between a faulty glymphatic system and disease concern Alzheimer's. In people with this form of dementia, beta-amyloid accumulates into distinctive plaques, while abnormal tangles of another protein called tau form inside brain cells.

In 2016, researchers including Nedergaard found there was reduced glymphatic transport in mouse models of Alzheimer's even before amyloid plaques formed. The implication was that impaired glymphatic clearance might allow beta-amyloid to accumulate in the brain, contributing to disease. Since then, evidence has grown that the glymphatic system transports these proteins in people too – this January, Iliff and his colleagues reported that it helps clear beta-amyloid and tau from the brains of people without dementia.

It isn't just Alzheimer's that's in the crosshairs, though. A study last year found reduced glymphatic clearance in the brains of people with early psychosis compared with controls. Other researchers have found links between poor glymphatic functioning and Parkinson's, migraine, major depressive

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disorder and post-stroke cognitive impairment. Together, these two studies offer some of the most tantalising signs that we may be able to boost clearance in people – although whether doing so protects their brain health is still unknown.

Of course, a note of caution is needed. These links don't necessarily mean it is the glymphatic dysfunction that's causing these conditions, says Iliff. For one thing, the conditions themselves could disrupt glymphatic clearance.

There's also another possible problem. Many human studies assess glymphatic function using a form of MRI called DTI-ALPS, which tracks the movement of water in the brain, and whose ability to capture glymphatic activity is disputed. In February, Ringstad, Eide and their colleagues compared it with their tracer methods – and found little correlation.

"You have a big part of the field running away with a technique that is invalid," says Iliff.

No method is perfect, certainly. Even the tracer techniques don't directly measure the clearance of actual waste chemicals. That said, connections between glymphatic problems and certain conditions seem likely to hold. "There are several diseases where it's very likely that the glymphatic system could be an important factor," says Hauglund. "What characterises a lot of these is that they're very slowly progressing, and that there's probably a lot happening in the brain before we really see an effect of it."

In theory, then, we may be able to intervene to ensure people's glymphatic systems work better to prevent such conditions. While there's

Exercise may help the glymphatic system remove waste from the brain

currently no approved treatment that does so, several interventions are being explored.

One uses near-infrared light, which is invisible to the naked eye but can penetrate flesh and bone, reaching deep into the brain, where it alters cellular functions and affects pathways involved in inflammation and vascular function. A 2022 review described evidence from animal experiments that transcranial near-infrared light could help treat neurodegenerative conditions, possibly by changing the shape of blood vessels and astrocytes to improve glymphatic flow. However, "we do not yet know that near-infrared light directly increases glymphatic flow in humans", says Bill.

There are hints it might. In one study, 57 people who had been diagnosed with or showed symptoms of dementia wore a near-infrared light helmet for 6 minutes twice daily for eight weeks and showed small cognitive improvements. One participant saw an 80 per cent improvement in their ability to draw a clock, for example, while others showed better learning and memory. Results varied considerably, though, leaving uncertainty about how well the treatment works.

Another pilot study tested a headset developed by Canadian company Vielight, which delivers near-infrared light to the brain through the skull and nose. After 12 weeks of regular use, the five participants showed



LAMBERT AND YOUNG/GETTY IMAGES

improvements in cognitive tests, while caregivers reported better sleep and less anxiety. But with no placebo group and a larger trial suspended because of recruitment difficulties, the evidence is still too thin to justify buying your own red-light therapy device for home use.

Boosting waste loss

Another approach uses focused ultrasound with microbubbles. Researchers inject tiny bubbles into a vein, where they travel to the brain. Focused ultrasound waves are aimed at the head, which causes the microbubbles to vibrate, jostling blood vessels, changing the flow of glymphatic fluids around them. In mice, this can accelerate the removal of beta-amyloid from the brain.

Meanwhile, Sephira Ryman at the University of New Mexico in Albuquerque has been experimenting with a different way to get brain vessels pumping – carbon dioxide. If people alternate between inhaling high doses of CO₂ for about 30 seconds and breathing normal air, it seems to improve the clearance of harmful proteins from the brain. The extra CO₂ causes blood vessels in the brain to widen, while switching back to regular air allows them to narrow, thus generating the pumping motion needed for glymphatic function – echoing what happens during sleep.

This isn't safe to try at home: inhaling CO₂ is extremely dangerous. However, when carried

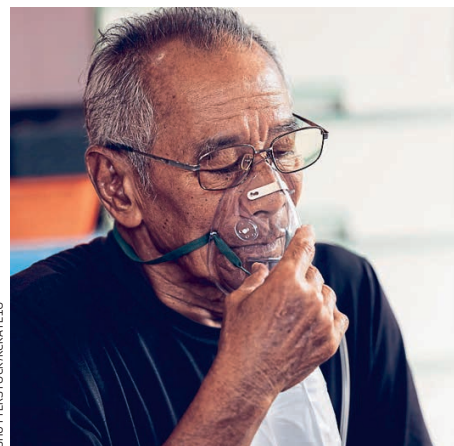
out under the watchful eye of Ryman and her colleagues, this simple technique can help remove alpha-synuclein, a protein that seems to contribute to Parkinson's. At a conference in July, Ryman reported similar findings for beta-amyloid. Together, they offer some of the most tantalising signs that we may be able to boost clearance in people – although whether doing so protects their brain health is still unknown.

Ultimately, Bill would like to develop “a statin for the brain”: a medication that would enhance the blood vessel-driven pumping in older people. “You could take a pill before you went to bed and open up your sluice gates, and the fluid would flow away,” she says.

A study published in March, which Illiff worked on, hints at this possibility. Older adults without any brain-related conditions received the drugs midodrine and dexmedetomidine, which increase the pulsing of blood vessels in the brain. During a single sleep, clearance of tau and beta-amyloid increased by about 10 per cent – although the findings await peer review.

Elsewhere, enthusiasm for brain clearance may have outpaced the evidence. When it comes to removing waste, the glymphatic system isn't the only game in town, and work relating to a second, better-known drainage system has recently come under some heat.

Some waste can reach the cerebrospinal fluid that bathes cavities deep in the brain and the meninges that surround it. From there, it can flow out into lymph vessels in the head and neck. Clinicians in China have seized on



SHUTTERSTOCK/KCKATEIG

In clinical trials, breathing in small amounts of carbon dioxide is linked with increased glymphatic flow

this mechanism, developing a surgical procedure called deep cervical lymphovenous anastomosis to connect lymph nodes in the neck to nearby veins, encouraging faster drainage. They claim this has significantly improved symptoms in people with Alzheimer's. However, some researchers have highlighted the limited evidence, small sample sizes and a lack of randomised controlled trials – and have flagged concerns over performing expensive, experimental surgery on vulnerable people. “When I first heard of this treatment, I was shocked,” Steven Proulx at the University of Bern in Switzerland told *New Scientist* in July. “There is basically no evidence supporting this.”

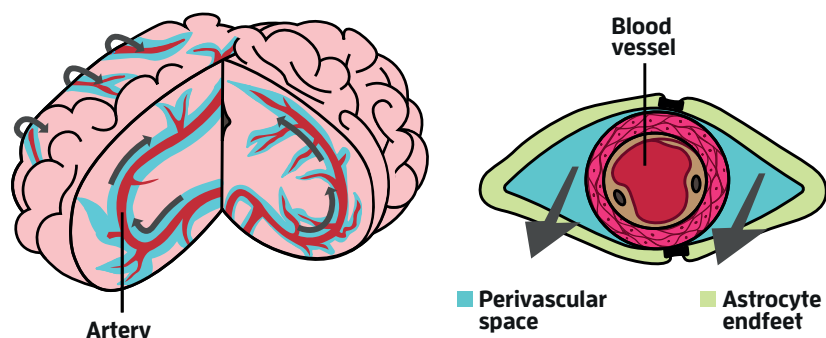
Chinese authorities have now banned the operation outside clinical trials and appear to have detained its inventor, microsurgeon Qingping Xie, although no criminal charges have been announced.

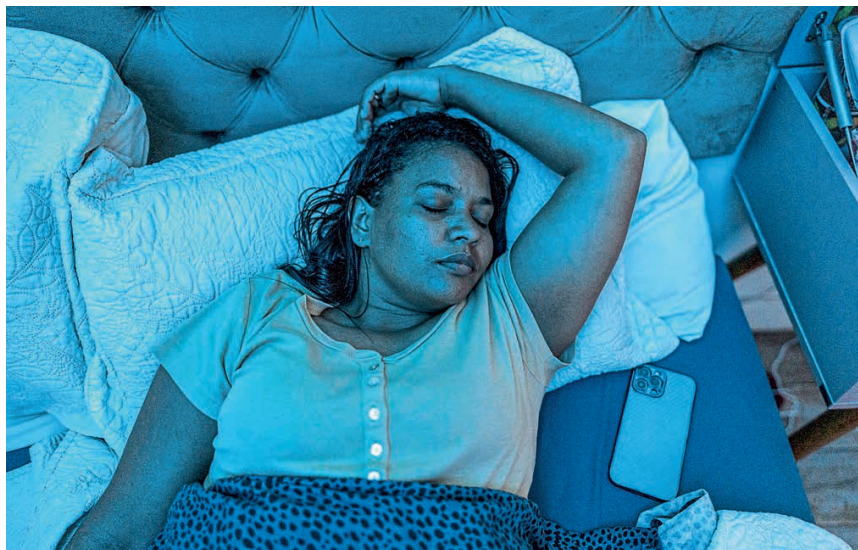
Even setting aside this specific controversy, treating neurodegenerative conditions by boosting brain clearance is problematic, says Hauglund. All such conditions are poorly understood, she says, and now we are trying to treat them by intervening in a system that we also don't understand very well.

Naturally, that uncertainty hasn't stopped social media filling with claims about ways to detox your brain, from yogic breathing to ➤

The brain's waste-clearance system

The glymphatic system comprises a network of channels running through the brain. They are formed by astrocyte endfeet (green) wrapping around blood vessels (red), and fluid flows through them (blue) to remove waste. The speed of flow changes as astrocytes dilate and constrict, and is also affected by lifestyle factors and various health conditions.





A good night's sleep is key to helping the glymphatic system do its job

sleeping positions. But beneath the hype is a reasonable question – is there anything we can do ourselves to help flush out the waste?

When it comes to home-based remedies, most research has focused on exercise, known to have extraordinary benefits for brain health. “Exercise has profound effects on the brain through cardiovascular fitness, cerebral blood flow, metabolism, inflammation, insulin sensitivity and neuronal plasticity,” says Bill. Glymphatic transport may be another part of that picture.

A 2025 study of 37 adults found that 12 weeks of increasingly challenging cycling appeared to boost glymphatic flow and was related to changes in immune- and inflammation-related protein biomarkers. The findings suggest that improved glymphatic flow may be a potential mechanism underlying the protective effects of exercise on brain health, but more evidence is needed to prove it actually boosts waste removal or protects cognition.

Other suggestions of how to “detox your brain” circulating on social media have less support. Claims that changing the position you sleep in, for instance, originate from a 2015 study, which showed that rodents that slept on their right-hand side had more efficient glymphatic flow and increased clearance of beta-amyloid than rodents that slept on their back or front. Tantalising indeed, but unfortunately, no follow-up trials have been carried out in humans.

Likewise, there are claims that yogic breathing – which involves intentional, controlled and sometimes modified breathing techniques such as holding one nostril – can help brain clearance. While small studies suggest that this boosts the

movement of cerebrospinal fluid around the brain, potentially helping with nocturnal housekeeping, there’s no evidence of it affecting the glymphatic system or waste removal just yet.

The one thing we should probably all focus on is getting a good night’s sleep. Here the evidence is clearer: deep sleep is associated with more efficient glymphatic clearance in animals, while evidence shows that people with sleep disorders tend to have impaired glymphatic function. Together, it gives another reason to try to improve your sleep habits, even if we can’t prescribe a precise sleep routine that optimises brain clearance.

One of the major hurdles of all of this is that it is really hard to measure glymphatic flow in humans. Current methods are slow, invasive

and expensive. Iliff wants tools that are non-invasive and easily used in clinics, “whether that’s a better MRI sequence, whether that’s [multiple] biomarkers, whether that’s the output of a wearable device”.

He works with a company called Applied Cognition, which has developed a wearable device that applies a gentle alternating electrical current to the brain and measures how well it passes through different regions. This seems to capture increases and decreases in glymphatic flow, which change how readily electricity can pass through. “That looks very promising,” he says. The device is still awaiting approval by the US Food and Drug Administration.

Another simpler, albeit indirect, measure of glymphatic efficiency could come from something you might already own – a smartwatch. A study published in August, which Nedergaard worked on, found that tiny fluctuations in heart rate vary in line with the noradrenaline oscillations driving glymphatic pumping. This suggests that heart rate variability – a metric recorded by most smartwatches – might offer a window into the brain’s waste clearance, potentially allowing people to monitor it at home and see whether changes in their habits make a difference. Bill agrees that this makes physiological sense, but she wants to see it tested directly.

Ultimately, better measurements in humans would allow researchers to establish which interventions boost clearance, before tackling the bigger question of whether that improves cognition and prevents disease.

It perhaps isn’t yet the revolution many hoped for. However, with so many interventions being trialled, hope is still high that some will prove successful. “It’s something that a lot of people are working on,” says Hauglund.

“Glymphatic function has entered the therapeutic era,” says Iliff. “The gates are open for evaluating therapeutics and evaluating interventions that modulate glymphatic function in people.” The challenge now is to figure out which ones make a meaningful difference. ■

“YOU COULD TAKE
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Michael Marshall is a science writer focused on life sciences, health and the environment

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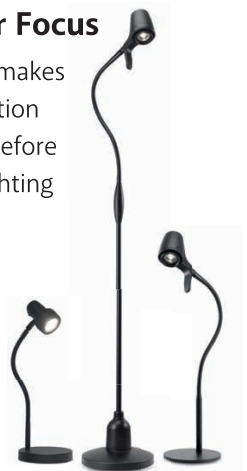
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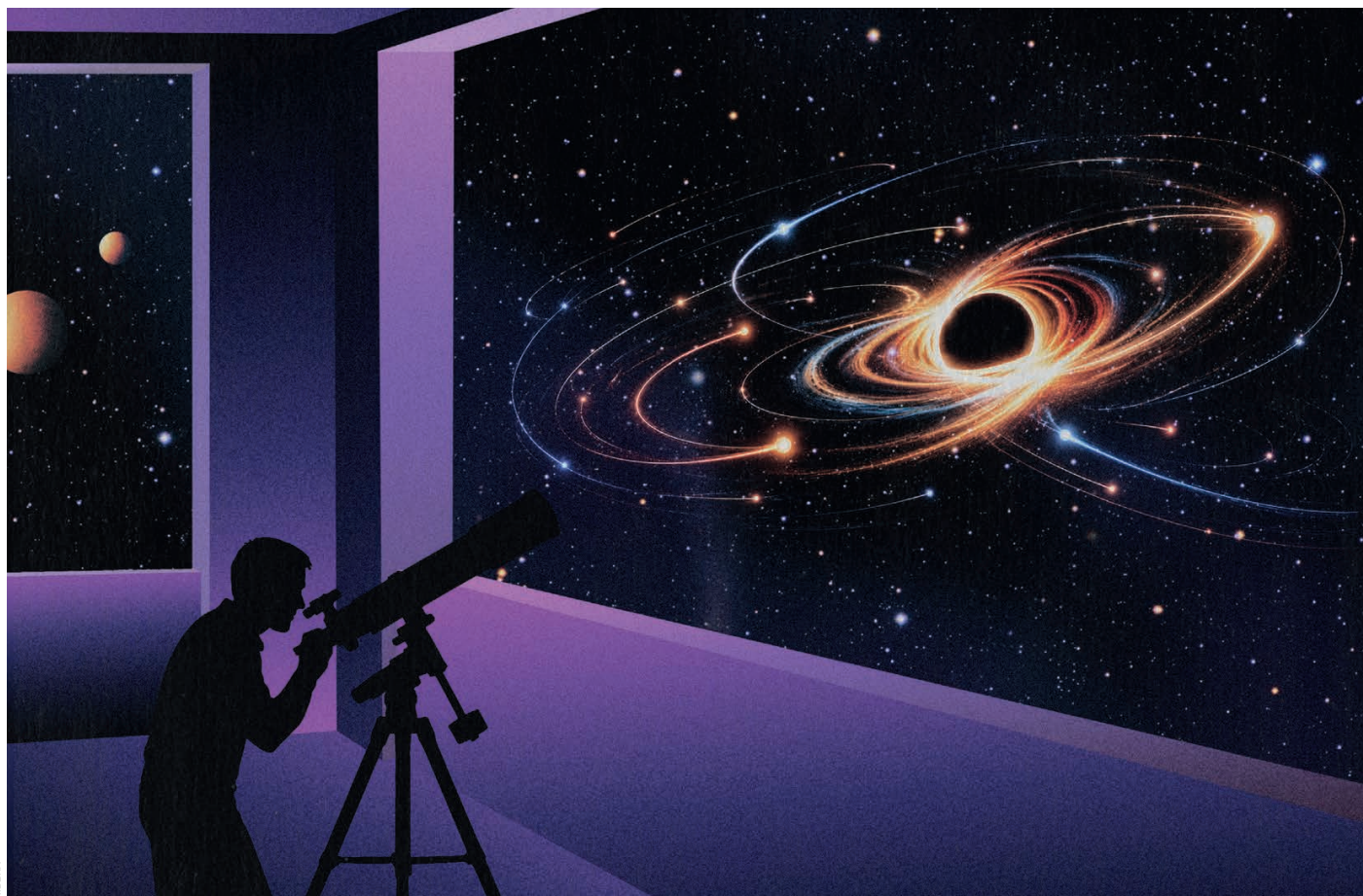
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Written in the stars

A swarm of stars that hurtles around the supermassive black hole at the centre of the Milky Way could be the key to understanding our galaxy, finds **Leah Crane**



NIBERA

THE star that astronomers call S301 isn't your average ball of fiery plasma. For one thing, this newfound star is travelling at more than 8 per cent of the speed of light. Blink, and you'll miss it. But there is an even more striking thing about it: the simple fact that it shouldn't exist.

S301 isn't an isolated oddity, either; it is the fastest-known member of a superhighway of stars frenetically circling the black hole at the centre of our galaxy. The extreme gravity in this region explains why the stars are zooming around so rapidly and why their very existence is unlikely. Black holes usually rip apart the clouds of gas and dust from which stars form.

But the fact that these stars do exist – and that we can now observe them – is extremely handy. The centre of our Milky Way galaxy is so bright and so crowded that, for decades, we could barely discern anything about what was going on there. Today, thanks to S301 and its ilk, that is changing fast. "It's such a beautiful astronomical system," says astronomer Stefan Gillessen at the Max Planck Institute for Extraterrestrial Physics in Germany. "It's a present that's in front of our door, and we just have to keep watching it, and we will learn so much."

There is plenty to learn. The stars could reveal hidden properties of the black hole at the centre of our galaxy, expose what lurks around it and even test gravity in one of the universe's most extreme places.

Earth is positioned in one of the Milky Way's spiral arms, some 26,500 light years from the middle of the galaxy. From where we are in the sleepy galactic suburbs, trying to look into the galactic centre is like squinting into the beam of a searchlight. The region is so crowded, and thus shines so brightly, that for most of astronomy's history, there was little hope of picking out individual objects. "This region is a complete mess... it's the waste bin of the

universe," says Albert Zijlstra, an astrophysicist at the University of Manchester in the UK. "Pretty much anything that is interesting is dumped in this region of space because of the black hole's gravity – everything falls in there – so it's very chaotic and hard to understand."

That isn't the only problem. Earth's atmosphere blurs our view, making tiny objects especially difficult to resolve. And the whole region is also shrouded in huge clouds of dust and gas. The central black hole, called Sagittarius A*, wasn't discovered until 1974, just a few decades after astronomers concluded that its neighbourhood was, in fact, the centre of the Milky Way.

Seeing stars

Only recently have astronomers been able to see through this mess well enough to pick out individual stars. "Think about a little glow worm next to the headlight of a car – if you don't have very, very good eyesight, you might miss the glow worm," says Gillessen. "What you need is the resolving power of a very big machine." In other words, a very big telescope.

There is just one snag: we don't have it, at least not yet. A conventional telescope would need a mirror that is some 30 to 40 metres across to pick out these ultra-close stars, and while several such observatories are being built, astronomers aren't keen to wait around. "We are very impatient people,"

says Gillessen. Instead, they have found clever workarounds to get a look at the stars near the galactic centre.

The first breakthrough was adaptive optics. Instead of relying on a rigid mirror, the technique uses one that can subtly change shape hundreds or thousands of times a second. Those tiny adjustments cancel out the blurring caused by Earth's turbulent atmosphere, dramatically sharpening the view.

In the late 1990s, two groups – one led by Reinhard Genzel at the Max Planck Institute for Extraterrestrial Physics, the other led by Andrea Ghez at the University of California, Los Angeles – used adaptive optics to pick out the very first stars spotted near the galactic centre. These stars were moving at around 2000 kilometres per second and passing within a light month of Sagittarius A*. "It seemed like magic, the resolution they were getting," says Zijlstra of those early observations.

Then, in 2002, Genzel's team found a star that would dominate the field for years, called SO-2. At its closest point to Sagittarius A*, it comes within just 17 light hours and reaches around 7650 km/s, almost 3 per cent the speed of light. By tracking its orbit, Genzel and Ghez could begin to weigh whatever sat at the centre of the galaxy. It had to be enormously massive and extraordinarily compact – compelling evidence that Sagittarius A* was, in fact, a black hole.

The next leap came in 2018, when SO-2 made another close pass. This time, the researchers used interferometry, a technique that combines light gathered by many telescopes to create the effect of one, much larger observatory. That let them track the star's orbit with unprecedented precision and pin down the mass of Sagittarius A*. The work earned Genzel and Ghez a Nobel prize in 2020. But that was just the beginning.

The stars orbiting our galaxy's behemoth ➤

“The centre of the galaxy just keeps getting interesting”

black hole are puzzling in their own right. As astronomers have watched the galactic centre more closely, they have found stars that fall into three distinct groups. There are the S stars, which come perilously close to the black hole; the clockwise-disc stars, which follow more orderly orbits further out; and the off-disc stars, whose paths are more chaotic and sometimes appear to run in the opposite direction to the others.

The S stars pose a particular puzzle, part of which has to do with how surprisingly young they are. These stars can't have begun their lives where they are now because there wouldn't have been enough gas and dust from which they could have formed. But, equally, they come from a family of stars that lives for only about 50 million years, far too little time to have migrated gradually and peacefully into the galactic centre. "Their lifetime is shorter than the time between when the dinosaurs went extinct and now; these stars are young," says Gillessen. So how did they get there?

One leading hypothesis is that they started out as binary systems – two stars orbiting one another – in more distant orbits. Then, if they drifted a little too close, Sagittarius A* could have torn the pairs apart, flinging one star out of the galaxy at extreme speeds as a hypervelocity star, while the S star got dragged into its perilously tight orbit. This would have sped up the process, allowing plenty of time for the S stars to get where they are now.

Orbits in disarray

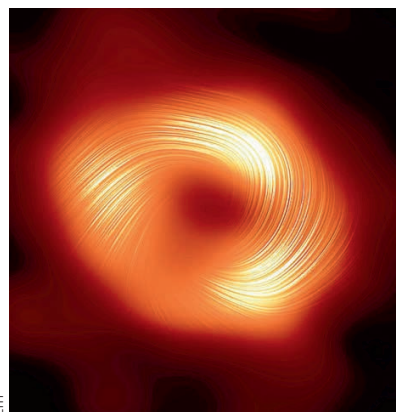
But that leaves another puzzle. The S stars have highly elliptical orbits, swooping close to Sagittarius A* and then flying much further away. This leaves a striking shortage of stars in close, circular orbits – the so-called zone of avoidance. Indeed, that is part of a bigger mystery: how did three distinct groups of stars come to coexist in such different orbits so close to Sagittarius A*? Explanations have been proposed for each population of stars, but until recently, none of them has been able to account for all three at once.

Xiaochen Zheng, a researcher at the Beijing Planetarium in China, and her colleagues have proposed a bold solution. Perhaps there is another massive object lurking nearby – a smaller black hole, hundreds to a thousand times the mass of the sun, or a dense cluster of stars – orbiting close to Sagittarius A*.

This mysterious object could have thrown stars that were born from the same disc of

“There’s an imprint of the laws of gravity on these stars’ orbits that you can start to measure”

Below: This image of Sagittarius A* was captured by the Event Horizon Telescope in 2022
Bottom: Adaptive optics mirrors give us a sharper view of the cosmos



EHT

debris into their current orbits, and may even explain the zone of avoidance. "This is the first unified model that attempts to concurrently explain all three populations rather than treating each in isolation," says Zheng.

It remains unproven, but the team already has sight of an object that could have done the deed, a cluster of stars called IRS-13E that may have a black hole of the right mass at its centre. Like so many of the ideas about the middle of our galaxy, it will take more time staring at the whole region to see if it works out.

If looking towards the galactic centre is like squinting into the sun with bare eyes, trying to study Sagittarius A* itself is a bit like trying to understand the sun's insides. We can see the matter around it and, in 2022, we even took a picture of its shadow with the Event Horizon Telescope – but the black hole itself is, by definition, invisible.

Fortunately, black holes are simple beasts. Aside from an electric charge, which they aren't expected to hold on to for long, they have just two properties that matter: mass and spin. Thanks to the work of Genzel and Ghez, we know the mass of Sagittarius A*. Its spin, though – that is, literally the rate at which it spins – remains elusive.

"Black holes are notoriously hard to pin down," says astrophysicist Ziri Younsi at University College London. "We can just about get their mass, but the spin is much harder. But just in the last 10 or 15 years, it's crazy how far things have come." We can roughly measure the spin of more distant black holes by measuring the matter falling into them or by the gravitational waves produced when they merge, but these routes are either too



ESO



The super-bright heart of our galaxy stands out in this radio frequency image of the Milky Way

imprecise or just plain impossible for our own black hole.

The trick that works is to watch a star complete enough of its orbit to reveal the black hole's influence. SO-2 takes 16 years to circle Sagittarius A*. "Once you have a complete orbit of SO-2 or one of these really close-in stars, you can now ask, how does gravity work near a supermassive black hole?" says Ghez. "There's an imprint of the laws of gravity on these orbits that you can start to measure."

One such imprint is called "precession". As the black hole spins, it drags the very fabric of space-time with it. If our understanding of space-time is correct, this should slightly nudge the orbits of nearby stars so that they don't retrace the same path each time around. Measure that shift precisely enough and, in principle, you can infer the black hole's spin. "The dynamics is really simple and beautiful," says Gillessen. "Then you can test your gravitational theory in the most direct possible way."

Those tests may have just gotten easier. In 2023, Gillessen and his colleagues spotted S301 using the Very Large Telescope in Chile. It is a star that comes 10 times closer to Sagittarius A* than SO-2, passing just about 1.8 billion km from the black hole at its closest approach. It completes an orbit in just 8.7 years, making it a far more sensitive probe of the black hole's gravity – and its spin. Gillessen thinks that could cut the wait for a measurement – it may be as little as a decade before we have it, he says.

Of course, it won't be as simple as just

watching a single star. "You have to put 30 years of data [together] accurately and precisely to measure these effects – it's really easy to go wrong," says Ghez. There are plenty of places for errors to creep in. "We spend a lot of time and effort worrying about that and thinking about how [those things would] rear their ugly heads."

But once we measure Sagittarius A*'s spin, it will open an unprecedented window into the details of our galaxy's behaviour. One long-standing mystery is why our black hole is so much quieter than others of its size. "The mass accretion rate of Sagittarius A* is ridiculously low. If you scaled Sagittarius A* to a human mass, it would be the equivalent of eating a grain of rice per year," says Younsi. Something appears to be stopping mass near the black hole from actually falling in, and the black hole's rotation may be part of the answer.

Extreme environment

Then there is the mystery of its missing jet. Many supermassive black holes fire enormous beams of energy out into space, and observations of other galaxies tell us that the size of these jets may be linked to how fast the black holes spin. One possibility, then, is that Sagittarius A* simply isn't spinning fast enough to power such a cosmic fountain.

"Almost every other galaxy in the observable universe hosts these prodigious jets, and yet we don't seem to have one at all – that's quite mysterious," says Younsi.

"It speaks to the history of our galaxy and also our future, where we're going, whether it could switch on one day."

Behind all these questions lurks a still-bigger one: how does gravity behave in such an extreme place? Albert Einstein's theory of general relativity has passed every test we have thrown at it so far, but there are signs that in the most extreme areas in the universe, it might fall apart. "Gravity is the most mysterious of the four forces of nature, and so the idea is that we can test our theories of physics and gravity in more and more extreme regions, and that could point us towards how to resolve some very big problems in physics," says Tuan Do, an astrophysicist also at UCLA.

Those problems include what is going on at the centre of a black hole, and whether general relativity ultimately gives way to the effects of quantum mechanics at its edge. The S stars offer one of the few ways we have to probe that territory from a safe distance.

The field is moving quickly; S301 has already pushed astronomers closer to Sagittarius A* than ever before, and more discoveries may be waiting in its glare. "The centre of the galaxy just keeps getting interesting," says Ghez. "The more we learn, the more questions there are to answer." ■



Leah Crane is a senior reporter at *New Scientist*, covering topics ranging from private space flight and cosmology to quantum mechanics



"There is a gradient between definitely not extinct, definitely extinct and everything in between"

Finding that long-lost plants and animals are still alive often isn't an unmitigated cause for celebration, says evolutionary biologist **Aelys Humphreys**. She tells Penny Sarchet that to get to grips with the true scale of species loss, we need to completely change how we think about extinction



NATALIE FOSS

THERE are tens of thousands of species of orchid, making it the second most species-rich plant family on Earth. Their exceptional diversity is driven in part by tightly evolved relationships with pollinating insects and root-boosting fungi. Each species has its own favourite collaborators, a feature that has driven orchids to success, but that also makes them especially vulnerable to extinction when these relationships are perturbed.

So, when the delicate, lemon-scented mignonette leek orchid, unseen since the 1930s, turned up again in 2020, there was cause for celebration. Recent rediscoveries like these – from the ring-tailed glider to the Santa Marta sabrewing hummingbird – are seemingly rare moments of joy amid the rapid loss of many plants and animals around the world. Globally, the number of species deemed to be at high risk of extinction has increased more than five-fold since 2000, and plant species in particular are being lost as much as 500 times faster than would be expected under normal evolution.

Yet, evolutionary biologist Aelys Humphreys at Stockholm University, Sweden, doesn't see rediscoveries as an unmitigated joy. As she told a recent summit at the Royal Botanic Gardens at Kew, London, the rediscovery of species also constitutes a failure. Extinct species are found again far more often than you might think; at the same time, problems with how and why we declare species extinct are also leading us to underestimate the scale of extinction globally.

New Scientist spoke with Humphreys about why we need to stop thinking in terms of a species being either extinct or not, and instead take a more nuanced approach to a philosophical problem that has vexed thinkers for thousands of years: how do you prove an absence?

Penny Sarchet: I was surprised to hear you tell the State of the World's Plants & Fungi symposium earlier this year that every rediscovery is a sort of failure, because it means we've got something wrong.

Aelys Humphreys: People react strongly

to that message. I don't want to give the impression that rediscoveries are a bad thing per se: they mean a species is not extinct, so conservation efforts can be renewed. Fundamentally, it's a good thing.

But the flip side is that an expert decided that a species was extinct and then it turned out that it wasn't. That can also lead to the erroneous withdrawal of conservation resources from that species. People have called this the Romeo error.

Is that named after Shakespeare's Romeo?

Yes. He thought that Juliet was dead, but she'd just taken a sleeping potion, and then he killed himself. That's what I find interesting about rediscoveries: their potentially grave implications.

So, how high are rediscovery rates?

We found it is about 35 per cent for plants and 36 per cent for mammals.

Do you have any favourite rediscovery stories?

One is *Psoralea cataracta*, a South African plant in the pea family, which is very distinctive and unusual as it has very long peduncles – the stem that leads to the flower. This species had only ever been collected once, in 1804. No one had recorded it since then, and it was declared extinct in 2008, but 12 years later it was found by a junior botanist. It's fantastic that something can be so poorly known, for so long, but is actually still out there.

Why is it so hard to say for sure that something isn't there?

It's very hard to prove absence. This philosophical question has troubled us since ancient times across a lot of different fields. In medicine, for example, just because no side effects have been recorded in a new treatment, it doesn't necessarily mean that there are none. And it's the same with law: just because there's no evidence that you're innocent, does that mean that you're not innocent? Absence of evidence is not evidence of absence. ➤

Aelys Humphreys:
“There is a
reluctance to
declare species
extinct out
of the fear of
getting it wrong”



“Even though
many extinct
species are later
rediscovered,
we are
underestimating
extinction”

How do conservationists typically determine if a species is extinct?

It requires repeated surveys in an area where the species is known to have occurred – and ideally in similar habitats where it might have moved to. These surveys must be carried out by experts who know what they’re looking for, over a number of years, to reduce the chance that they weren’t just unlucky once or twice in not finding it.

When you consider all those factors, it’s pretty amazing that we ever declare anything extinct.

Yes. Especially as species that are declared extinct may have been quite rare for a long time before that, and many of them are in remote areas that are difficult to access. It’s usually done by experts who feel they have the authority to declare something extinct because they’ve been returning to the same area for a very long time and they feel confident enough to say that if the species was here, I would have found it.

But there is a reluctance to declare species extinct out of the fear of getting it wrong, with the implications of resources being removed and nobody continuing to look for it. So, even though many extinct species are later rediscovered, we are underestimating extinction, because there are plenty of species that people think might be extinct but are not taking the final step to say so.

On top of that, it’s been estimated that 3 in 4 plants that haven’t yet been described scientifically are already threatened with extinction. That suggests a very high rate of so-called dark extinction – species that

go extinct without us even knowing about them.

Absolutely. That’s a staggering statistic. It’s also been estimated that around 2000 new plant species are described scientifically every year. So, new species description is happening constantly, and if 75 per cent of them at the time of scientific description are already endangered or have a high extinction risk, that’s really striking.

In another study, botanists quantified how long new-to-science species that have been collected lie around in herbaria [plant specimen libraries] before they are actually described as species. They found an average time of 24 years.

Does that mean there’s a realistic chance that some of those are extinct by the time we realise that they’re new species?

Exactly. By the time it’s been described, it is already extinct.

To tackle these issues, you’re a proponent of introducing a more probabilistic, less binary, way of viewing extinction.

The way that species have traditionally been declared extinct is within a categorical system: “extinct” or “not extinct”. But in most [other] scientific practices, we have some kind of estimate of how sure we are.

So, this alternative way of assessing extinction gives a probability that a species is extinct, ranging between 0 and 1. Then we can assign some kind of cutoff at which we’re comfortable saying it’s extinct. For example, if there’s a probability of 0.9 that a species is extinct, we can be quite confident. But if we

have a probability of 0.6, we may say that, based on the information that we currently have, we’re not sure. There is a gradient between definitely not extinct, definitely extinct and everything in between.

Could this approach help solve the rediscovery problem?

It offers a way out of this paradox where we want things to be rediscovered, but we ideally wouldn’t have declared them extinct in the first place. Using this approach, if there are rediscoveries, we can say well, actually, it only had a 75 per cent chance of being extinct. It avoids us sending out a very certain message that then turns out to be wrong – which can give the impression that scientists are exaggerating the extinction crisis.

And if you have a more quantitative scale for extinction likelihood, you can estimate this mathematically, and someone else with new evidence can go in and re-evaluate it. You’ve got this model and you add the new evidence and you run the model again. For example, if you find that there was another sighting of a species five years ago, you can ask: how does that influence the probability that the species is extinct? The model will tell you. You don’t have to rely on individual experts taking the decision that a species is extinct.

What other kinds of information are fed into these models?

Some models take into account unsuccessful searches. Some models use information on how much of the possible habitat has been searched. There are also things like detectability. How



easy is this species to find and identify? Are there other things in its habitat that look similar? Is it a big tree and it's always there, or is it a herbaceous plant that might not be detectable if you go there in midwinter?

You've found that when expert assessors use models, extinct species are much less likely to be rediscovered.

I did a survey with ecologist Diana Fisher at the University of Queensland, Australia, in 2023, of species that have been listed as extinct. We uncovered 155 species that had had their extinction status evaluated by a probabilistic extinction model. Of these, only 2.5 per cent had been rediscovered. That's really promising. Although, these probabilistic models tend to be used on recently extinct species, which have had less time to be rediscovered. The best approach is to combine expert opinion with these models. If an expert says it's extinct, and the model says it too, then we've done all we can.

How will a more probabilistic view of extinction change our view of the biodiversity crisis?

It will allow us to scale up extinction estimates across a much bigger proportion of all species globally. The manual assessment of extinction takes a lot of effort for a single species, but if we use models, we can also use past surveys, herbarium information and natural history collections to get a first estimate of how many species are likely extinct. This will also flag the species that haven't recently been searched for, so that they can be added to a most-wanted list and we can look for them. Ultimately, we want a more accurate estimate of the number of

Flying drones in Hawaii (top right) is one way to spot extremely rare species, such as the Haleakalā silversword plant (above) and *Lysimachia iniki* (above, right)

The mignonette leek orchid, last documented in 1933, was rediscovered in Australia in 2020



species that are already extinct and species that are becoming extinct at the moment.

Can we also use technology to make searching for lost or most-wanted species easier?

I really like the stories of flying drones in Hawaii, where there have been many interesting rediscoveries. Hawaii has got this unfortunate name of the "plant extinction capital of the world". It's partly because lots of unique species are there that don't occur anywhere else. If something only occurs on a steep cliff on a single island and there's a landslide, that's it, they're gone. Also, a lot of people live there, there's a lot of human activity, and invasive species too. But by flying drones, a number of species have been rediscovered. Modern technology can help us find things that would be very difficult and time-consuming for manual discovery.

What would you like people to better understand about extinction?

I have worked mainly on global scales but there is another aspect, and that is local extinction. Species that are becoming extinct in Britain in local woodlands, for example, might still be present in other parts of Europe, so they are not listed as globally extinct. Species are becoming extinct everywhere, really close to home, in people's back gardens. ■



Penny Sarchet is managing editor at *New Scientist* and co-host of *New Scientist's* podcast *The world, the universe and us*

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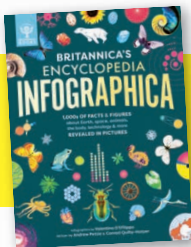
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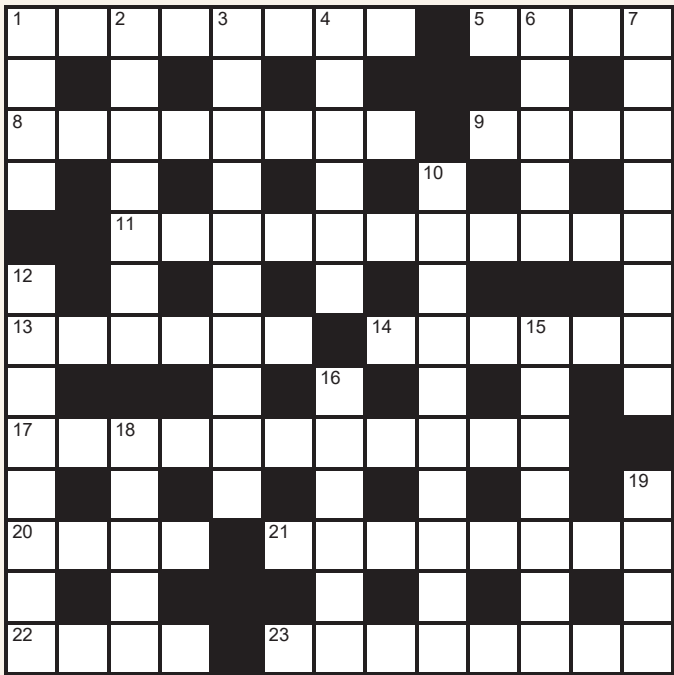
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Cryptic crossword #198 Set by Rasa



Scribble zone

Quick crossword next week

ACROSS

- 1 Deer, badgers and such fill wide ground (8)
- 5 Setter's current desktop (4)
- 8 Worry 50 per cent of oxygen is gone from room in unit (8)
- 9 Chemical group seen in Marylebone (4)
- 11 Provide food for and support larva (1,1)
- 13 Weakened police officer plucked instrument (6)
- 14 Expert politician beginning to trust AI instruction (6)
- 17 Biometric technique using rhenium, tin, aluminium, sulphur, calcium, nitrogen (7,4)
- 20 Crow or rook in sack (4)
- 21 Genius drops Isla's cap in taxi on the way back (8)
- 22 And so, bit of work comes to nothing (4)
- 23 Ugly laughs captured by heartless fan's speedlight (8)

DOWN

- 1 Eighties band with corny performer (4)
- 2 Sensible pub protects unfinished drink (7)
- 3 Translated Latin "stet" note! (3,2,5)
- 4 Beds john in forest on the regular? (6)
- 6 Extra-large mushroom (5)
- 7 They offended extreme sects seizing power over Rhode Island (8)
- 10 Animal trackers stripped amid swamp reptiles, keeping cool (10)
- 12 Sweet new oar blade (8)
- 15 Watching diamonds smuggled by underground activity (7)
- 16 Test follows if fowl ultimately like the smell of geraniol (6)
- 18 Piece of tech on early computer makes guitar sound (5)
- 19 Rip off symbol on a phone (4)

Quick quiz #373

set by Chelsea Whyte

- 1 A mathematician has discovered a rare shaped called a genus-3 polyhedron. How many faces does it have?
- 2 EEG monitors let researchers identify which component of human speech dogs are most attuned to. What is that component?
- 3 A skin patch can predict ovulation by measuring what in the wearer's sweat?
- 4 What form of life has broken the heat-tolerance level for complex organisms known as eukaryotes?
- 5 Which country's national health website was hacked by an AI agent?

Plus Side

created by Puzzlr

Circle numbers in the grid below to use them, or cross them out to get rid of them. Circled numbers must add up to both the target at the end of each row and the target below each column.

4	7	1	4	1	4
9	9	2	2	9	13
2	7	6	1	2	10
9	1	2	8	8	3
4	7	4	8	2	6
19	1	10	2	4	

Answers to this week's puzzles on page 47



Our games are now playable online
[newscientist.com/games](https://www.newscientist.com/games)

Mirror mirror

Why do people appear younger and better-looking in a mirror than in a photograph?

Mike Follows

Sutton Coldfield, West Midlands, UK

"Mirror, mirror on the wall, who's the fairest of them all?" The wicked queen in *Snow White* trusted her mirror to tell the truth. But do mirrors sometimes lie?

A smooth mirror produces specular reflection, preserving fine detail. But dust or a thin film of grease on its surface can scatter a little light from bright areas into neighbouring darker ones, rather like a photographic soft-focus filter. This reduces the contrast of pores, blemishes and fine wrinkles.

A photograph captures a fraction of a second and can preserve a fleeting expression that we would barely notice in a moving face but may find unflattering in a still image. Photographs taken at close range can also exaggerate nearer features, particularly the nose, while lighting can emphasise skin texture, wrinkles and blemishes. In a mirror, by contrast, we receive continuous feedback, adjusting

"Because faces aren't symmetrical, after a lifetime of seeing our mirror image, the photograph version can look wrong to us"

our expression, head angle, posture and gaze.

Some people simply look better in person – and perhaps in a mirror – than in a photograph. Faces are animated: eyes move, smiles develop and disappear, and changes in head position alter both expression and how light falls across the face. For some people, these changing expressions and head movements may make them more attractive to others.

There is also familiarity.



WILLIAM LOVE/ACEGETTY IMAGES

This week's new questions

Emotional tunes Why do certain pieces of music evoke emotions such as joy or sadness, and do people from different cultures react in the same way? *Jean Allen, Grantham, Lincolnshire, UK*

Sour face Why do we scrunch our faces up when we taste something sour? *Alexandra Thompson, London, UK*

A photograph normally shows the version of our face that other people see, whereas a mirror reverses left and right. Because faces aren't perfectly symmetrical, after a lifetime of seeing our mirror image, the photographic version can look subtly wrong to us, while appearing perfectly normal to everybody else.

Perhaps we just need to take photos of our mirror reflections.

Philip D. Welsby

Glastonbury, Somerset, UK

The images in a photograph are static. But mirror appearances, and particularly facial expressions, are dynamic and therefore perceived as younger and inevitably better-looking. At least that is what the (non-existent) person in the mirror will think!

Don't spiral

What forces are acting on a particle of fluid that makes it start spiralling or moving helically down a pipe instead of flowing smoothly?

Ron Dippold

San Diego, California, US

The main players are the inertia of the fluid, the friction and adhesion between the pipe and liquid, and any turbulence due to variations in the material or temperature of the pipe wall.

Liquid and gas are both fluids and their flow is governed by the Navier-Stokes equations, which are non-linear. Microscopic defects cause much larger vortices, similar to how a fast-moving truck can be sent flying in another direction after hitting a pebble.

Why does music elicit such strong emotional responses, and are they universal?

The simplest factor to understand is the inertia of all the fluid travelling down the pipe from gravity or pumping. In a perfectly temperature-controlled, frictionless pipe, it would be smooth and straight-flowing everywhere, even with kinks in the pipe. This is called laminar flow.

But nothing is frictionless, and chemical and electrical forces attract the liquid to the pipe wall. So, fluid at the edges is slowed by contact with the pipe – this cylinder of fluid that is slowed is called the boundary layer. If the pipe is perfectly straight and long, this actually helps calm things, but as soon as there's a curve, it creates a spiral.

Liquid tends to hug the inside curve because of that boundary layer – this is called the Coanda effect. You can see this for yourself with a sink and spoon. Run a small, steady stream of water from your faucet, then slowly move the back of the spoon into the stream. In the absence of friction and the Coanda effect, you would expect to see the water just fall straight down, but instead, you will see it hug the surface of the spoon and come off the tip of the spoon at an angle. Back in our pipe, that means the fluid isn't going straight down the pipe, which means it starts spiralling. Any curve, valve or pump will give you this spiralling.

And no pipe is completely smooth. Even "smooth" glass has microscopic defects. When the liquid hits a tiny defect, or even if there's a slight temperature variation – since hot fluid is less dense and rises – a small amount is deflected. This creates a small eddy, or swirl. If the liquid is moving slowly enough, the boundary layer acts as a damper and these just die out. Once the fluid reaches a critical speed, however, the damping can't keep up, and this is where the non-linearity comes in. Since the fluid closer to the centre of the



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Tom Gault
for New Scientist



pipe is moving faster than the fluid at the edges, it stretches these swirls down the pipe. And, like a skater pulling in their arms, a stretched, narrower swirl spins faster and harder, pulling energy from the fluid to grow longer and narrower. These swirls don't cancel each other out; they just feed on each other and twist into crazy shapes. You get what's called turbulent flow, for obvious reasons. You may see spiralling, but also unpredictable thrashing and surging around. Any trapped gas bubbles make things much worse as they tumble around wildly.

So, how do you stop this? Slowing down the liquid helps, but you usually don't want much less flow. If it's below the critical turbulence speed, you can run it through a long, straight pipe and it will settle down thanks to the drag from the boundary layer. In the best case, this length is about 15 times the diameter of the pipe after a single curve, but can be much longer – it depends on the viscosity of your liquid,

“Like a skater pulling in their arms, a stretched, narrower swirl spins faster, pulling energy from the fluid to grow”

the roughness of the pipe and how convoluted your pipes are.

If we really need laminar flow immediately, we use flow conditioners. These divide the big pipe into many smaller pipes for a bit or just add flat plates with carefully designed holes cut in them. These kill any large swirls, which have most of the energy, because the swirls are much larger than the holes. And in smaller pipes, 15 times the diameter of the pipe is a much shorter distance.

The downside is that you are slowing the fluid by cutting down the pipe volume – so, if you need to get the final flow rate higher, you have to pump harder, which means, yes, more turbulence upstream.

So just invent frictionless pipes

to solve all this, and please remember me when your royalty cheques arrive.

Smelly illusions

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

Richard Towers

Barnstaple, Devon, UK

Further to the answers already published in response to the question, I can add my own experience.

Between my teens and my early sixties, I suffered occasional migraine attacks. These were preceded by a changing set of symptoms: auras, partial sight loss, difficulty reading, light and sound sensitivity, etc. At one time, I would experience odours for which there was no discernible cause.

Reading around, I found references to these olfactory illusions as a possible precursor of migraine, which was somewhat reassuring. ■

Answers

#198 Cryptic crossword
ACROSS 1 Wildlife, 5 Mac, 8 Angstrom, 9 Ayl, 11 Caterpillar, 13 Dilute, 14 Prompt, 17 Retinal scan, 20 Brag, 21 Brainiac, 22 Ergo, 23 Flashgun
DOWN 1 Wham, 2 Logical, 3 Let it stand, 4 Floors, 6 More, 7 Culprits, 10 Microchips, 12 Adorable, 15 Minding, 16 Floral, 18 Twang, 19 Icon

Quick quiz #373
1 Eight
2 Consonants
3 Sex hormones
4 An amoeba
5 Australia

19	1	10	2	4
4	7	4	8	2
9	1	2	8	6
2	7	6	1	2
9	9	2	9	10
4	7	1	4	13
4	1	4	1	4

Plus Side
Solution

A very public break-up

Feedback is on a quest to find the most niche science-themed tourist attractions in the world – by being told about them, rather than by actually visiting anything, as that would require a budget.

Reader Earle McNeil advises us to explore Zagreb, Croatia. This city “must have the most museums per square kilometre of any town on the planet”, he says. “This then has to include the oddest.” Earle evinces two examples: the Museum of Broken Relationships and the Museum of Hangovers. We initially didn’t believe this, but we looked them up and they are indeed real.

The Museum of Broken Relationships was founded by two former lovers: film producer Olinka Vištica and sculptor Dražen Grubišić. After breaking up, they joked that they should set up a museum for all the personal items left over from their relationship, and a few years later, they did exactly that. Two decades on, the museum is described by visitzagreb.hr as “the most popular museum in Zagreb”, and there is now a second permanent site in Chiang Mai, Thailand.

Feedback isn’t sure this really counts as science-themed, except in the absolute broadest sense of the word “psychology”, in which case *Heated Rivalry* is also scientific and *New Scientist* should assign someone to review season two.

However, the Museum of Hangovers surely does count, filled as it is with chemistry and neurophysiology. Visitors can try crossing a tilted floor while wearing goggles that let you experience what it’s like to walk while drunk, or take the wheel of a drunk-driving simulator to see just how badly alcohol affects your ability to drive (spoiler: a lot).

While researching these two institutions, Feedback fell down a glorious Wikipedia rabbit hole. We first learned about the Museum of Failure, a touring exhibition most recently found in Paris, that collects failed and unpopular products like the Apple

Twisteddoodles for New Scientist



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Consideration of items sent in the post will be delayed

Newton, Betamax video cassettes and the Tesla Cybertruck.

From there, we wandered afield from our science-themed mandate, but we do have to tell you that there is a Museum of Bad Art and that it has, or at least had, a competitor: the Museum of Particularly Bad Art.

To quote or not to quote

In our 19 September instalment, we reported that there are now thousands of scientific papers that reference song titles or lyrics by the Beatles in their headings. This prompted readers to wonder which other artists are being heavily referenced by researchers.

Simon Shuel wonders if anyone has done a similar analysis for the work of musician Frank Zappa. Feedback prowled the internet for a while, to little avail. All we could find were some species named

after him. For instance, the spider *Pachygnatha zappa* was so named because it has markings that resemble Zappa’s moustache.

Meanwhile, reader Jonathan Arch was recently alerted to a paper that uses a rather tortured Shakespeare reference in its title: “Through beta2 or not through beta2—That’s the question”. He first asked if Feedback might perform a systematic search for lines from Shakespeare in scientific papers. Readers are welcome to hope for this eventuality, but oft expectation fails.

Happily, Jonathan then flagged a 2005 paper from *BMJ* by Neville Goodman, “From Shakespeare to Star Trek and beyond: A Medline search for literary and other allusions in biomedical titles”. Between 1951 and mid-2005, Goodman found more than 1400 Shakespeare

allusions in the titles of medical papers. There was a strong clustering effect in the allusions: “a third of them to ‘What’s in a name’ and another third to *Hamlet*—mostly to ‘To be or not to be.’” However, Goodman did find some gems, like “Much ado about the null hypothesis” and “All that is excreted does not glisten: Or why do we keep on collecting urine to measure creatinine clearance?”.

Goodman was disappointed to find that no obstetrical papers were titled “Once more unto the breach”. Feedback is happy to report that this gap has since been filled by a 2015 paper: “Once More Unto the Breech: Planned vaginal delivery compared with planned Cesarean delivery”.

We await with interest reader examples of papers referring to the works of R.E.M., Dolly Parton, Dan Brown and other artists of various calibres.

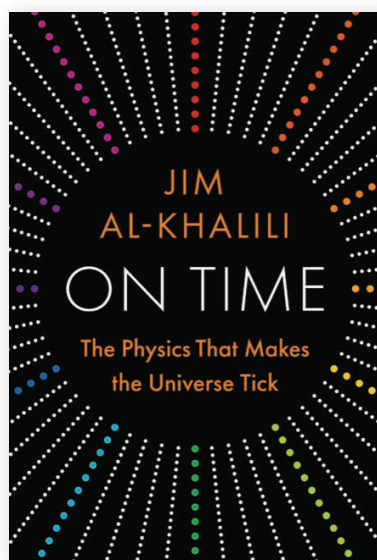
Gold-standard material

The roots of nominative determinism run deep. Reader Peter Mayer was reading a story in *The New York Times* entitled “Plumbing the Shipwrecks of an Infamous Pirate Cove”, about marine archaeology in the Bahamas. This mentioned “the godfather of Nassau’s pirates”, active in the early 1700s, one Benjamin Hornigold. Stop sniggering at the back there: the surname is apparently derived from an English place name.

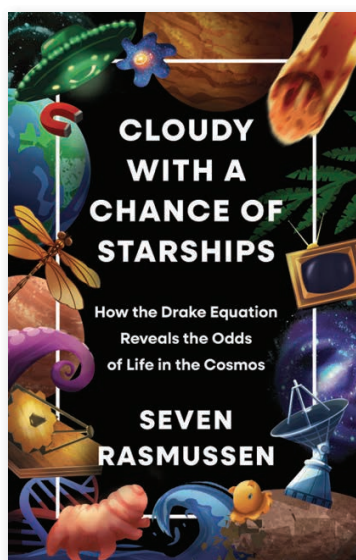
Meanwhile, author Charlie Jane Anders took a break from writing her new *Star Trek* comic to tell us about a recent episode of *American Campus Podcast*. This was built around “an interview with a British professor of pharmacology who studies the history of drugs going back to their earliest botanical roots. His name: Rod Flower”.

Feedback was shocked to learn that Flower was flagged in *New Scientist*’s pick of the best popular science books in July. Once again, if only we read our own magazine with proper care, we would probably find writing this column a lot easier. ■

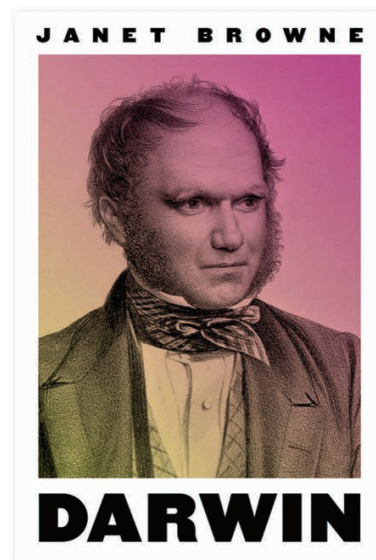
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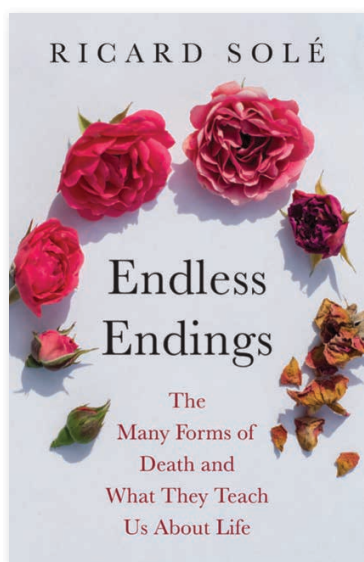
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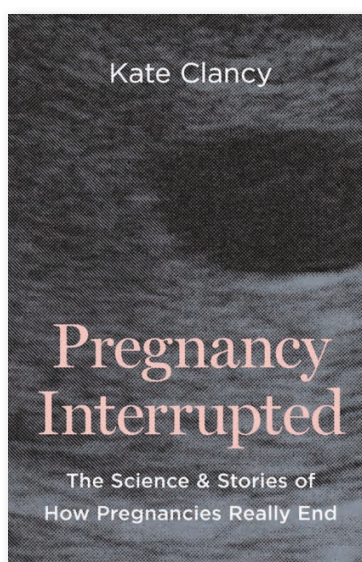
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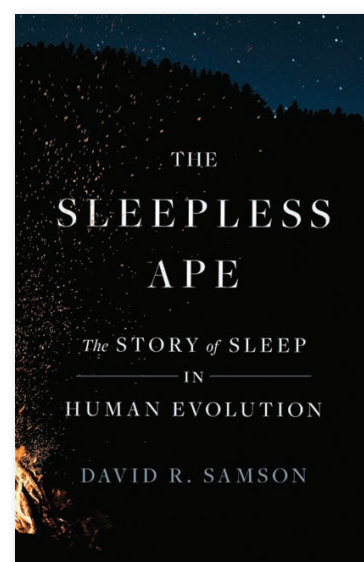
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