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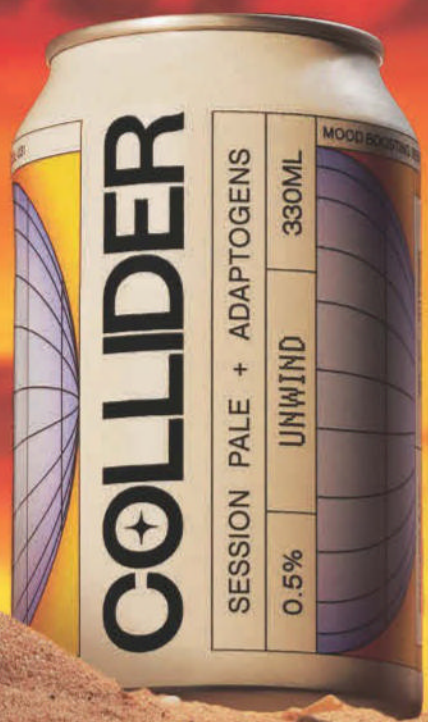

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Elsewhere on New Scientist

Instant Expert

Mind-body connection

Unravel the complex links between our physical and mental worlds, such as the placebo and nocebo effects, and learn how the body is central to the mystery of consciousness. Join six leading experts to discover what this all means for our future health and well-being. This Instant Expert event takes place on 26 April at London's Congress Centre.

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Tour

Alfred Russel Wallace cruise, Indonesia

Explore the Maluku Islands (Spice Islands) and Raja Ampat Islands as naturalist Alfred Russel Wallace did in the 19th century. Sail aboard a traditional Indonesian schooner as you marvel at the biodiversity of the habitats that shaped Wallace's discoveries in evolution and epidemiology. This 13-day tour, led by biologist George Beccaloni, starts on 23 January 2026 and costs $13,999.

newscientist.com/tours

Podcast

Weekly

The team discuss what is at stake for science in the US, which is by far the biggest funder of such research in the world – including how the Trump administration has deleted web pages that reference climate change. Hear about a new analysis of the complexities of whale song that suggests it is a kind of language. Plus, find out the scientifically perfect way to boil an egg.

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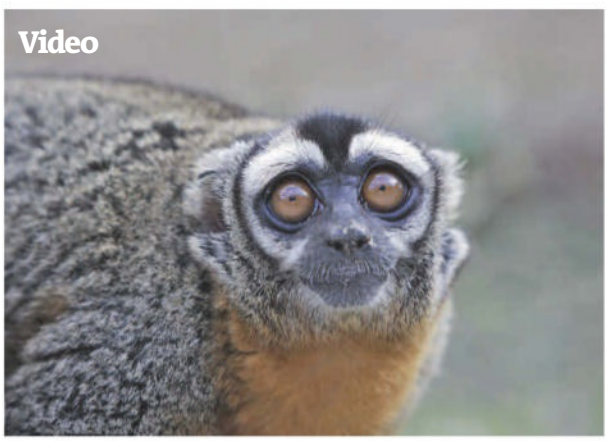

YLVAIN CORDIER/GAMMA-RAPHO VIA GETTY IMAGES

Night monkey This particular species is endemic to Brazil and Peru

JESSE ROCKWELL/ALAMY

Down to Earth What can space rocks tell us about the solar system?

Video

Rainforest guardian

Colombian conservationist Ángela Maldonado founded the Entropika Foundation, which protects rainforests in the Amazon. She has campaigned to protect Nancy Ma's night monkeys (*Aotus nancymaae*), which have been captured and sold in the illicit trade in animals for testing. Her efforts led to one lab's animal testing licence being revoked in 2012.

youtube.com/newscientist

Newsletter

Launchpad

Features editor Joshua Howgego offers a peek at his new book, *The Meteorite Hunters*, which tells the incredible stories of the adventurers and scientists who find space rocks by scouring wild deserts and Antarctic ice sheets. Find out how these incredible treasures are helping to write a new history of the solar system.

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"We are witnessing an all-out assault on federal science in the US"

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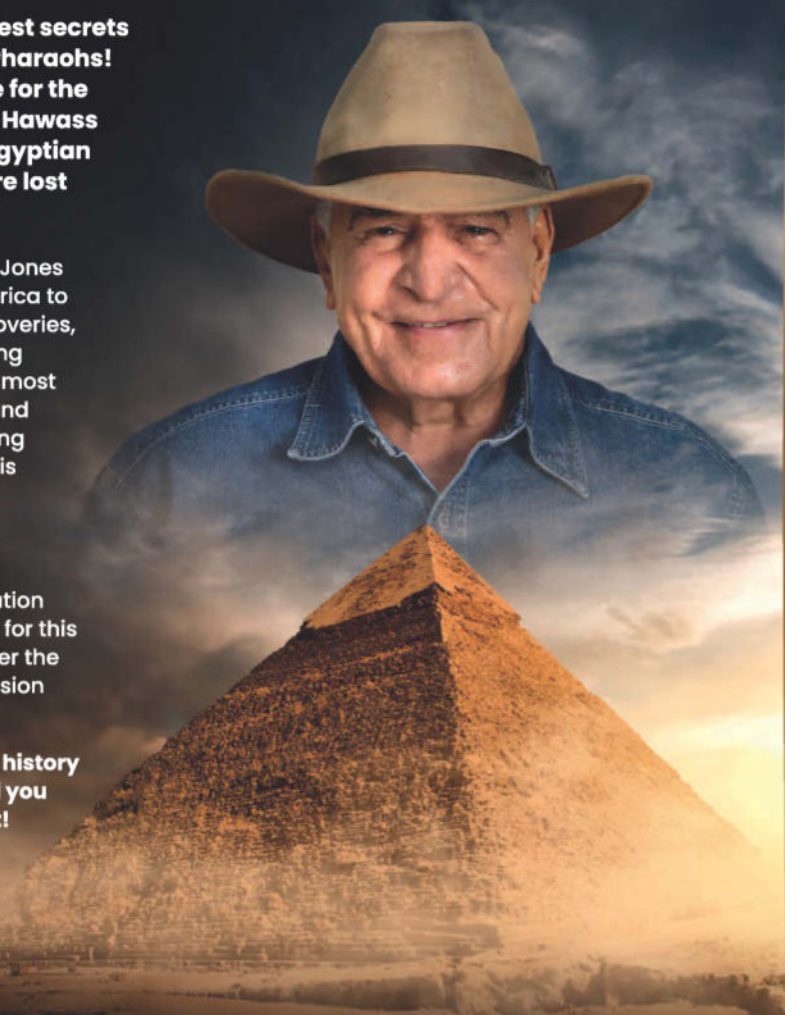

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Leah Crane
Space and physics reporter

When to believe the hype

There's a right way and a wrong way to develop new technologies

WHAT is the difference between artificial intelligence and quantum computing? One is a sci-fi-sounding technology that has long promised to revolutionise our world, providing researchers can sort out a few technical wrinkles like the tendency to make errors. Actually, so is the other.

And yet, while AI appears to have breathlessly and inescapably taken over, well, everything, the average person has had no experience with quantum computing. Does this matter?

Practitioners in both fields are certainly guilty of hyping up their wares, but part of the problem for would-be quantum proponents is that the current generation of quantum computers is essentially useless. As we detail in our special report on the state of the industry (see page 8), the race is now on to build a machine that can actually do useful computations of a kind not possible on regular computers.

The lack of a clear use case hasn't prevented tech giants from forcibly injecting AI into the software we use every day, but bringing quantum computing to the masses in the same way is much more difficult due to the finicky nature of this hardware. You will probably never own a personal quantum computer – instead, the industry is targeting businesses and governments.

> "Practitioners in both the AI and quantum computing fields are guilty of hyping up their wares"

Perhaps that is why quantum computer builders seem to be retaining a foot in science, publishing peer-reviewed research while also drumming up business. The big AI firms seem to have all but given up the publishing part – why bother, when you can simply charge people a monthly fee to use your tech, whether or not it actually works?

The quantum approach is the right one. If you are promising a technology that will transform research, industry and society, explaining how it works in the most open way possible is the only means of actually convincing people to believe the hype.

It may not be showy, but in the long run it is substance, not style, that really matters. So, by all means, aim to revolutionise the world – but please, do show your working. ▮

PUBLISHING & COMMERCIAL

Commercial and events director Adrian Newton

Display advertising
Tel +44 (0)203 615 6456
Email displayads@newscientist.com
Sales director Claudia Nicoletti
Account manager Mila Gantcheva
Agency partner Tilly Pollock

Recruitment advertising
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New Scientist Events
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CONTACT US

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General & media enquiries
US 600 Fifth Avenue, 7th Floor, NY 10020
UK 9 Derry Street, London, W8 5HY
Australia 58 Gipps Street, Collingwood, Victoria 3066

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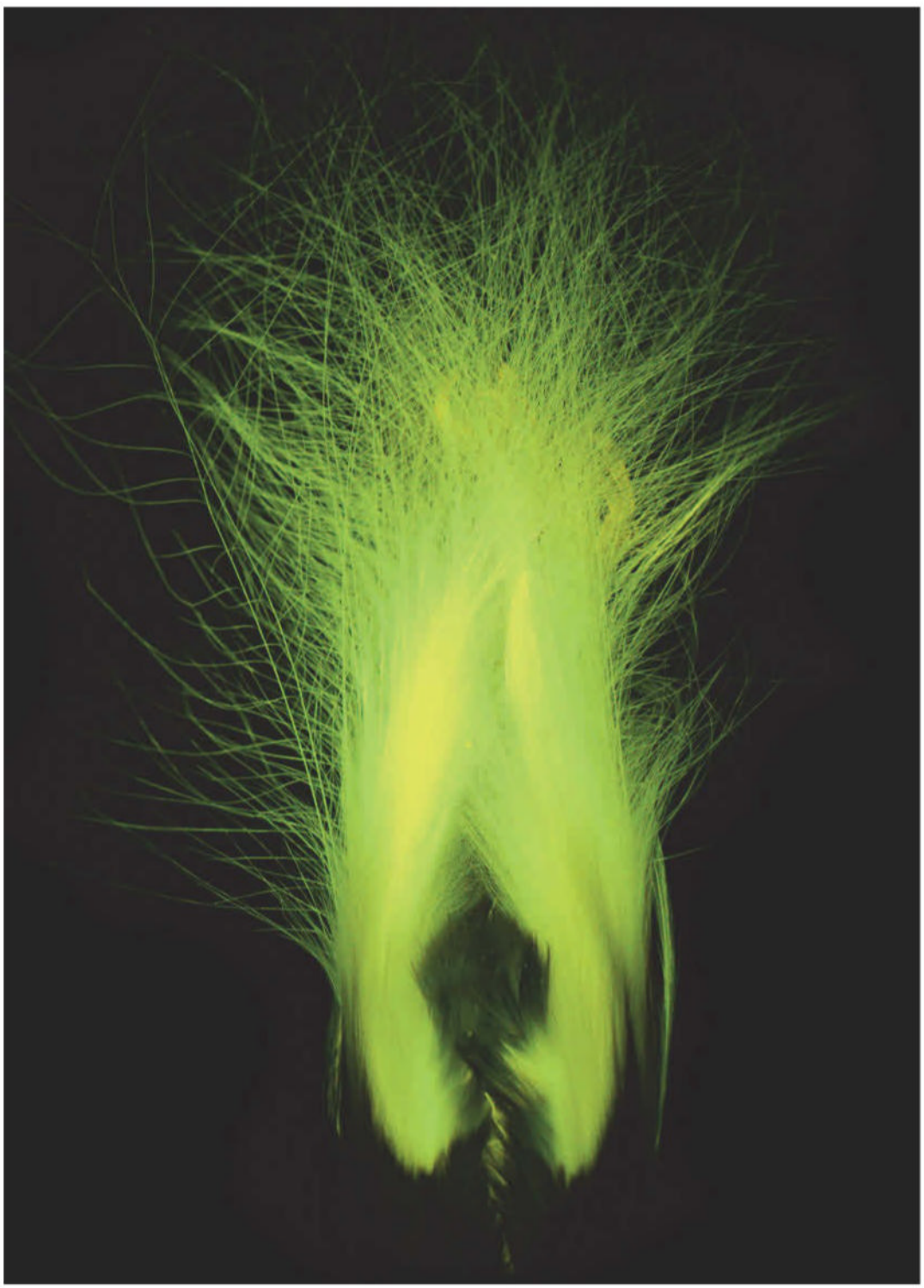


AMERICAN MUSEUM OF NATURAL HISTORY

Ornithology

Fluorescent feathers

THIS striking plume of yellow is the fluorescing tail feathers of a male emperor bird-of-paradise (*Paradisaea guilielmi*). Birds-of-paradise are known for their bright colours and courtship displays. Now, it turns out that many species also fluoresce – absorbing light and re-emitting it at lower-energy wavelengths. Fluorescent patches are found in body parts used during courtship, like tail feathers and bills.

Technology

The grand quantum race

Firms around the world are trying to commercialise quantum computers, but the jury is still out on who is going to pull ahead, finds **Karmela Padavic-Callaghan**

THERE has never been a better time to be in the quantum computing business. "Some 10 years ago, it was not obvious that quantum computing was more than an interesting lab experiment. Since then, an entire globalised ecosystem has emerged," says Laurent Prost at French quantum computing start-up Alice & Bob, one of hundreds of firms in the sector. Krysta Svore at Microsoft puts it even more succinctly: "Quantum computers are working."

But working on what? Practical uses for quantum computers remain limited, with no sign yet of the long-promised ability to solve problems that can't be tackled by traditional computers. To deliver on that promise, they need to become large enough to run complicated calculations and they must make fewer errors to ensure that those calculations are meaningful. The two issues also compound: adding more qubits, which are the building blocks of any quantum computer, to a device typically introduces more errors.

To circumvent this, researchers have begun to group physical qubits into "logical qubits" that can catch and fix errors as they happen. "You need to be able to detect errors, correct errors and do all that during computation," says Svore. The basic path towards truly useful quantum computers, then, is to build a device with as many logical qubits as possible. But in reality, rather than there being a single route, competitors around the world are taking very different approaches in the hope of taking the grand prize.

By one measure, California-based start-up Atom Computing is ahead of the pack. It holds the record for the largest quantum computer yet, with 1180 qubits made from extremely cold ytterbium atoms, also known as "neutral atoms" because they have no electric charge. Another start-up, Pasqal, has recently reported assembling 1110 atoms in its quantum computing processors, without using them for calculations, while a research team at the University of Science and Technology of China in Hefei has shown that artificial intelligence could be used to speed up such assembly.

MATT MURPHY

"There has been amazing progress. We got over the hump of 'Can you build a system at all?' to 'Can you build it better?'," says Ben Bloom at Atom Computing. "I think neutral atoms are in the lead."

Not just a numbers game

But sheer numbers may not be enough. "Building useful quantum computers involves work beyond building better qubits," says Nicholas Harrigan at Nvidia, which isn't building its own quantum computing hardware but is partnering with several companies to develop the best ways to use it. Other stalwarts of the traditional computing industry have had the same idea: last year, Microsoft worked with Atom Computing to create 24 logical qubits linked through quantum entanglement, a necessary first step on the path to useful devices.

"Ten years ago, it wasn't obvious that quantum computing was more than just an interesting experiment"

That wasn't enough to beat Boston-based neutral atom start-up QuEra, which has demonstrated more than 40 logical qubits. But QuEra also can't claim the logical qubit crown – that belongs to a start-up called Quantinuum, based in Cambridge, UK, and Colorado, which has now created and entangled 50 logical qubits, taking the lead. Later this year, the firm will launch a quantum computer able to encode a trillion times more information than this machine, says Rajeeb Hazra at Quantinuum.

The company takes a different approach to its qubits, using charged ytterbium ions held in place by electromagnetic fields, rather than neutral atoms. These "trapped ion" qubits are also being pursued by companies like Oxford Ionics and Maryland-based IonQ. One advantage both types of hardware share is the ease of switching up the connections between qubits, says John Gamble at IonQ, making them more amenable to executing many different algorithms, including various ways of connecting physical qubits into logical qubits for error correction. "Flexibility and versatility is king right now," he says.

This flexibility is part of the reason why trapped ion and neutral atom backers are hoping to eventually outpace technology giants like Google and IBM. Google, in particular, looms large in the quantum computing industry, having been first to claim "quantum supremacy" – the ability to run a calculation that a conventional computer never could – in 2019. While this was later disputed, Google claimed it again in 2024 with a new chip called Willow. The firm said it could carry out a specific computational task in 5 minutes that would take the world's leading conventional supercomputer about 10 septillion years.

Both Google and IBM make their qubits from tiny superconducting circuits that have their own benefits, in that they can execute calculations more quickly than their atomic and ionic counterparts and are, at times,

comparatively more reliable. With neutral atoms, qubits run the risk of falling out of their precisely calibrated, laser-controlled quantum states.

But these benefits may not be enough to truly pull ahead of the competition. The superconducting qubits are wired in place and easily connect only to their nearest neighbours. This makes it much more difficult to implement several of the error-correcting algorithms that have been developed more recently and to experiment with these codes further.

"Developments with new error-correction codes happened very quickly, and I'd be surprised if this was the end," says Gamble. Bloom says he used to work with other types of quantum computers, but shifted focus to neutral atom qubits because they seemed to offer more solutions to the field's fundamental challenges. Once the industry favourite, the superconducting approach may now be at risk of running out of road.

Google's vital step

That isn't to say Google's efforts have been in vain. The company has demonstrated that adding more physical qubits to Willow's logical qubits increases their error-correcting abilities, a vital step in making large-scale computers.

Meanwhile, IBM's Condor quantum processor has only 59 qubits fewer than Atom Computing's record-breaking machine and the firm is on track to breach 4000 qubits in 2026. To that end, IBM is developing quantum computer components that will let it link existing devices into larger and more powerful machines. The company says this will also allow it to implement more error-correction codes than direct competitors like Google.

David Rivas at Rigetti Computing, which specialises in superconducting qubits, says that, in his view, superconducting quantum computers haven't hit a dead end yet. There is value in this type of quantum computer "as we speak", he says. Rigetti Computing sells a ready-to-ship quantum computer with 9 qubits, along with access to a larger 84-qubit quantum processor, and Rivas says the firm has sold quantum computers to both governmental labs and commercial businesses, mostly for further explorations of the technology.

Alice & Bob also makes its qubits from superconducting components, but its basic design differs from others by prioritising the suppression of errors even before creating logical qubits. Because of this, Alice & Bob researchers say they could reach fully error-free quantum computing with thousands of qubits where their competitors may have to build millions. They haven't demonstrated any logical qubits yet, but aim to have a truly useful quantum computer by 2030.

"We're in the business of setting very challenging timelines for ourselves"

Give it five years

Similar five-year timelines loom large for many competitors in the race towards building a useful quantum computer, but California-based quantum start-up PsiQuantum has the most ambitious plan among them. The firm has foregone demonstrations and experiments with several-qubit devices and is aiming to present a large-scale, supercomputer-like quantum computer in 2027 (see page 10).

"We're in the business of setting very challenging timelines for ourselves and we have rational, evidence-based reasons to believe that that is doable," says Pete Shadbolt at PsiQuantum.

With so many qubit platforms to choose from, who is likely to pull ahead? John Preskill at the California Institute of Technology is tentatively betting on atoms. The prospect of making many of them and being able to connect them in just the right way for your quantum algorithm makes them the most promising, he says. "I think what a [neutral atom quantum computer] might be able to do with a few times 10,000 qubits would be comparable to what, in a superconducting quantum computer, might require hundreds of thousands of qubits."

But the best qubit may be the one you never even notice. Today's quantum computing researchers want the engineers of the future to think of their devices as just one other great computing resource, alongside supercomputing or AI, rather than exotic machines where you need to understand the nitty-gritty of hardware. "My hope is that eventually, no one will ever have to think about physical qubits ever again," says Bloom. At that point, quantum computers may not just be working, but tackling problems that could truly change the world.

Quantum everywhere

While the quantum computing industry is still figuring out the best way to build its devices (see main story), other industries are already trying to put them to work in surprising places. For instance, Cleveland Clinic, a non-profit medical centre in Ohio, houses one of IBM's quantum computers – the first in the world to be uniquely dedicated to healthcare research. Elsewhere in healthcare, biotechnology company Moderna, now known for its mRNA vaccines, has already used IBM quantum computers to calculate the behaviour of certain molecules that may be relevant for its drug-development process.

Banks are also big quantum backers, with HSBC, JPMorgan Chase, Goldman Sachs and Wells Fargo all hosting their own quantum divisions, which are tasked with exploring quantum algorithms for price optimisation and ultra-secure transaction verification processes. In fact, in 2024, Quantinuum partnered with Mitsui & Co., one of Japan's largest trading companies, to demonstrate a lab-scale test of quantum tokens – a bit like a quantum version of cryptocurrency.

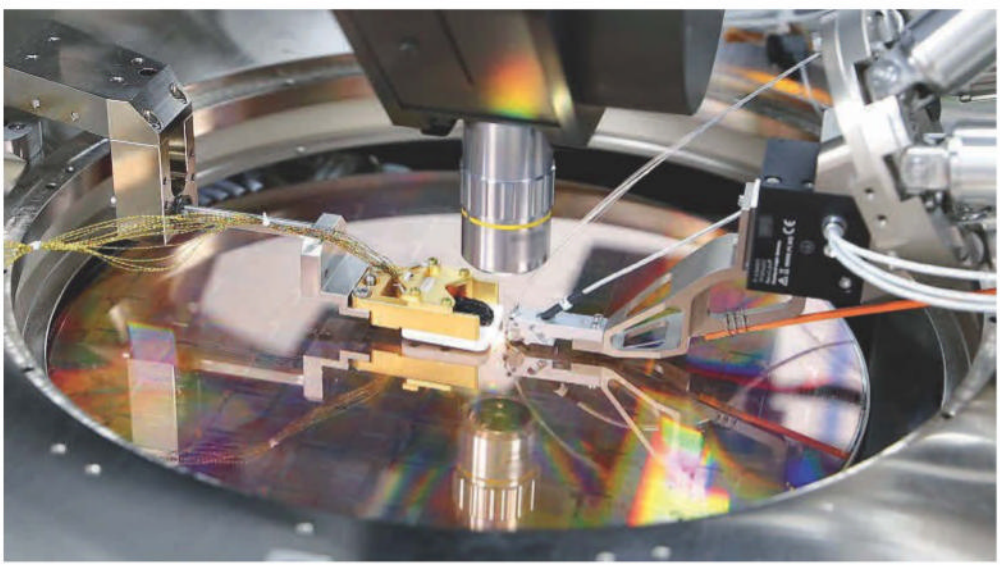
Automotive giant BMW has also been exploring quantum computing since 2017, with an eye towards using these new computers to develop novel materials and optimise the company's logistics. But not all of these quantum experiments work out – in 2024, for example, Chinese e-commerce and cloud-computing company Alibaba and the country's leading internet search provider Baidu both closed their quantum computing research labs.

Fieldnotes **PsiQuantum in Brisbane, Australia**

Inside the plan to build the world's largest quantum computer

While rivals have been working on smaller machines, PsiQuantum has its eyes on the biggest prize, says **James Woodford**

PSIQUANTUM/HANDOUT VIA REUTERS



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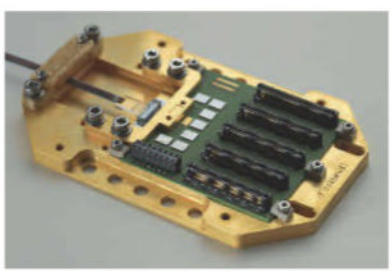


ON A large table in front of me is some of the world's most advanced photonic hardware, which may soon drive one of the great technological revolutions of our time. I can see tiny microchips that look like precious jewels, with nanoscale patterns that make them glow like rainbows, along with detectors, filters and switches connected by fibre-optic cables, laid out on smartphone-sized circuit boards. These are the fundamental components of a massive photonic quantum computer that could be up and running in just a few years – though to me, it looks more like the shamble of cables and boxes of my home Wi-Fi gear.

I have come to the Australian head office, in Brisbane, of PsiQuantum, a startup that, until last year, was flying under the radar. That all changed when the Australian federal government and the state government of Queensland announced a AUS$1 billion investment in the firm – the largest bet by any government, anywhere, on a private quantum computing firm. So what will Australia get for that money? Geoff Pryde, PsiQuantum Australia's chief technical director, is clear: "We think once we turn this thing on, the quantum computing era begins."

That is a big claim for a company only just beginning construction of a facility to house its quantum computer, at a 13-hectare site near Brisbane Airport. But to understand why PsiQuantum thinks it can beat the big players in the quantum computing industry, it helps to look at the route it is taking.

"It's not the same trajectory," says Terry Rudolph, one of the firm's four co-founders, who also happens to be the grandson of legendary quantum physicist Erwin Schrödinger. "If your goal is to reach the top of a skyscraper, then building a really big ladder might make sense. However, once you realise the goal is the moon, then it doesn't matter how many ladders you stack up on top of each other. If you look at what we have been building, we are developing a rocket, and the moon has been our goal since we started the company."

Put more technically, PsiQuantum has excused itself from participating in what the industry calls the era of noisy intermediate-scale quantum (NISQ) computing, in which key players have built machines with up to 1000 qubits, or quantum bits, which are error-prone and have limited application. It is widely held that these NISQ-era computers are marvels of technology but have little practical use.

Main image: **A PsiQuantum silicon wafer containing thousands of quantum devices**

Top right: **A cryoplant will keep the computer cool**

Bottom right: **An integrated photonic chip**

"We think once we turn this thing on, the quantum computing era begins"

"In the past few years, it has become quite clear that the value proposition of NISQ is far less rosy than originally thought," says Andrea Morello at the University of New South Wales in Sydney. "There really isn't much useful computation that a NISQ device can perform which cannot be done on a classical machine."

Instead, PsiQuantum plans to scale up, fast, to a million-qubit machine by the end of 2027 – far larger than any that exists today. It all begins with the mess of hardware in front of me. PsiQuantum has thrown itself wholly into photonic quantum computing, which means that it has to manipulate particles of light into quantum states that will serve as the qubits in its computer, equivalent to the transistors found in conventional computers.

That comparison is apt, because PsiQuantum is using the same semiconductor fabrication techniques that are used to make the huge number of tiny transistors found on regular computer chips. "PsiQuantum worked out how to miniaturise to the nanoscale all requisite photonic components and manufacture them using the same

technology used to build laptops and cell phones," says Rudolph. "Such semiconductor engineering is the only approach to building billion-component machines that humans have invented thus far."

PsiQuantum has partnered with US-based chip manufacturer GlobalFoundries to produce its photonic chips. Some of those components are sitting on the table in front of me, including a small black case that looks like it is housing a precious gem. In fact, it is an example of the microchips that have been developed to drive the control and filtering of photons in PsiQuantum's device.

The benefits of experience

This approach aims to benefit from decades of experience both in chip fabrication and manipulating quantum states of light. There are a number of different technologies that can be the basis of a quantum computer, including superconducting materials and trapped ions, but photonics can be more robust than these. "This combination of existing large-scale, efficient, high-tech industry capability and light's noise resistance makes photonics a strong candidate for the first useful quantum computer," says Rudolph.

That isn't to say the path has been easy. PsiQuantum's Dylan Saunders says the firm had to overcome the challenge of building microchips that are room temperature on one side and as cold as deep space on the other. Another crucial breakthrough was successfully manufacturing filters that can block out unwanted light from the photon source but let the qubit photons go through.

"We need to block that unwanted light by 12 orders of magnitude, which is a lot," says Saunders. "An analogy is, it's kind of like letting off a nuclear explosion at one end of a lecture theatre and blocking the explosion so much that you could hear me talking to you if you were standing there. That's how much we need to suppress it."

"They have a robust and serious plan and are in a position not to have to show off baby steps"

Many challenges still remain, particularly in the integration of so many millions of components and the optimisation of the photonic qubits. These small parts in front of me will need to be replicated on a massive scale: PsiQuantum must manufacture tens of thousands of photonic chips and connect them with over 1000 kilometres of optical fibre. Once complete, the photonic quantum computer will cover an area of 100,000 square metres, which includes the cryoplant needed to keep it cool.

Despite the task ahead, Pryde says there are no insurmountable gaps between where the team is now and the big switch-on in 2027. "There's no point in this hardware picture where some miracle needs to occur," he says.

In fact, PsiQuantum is so confident of its progress that it already has a team of quantum software programmers working with numerous industry clients to develop algorithms for extracting useful information from the quantum computer when it is up and running. These clients include pharmaceutical giant Boehringer Ingelheim, which wants to study the properties of enzymes that are vital for drug absorption, and Mercedes-Benz, which hopes to use the quantum computer to improve battery design for electric vehicles.

"Once the hardware is installed and the system is validated, we want to have the algorithms that we've prepared ready for that generation-one machine running ASAP," says Pryde.

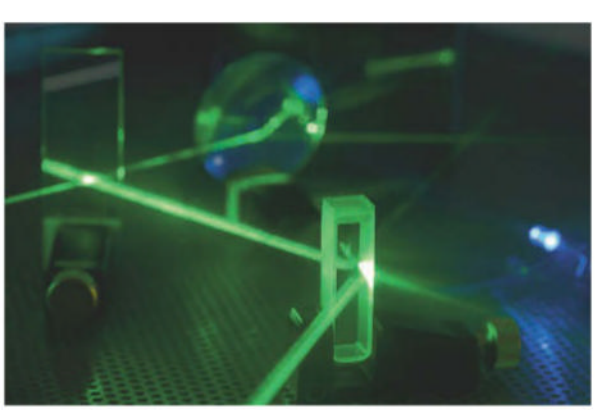
So, will the big bet of skipping the NISQ era pay off? Stephen Bartlett at the University of Sydney says there are clear benefits to not building smaller devices. "It may be important as part of technological development, and realising those things and showing them off may be exciting, but you could easily argue they are a distraction from the main game. PsiQuantum want a million-qubit device. They have a robust and serious plan and are in a position not to have to show off baby steps and instead go for the main game."

Morello says there is an argument that the NISQ era was "useful and necessary as an intermediate step" for researchers to get experience in engineering and programming quantum computers, but ultimately PsiQuantum may prove this was unnecessary. "They said 'we're just going all the way for the big thing'," he says. "And by now, I think it's fair to say that they were right."

100,000
Size of PsiQuantum's planned computer, in square metres

But exactly what a million-qubit device will be able to do – and whether it will truly herald the start of the quantum computing era, as Pryde claims – remains to be seen. "We are all waiting for the day when a quantum computer is able to give a convincing demonstration that it can do something useful that cannot be done by a classical supercomputer," says Bartlett. And while PsiQuantum has a clear plan to scale up, it may not be the first to get there.

"Nobody yet knows what technology is going to enable large-scale, useful quantum computing," he says. "It could be photonics, superconductors or ion spins in semiconductors, and there's more. We don't know yet who is going to win." ▮



LABORATORY/ALAMY

Photonic devices are one of many approaches to building quantum computers

Analysis **Geopolitics**

No solace for quantum Fears that quantum computers could give nations an advantage are leading to crackdowns that make it harder for researchers, says **Matthew Sparkes**

QUANTUM computers were once nothing more than a plaything for physicists, but as their capabilities have grown, so too has the attention from governments. The US, China and European nations are all racing to develop these exotic machines, while carefully balancing national security needs with commercial opportunities. But have they got the balance right?

The first nation to develop a sufficiently powerful quantum computer will be able to crack many encryption algorithms in use today and gain access to the rest of the world's secrets – including encrypted data that is being collected now in the hope of decrypting it in the future. That means there is a geopolitical advantage in getting there first and stopping adversaries catching up, says Pia Hüsch at the Royal United Services Institute for Defence and Security Studies.

In terms of getting there first, state spending is already high. Figures from a 2022 report by consultancy firm McKinsey suggest that China had committed $15.3 billion at that point, while European Union governments had earmarked $7.2 billion – including the EU's own Quantum Flagship project – and the US $1.9 billion, some through its National Quantum Initiative Act. More recent figures are harder to come by, and these numbers also ignore the fact that outside China, a lot of investment in this sector involves private companies, such as Google, IBM and Intel.

For your eyes only

And no one seems too keen on sharing their work. As *New Scientist* reported last year, countries across Europe have implemented stringent export controls on quantum computers, while the US has since followed suit and banned its citizens from investing in quantum technologies in China and some other countries. Hüsch says similar export controls on other key technologies, such as chips used for AI research and cryptography, have had limited success. "They will delay the competition for a while, but history has shown that they're typically not a silver bullet to stop adversaries," she says.

SHUTTERSTOCK/NIPHON SUBSRI

China and the US are in an uneasy quantum rivalry

Quantum computing researchers are already unhappy about being caught in this geopolitical tussle. "I have wonderful quantum computing colleagues in China who seem as open as can be, but collaboration between the US and China in quantum computing has indeed become harder," says Scott Aaronson from the University of Texas at Austin. "It's now extremely difficult for Chinese students to get visas to study quantum computing in the US. I view this as not only sad, but a massive self-own for the US, since so many of these students would settle in the US if we let them, and contribute further to the US's lead in this area."

"I have wonderful quantum computing colleagues in China who seem as open as can be, but collaboration is hard"

Aleks Kissinger at the University of Oxford says he and colleagues have been warned by the university to watch for approaches by potential foreign spies, and he is concerned that simply publishing research could fall foul of the vague wording of current export controls. "It's almost entirely up to interpretation," says Kissinger. "And that's kind of pouring some cold water on people wanting to start up big international collaborations."

A semi-secret service

The tense situation is also affecting commercial operations. Richard Murray at UK quantum computer startup Orca Computing says that despite the fact current machines aren't sophisticated enough to get caught by export controls, he wouldn't consider selling to a Chinese customer. "There's sort of an unwritten rule, or a sort of gut-check that we all do about those things," says Murray. With the anticipation that quantum computers will eventually progress to the point that export controls apply, Orca has focused on working with European, Japanese and US clients, rather than push into markets like China. "It's incentivised us to be out there working with those countries. It presents less of a risk, both in terms of more long-term business, but also short-term questions asked [by the UK government]."

Celia Merzbacher at the Quantum Economic Development Consortium, a trade body for quantum companies, says that at this point in the burgeoning industry, openness and international collaboration would be a better approach to secure progress than shoring up national capabilities. "Sweeping trade barriers, including sanctions and export controls, and also subsidies to indigenous businesses, can slow innovation and threaten competition, which is bad for business," she says.

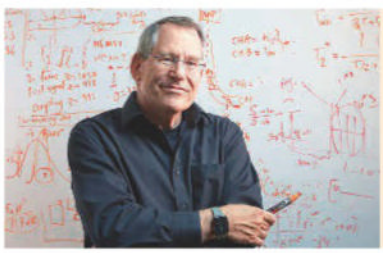
Overall, Kissinger says that concerns about the security threat of quantum computers and the need for export controls are probably overblown – but the issue is that state secrecy means we don't know for sure why governments are putting limits in place. "NSA [the US National Security Agency] employs some very smart people who probably don't talk about what they do," he says.

The megaquop machine

One of the most respected voices in quantum computing has a new challenge for the field, finds **Karmela Padavic-Callaghan**

THE past decade has seen significant advances and investment in quantum computing, and yet the devices we have today essentially have no practical purpose. That is down to two main reasons: the first being that the qubits, or quantum bits, that make up today's machines still struggle with noise, or errors, that we are only just learning to correct. The second is that devices that could solve practical problems are expected to require many more qubits than even the biggest quantum computers currently have.

In 2018, John Preskill at the California Institute of Technology coined the phrase "noisy intermediate-scale quantum", or NISQ, to describe this current era of quantum computing – devices that are promising but imperfect, essentially a stepping stone towards larger machines that will crackle with fewer errors, eventually becoming "fault tolerant". Now, he tells *New Scientist* how he is setting his sights on the next era of quantum computing: the "megaquop machine".



GREGG SEGAL

Profile
John Preskill is director of the Institute for Quantum Information and Matter at the California Institute of Technology

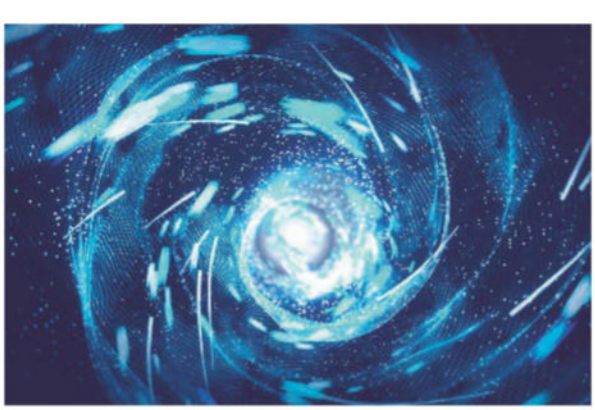
Your idea of the "NISQ era" has been fully embraced by the quantum computing field – was that a surprise?
I didn't expect the term to be so widely embraced, but I did feel like we needed a word to succinctly express the idea that we were entering the era where we had machines that could perform at least some tasks that were very hard to simulate with conventional computers. I was trying to emphasise the message that we're probably going to need fault tolerance to really run applications that most people will care about. But in the meantime, we had an opportunity to experiment with these NISQ machines and maybe find some things that they can do that are useful, at least to scientists and possibly to businesses.

Now you are calling for a device that can perform a million quantum operations, or the "megaquop machine". Why?
I think it's important to have goals like the megaquop machine, something to shoot for. Why did I choose a million operations? First of all, because I don't think we'll be able to get into that regime without using error correction and achieving fault tolerance. It is significantly beyond the quantum circuits that we can run without error correction, and it's kind of on the edge of where we can start to do simulations of matter that I think at least scientists will find significantly more informative than what we can do in the NISQ era. Right now, people have run circuits with about 13,000 operations but you've got to do a lot of error mitigation and the amount of physics you can get out is rather modest.

"We're going to start by using these machines to do science, and not necessarily for applications that affect the average person"

Does such a machine have a counterpart in the history of traditional computing?
Computers were developed in the late 1940s and early 50s, largely motivated by wanting to use them to simulate physical systems. That will be interesting with machines at the megaquop scale. Those will be the most important applications, with practical implications for chemistry and material science. There's something analogous to conventional computing there, in that we're going to start by using these machines to do science, and not necessarily for applications that affect the average person directly.

My other thought is, people often say that with quantum computing we don't have the transistor yet – we're still in the vacuum tube era or something – so there could be a technological shift that occurs when we come up with better quantum platforms that we can scale more easily.



YUICHIRO CHINO/GETTY IMAGES

No one knows exactly what the future of quantum computing looks like

How can the growing number of quantum computing companies be part of meeting the megaquop machine challenge?
People should be thinking about, OK, what can I now do that I couldn't do before? We should continue to try to apply some fresh thinking to what the applications are.

I have the concern that in the industry, there are overly optimistic expectations about the economic impact of quantum computing in terms of the time scale for reaching it. And that was true when we were talking about NISQ devices some few years back, and I think it's going to be true of early fault tolerance as well. I think we really have a long road ahead of us to get to real economic value.

If you woke up tomorrow and someone handed you a megaquop machine, what would you do with it?
I have an interest in quantum field theory and the new types of phenomena that occur in strongly coupled field theories. We have pretty good tools for conventional computers for simulating these theories in one dimension, but the tools in two dimensions are not very good at all for conventional computers. So, for me, that's an opportunity to do something interesting. The megaquop machine would maybe be a little short of what we'll need, but a good start for studying some phenomena that are just beyond the reach of conventional computers.

Botany

Rice variant slashes planet-warming methane emissions

James Woodford

A NEW strain of rice created by simple crossbreeding could reduce the crop's emissions of methane by nearly three-quarters.

Rice growing is responsible for about 12 per cent of anthropogenic release of methane, a gas that has a warming effect 25 times stronger than that of carbon dioxide. The emissions come from soil microbes in the flooded paddy fields where rice is grown. These break down chemicals known as root exudates released by the plants, producing nutrients that the plants can use, but also making methane.

To learn more, Anna Schnürer at the Swedish University of Agricultural Sciences and her colleagues grew two strains of rice in a laboratory: a Japanese cultivar called Nipponbare with average methane emissions and a genetically modified strain with low methane emissions called SUSIBA2.

SUSIBA2 produced less fumarate, a root exudate known to be a key driver of methane emissions, than Nipponbare. But when both strains were treated with a chemical that inhibits the breakdown of fumarate by bacteria, the SUSIBA2 strain still produced less methane. This meant there was another factor behind the difference in methane emissions.

It turned out that the SUSIBA2 crop was secreting high levels of ethanol, which also seemed to suppress release of the gas.

The team then bred a new rice strain using traditional methods rather than genetic engineering, by crossing a high-yield elite variety with a strain that produces low fumarate and high ethanol. Over two years of field trials in China, the new strain produced crop yields of more than 8 tonnes per hectare, compared with the global average of just over 4 tonnes, and it emitted 70 per cent less methane than the elite variety it was bred from (*Molecular Plant*, doi.org/n5ns). ▮

Zoology

Bonobos may also have theory of mind

Sophie Berdugo

BONOBOS are quick to help a person who doesn't know what they know, a sign that they can deduce the mental states of others.

The capacity to think about what others are thinking, known as theory of mind, is an essential skill that allows humans to navigate their social worlds. It enables us to recognise that someone

"This shows that they can take action when they realise somebody has a different perspective"

may hold different beliefs or perspectives from our own, underpinning our ability to understand and help others.

The question of whether our closest living relatives also have theory of mind has been hotly debated for decades. Despite some mixed results, non-human great apes seem to have some aspects of this capacity, suggesting it is more evolutionarily ancient than once thought. For example, wild chimpanzees that see a nearby snake, albeit a fake one, seem to call out to alert group members they know haven't already seen it.

But we have been missing clear evidence from controlled settings that primates can track a perspective that differs from their own and then act upon it, says Luke Townrow at Johns Hopkins University in Maryland.

To investigate this, Townrow and Christopher Krupenye, also at Johns Hopkins University, tested whether three male bonobos at the Ape Initiative research centre in Iowa could identify ignorance in someone they were trying to cooperate with, and then gesture to them to help solve the task.

On a table between the bonobo and an experimenter were three upturned plastic cups. A second researcher placed a barrier between the experimenter and the cups, then hid a treat, like a juicy grape, under one of them.

In one version of the experiment, a window in the barrier allowed the experimenter to see where the treat was placed. In another version, their view was completely blocked. If the experimenter found the food, they would give it to the bonobo, providing a motivation for the ape to share what they knew.

APE INITIATIVE

Nyota, one of the captive bonobos whose mental abilities were tested

Bolster cooperation

Townrow and Krupenye found that, over 24 trials for each version, the bonobos took 1.5 seconds less time to point at the cup after the barrier had been removed, on average, and pointed in approximately 20 per cent more trials when the experimenter's view was completely blocked (*PNAS*, doi.org/n5n2).

"This shows that they can actually take action when they realise that somebody has a different perspective from their own," says Krupenye. It appears that bonobos understand features of what others are thinking that researchers have historically assumed they didn't comprehend, he adds.

Finding this capacity in these three bonobos indicates that the potential exists within their biology and, it is very likely, the biology of our common ancestor as well, says Krupenye.

"It suggests that our ancient human relatives likely also had these abilities and could use them to bolster cooperation and coordination with one another," says Laura Lewis at the University of California, Berkeley. ▮

Space

Closest ever Einstein ring spotted

Stunning image shows rare phenomenon just 600 million light years from Earth

Alex Wilkins

ASTRONOMERS have identified the closest ever Einstein ring, a rare phenomenon where light from a further-off galaxy is bent by the gravity of a galaxy closer to Earth.

Thomas Collett at the University of Portsmouth, UK, and his team realised that the galaxy NGC 6505, which is about 600 million light years from Earth, was actually bending the light of a second galaxy behind it, about 6 billion light years from us (*Astronomy & Astrophysics*, doi.org/n5xw).

The Einstein ring – the circle at the centre of this image and in close up in the inset – was spotted while validating early testing data from the Euclid telescope, which has started scanning billions of galaxies over an area that will eventually span a third of the night sky.

"There was this abundantly obvious Einstein ring," says Collett. "This is probably the prettiest lens we will find in the mission."

ESA/EUCLID/EUCLID CONSORTIUM/NASA, IMAGE PROCESSING BY J.-C. CUILLANDRE, T. LI

Neuroscience

Brain cells found that may tell us to stop eating

NEURONS in the brains of mice tell them to stop eating when they have had enough food – and since people probably have these cells, we might one day be able to target them to help treat obesity.

The finding came amid a wider look at the brain. "The major question that we were seeking to answer was how the brain senses and responds to different signals," says Alexander Nectow at Columbia University in New York.

To learn more, he and his team used a type of molecular profiling to distinguish between different cell types in the brains of mice. In the dorsal raphe nucleus – a part of the brainstem linked to functions including eating, mood and sleep – they came across cells that produce a hormone called cholecystokinin, which helps regulate appetite.

To study what these cells are sensing to kick them into action, the researchers measured their activity as the mice went about their day.

"Every time the animals went for a bite of food, the activity ramped up and then decayed," says Nectow. "We are able to show that these neurons sense things like the smell and sight of food, the taste of food, the sensation of food in the gut and the neural hormones that are released in response to food in the gut, and leverage that information to actually terminate a meal."

Next, the researchers engineered the neurons so they could be switched on and off with light. When they used light to activate them, the mice slowed down their eating. The more intense the activation, the faster the animals slowed and then stopped (*Cell*, doi.org/g834gm).

Because the neurons sit in the brainstem, an ancestral feature that is similar across vertebrates, Nectow thinks we probably also have them. "Even though we haven't confirmed it, my guess would be that humans have these neurons, certainly."

"These neurons sense things like the smell, sight and taste of food, and if there is food in the gut"

The team also found that the mouse neurons could be activated by a compound called a glucagon-like peptide-1 (GLP-1) agonist, a type of drug used to treat obesity and type 2 diabetes, the most familiar being semaglutide, sold under brand names such as Ozempic and Wegovy.

If these neurons have the same function in people, we could, in theory, modulate them to control eating habits in those with obesity or even combine this approach with GLP-1-based drugs, to achieve greater weight loss, says Nectow.

Chris Simms

Archaeology

Mysterious ancestors of Europeans came from Ukraine

Michael Marshall

A HUGE trove of genetic data has revealed the origins of the people who were the ancestors of all modern Europeans. This crucial population was formed when multiple groups mixed in the region north of the Black Sea, in what is now Ukraine.

Modern humans arrived in Europe in three waves. The first wave were hunter-gatherers who arrived from about 45,000 years ago. They were followed by farmers who came from the Middle East starting around 9000 years ago.

The third and final group came from the steppes of central Eurasia. They emerged around 5300 years ago and spread to Europe over the next 1800 years. They are named for their characteristic pit burials: Yamna in Ukrainian or Yamnaya in Russian.

Iosif Lazaridis at Harvard University and his colleagues have spent the past decade compiling ancient DNA from 435 people from central Eurasia who lived between 8400 and 4000 years ago, to try to find out the origins of the Yamna.

"We didn't have a clear idea where they're coming from," says Lazaridis. "In order to understand where they're coming from, we have to sample the people [who came] before."

"Once the Yamna were established, they rapidly expanded in several directions"

The genetic data identified two key steps in the formation of the Yamna population. In the first, people from the Caucasus – the region between the Black Sea and Caspian Sea – moved north-west into what is now Ukraine. There they mixed with local hunter-gatherers, forming a culture called the Serednii Stih.

The Serednii Stih lived between the Dnipro and Don rivers. After about 1000 years, the Yamna emerged from one subgroup of the Serednii Stih.

In other words, the Yamna originated from the mixing of populations (*Nature*, doi.org/g835dw; doi.org/g836d4). "This 'homeland' is more like a contact zone than a homeland," says Lazaridis. "It's a diverse place."

Precisely where in this region the Yamna originated is less clear, he says. However, the team has tentatively identified an archaeological site called Mykhailivka on the eastern banks of the Dnipro in Ukraine. An individual from there was genetically Yamna but lived between 5300 and 5700 years ago, before the Yamna expansion. For this reason, Lazaridis calls Mykhailivka "a very good candidate for where this [mixing] has happened", but cautions "it's not a slam dunk".

Once the Yamna were established as a population with a distinctive culture, they rapidly expanded in several directions. Their use of wheeled carts pulled by horses seems to have been key: "These people with their horses and carts could go far fast," says Lehti Saag at the University of Tartu in Estonia.

The circumstances of this expansion are unclear. Some archaeologists have characterised the Yamna as murderous conquerors because in some cases Yamna genetic variants replaced other variants almost entirely. "There's a lot of discussion on this, and it is not entirely clear," says Saag.

In at least some regions of Europe, local populations declined before the Yamna arrived, for reasons unknown. "It might be that it was just that there were not so many people actually in Europe at the time when they came, so they didn't have to fight," says Saag. ▮

The ancient Yamna were herders from what is now Ukraine

ADARIUKOV OLEKSANDR/SHUTTERSTOCK

Technology

AI helps read volcano-scorched ancient scroll

Matthew Sparkes

AN ANCIENT Roman scroll has been read for the first time since it was charred in the volcanic eruption of Mount Vesuvius two millennia ago, thanks to artificial intelligence and a high-powered X-ray facility.

The papyrus scroll was one of 1800 rescued from a single room in the remnants of an ornate villa in the Roman town of Herculaneum during the 1750s, which is now the Italian town of Ercolano. All of them were carbonised by the heat of the volcanic debris that buried them.

Around 200 have since been painstakingly opened and read by mechanical devices based on clocks, which slowly tick and prise the scrolls open millimetre by millimetre.

Now, one scroll, known as PHerc. 172, has been imaged and analysed using machine learning algorithms. It was scanned at Diamond Light Source in Oxfordshire, UK, home to an extremely high-powered X-ray machine known as a synchrotron, and the resulting data was made available to participants in the Vesuvius Challenge – a competition with a $700,000 grand prize for interpreting text from scrolls.

This method is much better than opening the scrolls mechanically, says Peter Toth, a curator at the UK's Bodleian Library, where the scroll is kept. The main risk was moving the scroll from the library for scanning: "We were very, very nervous," says Toth. To transport it, a specially 3D-printed case was created and placed inside another padded box.

Researchers have so far revealed several columns of text, with about 26 lines in each column. Academics are now hoping to read the whole scroll, but can already make out an ancient Greek word that translates to "disgust". Toth suspects that it will relate in some way to the philosopher Epicurus, as many of the other scrolls found at the same site have. ▮

Health

A new way to slow ageing

Taking omega-3 pills alongside vitamin D supplements and exercise reduced biological age

Carissa Wong

A DAILY omega-3 supplement seems to slow biological ageing in older people, particularly when combined with vitamin D and exercise.

We already knew that omega-3s – "good" fats found in seeds, nuts and some fish – can boost our immunity, heart health and brain function. They have also been linked to changes in epigenetic markers, chemical tags on DNA that alter the activity of genes and, in turn, how cells behave. This suggests that omega-3s reduce the pace of biological ageing, often defined as a measure of how quickly someone's body is deteriorating compared with other people.

Heike Bischoff-Ferrari at the University of Zurich in Switzerland and her colleagues wanted to explore omega-3's effect on ageing further, as well as find out how it may work alongside vitamin D supplements and exercise.

"Omega-3 plays on multiple pathways of ageing, such as being anti-inflammatory. Similarly, vitamin D and exercise have multiple benefits," says Bischoff-Ferrari. "We thought, if you play on each of these differential pathways, do you get an additive benefit?"

YOSHIKAZU TSUNO/AFP VIA GETTY IMAGES

Exercise boosts the anti-ageing effect of taking omega-3

3 months

How much lower biological age was after three years of taking omega-3, compared with placebo

The team split 777 people in Switzerland, aged 70 to 91, into eight groups. On top of their existing lifestyle habits, each group was told to take varying combinations of a daily 1-gram dose of omega-3, placebo pills and 2000 international units of vitamin D. In addition, some groups were instructed to do 30 minutes of strength training three times a week.

At the start of the study, the team estimated the participants' biological ages using epigenetic clocks. These analysed DNA markers called methyl groups in blood that generally decline with age, impairing cell function.

By doing the same three years later, the scientists found that the participants who took omega-3 only had aged by around 3 months less, on average, than those who were only given placebo pills (*Nature Aging*, doi.org/g83wk7). They accounted for factors that could affect the results, such as the participants' actual age and sex.

"This is the biggest trial we have today that hints that a simple supplement contributes to slowing biological ageing," says Bischoff-Ferrari.

What's more, those who took omega-3 along with vitamin D and did strength training aged even less, compared with people who didn't introduce any of these habits. "The effect was somewhat more pronounced, almost four months of rejuvenation," says Bischoff-Ferrari.

These effects may seem small, but could be important for some, says Richard Siow at King's College London. "For an older person, in about three months, there could be a lot of age-related decline going on, so this becomes more significant," he says. ▮

Palaeontology

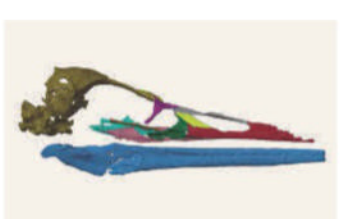
Ancient relative of geese is the earliest known modern bird

A 69-million-year-old skull found in Antarctica has been identified as a relative of geese and ducks, making it the oldest known modern bird.

It belongs to a species named *Vegavis iaai*, which was first identified two decades ago and lived in the late Cretaceous Period alongside the last dinosaurs. But as only skull fragments had been found previously, it was unclear what kind of bird it was or whether it was a bird-like, non-avian dinosaur.

The almost complete fossil skull was discovered in 2011 on Vega Island. However, it was encased in rock so hard that it took hundreds of hours of chipping away at the stone before the skull could be scanned to reveal its internal details.

Patrick O'Connor at Ohio University, who worked on the analysis, says two features of the skull only ever occur in modern birds. First, the upper beak is primarily comprised of a bone called the premaxilla, while a second bone, the maxilla, is greatly reduced in size and contributes to only a small portion of the bony palate.



C. TORRES AND J. GRONKE

Digital reconstruction of the *Vegavis* skull found encased in stone

Second, in modern birds, the forebrain is massive relative to the rest of the brain; in pre-modern birds and near-bird dinosaurs like *Velociraptor*, these areas are proportionally much smaller (*Nature*, doi.org/n5mp).

While *Vegavis* has features that clearly mark it as being in the same group of waterfowl as ducks and geese, it would have looked very different, says O'Connor. The bird's beak shape, jaw musculature and legs suggest it was highly specialised for diving for fish.

"It would probably be easily mistaken for modern grebes or loons, which are only distantly related to ducks," he says. ▮

James Woodford

Cosmology

Biggest object in the universe found

Spanning 1.4 billion light years, the structure may violate a fundamental cosmic assumption

Alex Wilkins

ASTRONOMERS have found the largest known structure in the universe. It is 1.4 billion light years across and contains nearly 70 galactic superclusters. It is also hundreds of thousands of times more massive than a single galaxy, such as the Milky Way.

Hans Böhringer at the Max Planck Institute for Physics in Munich, Germany, and his colleagues have named this cosmic structure Quipu after an Incan counting system made from knotted rope. Böhringer saw the ropes in a museum near Santiago, Chile, while he was working at the European Southern Observatory and thought it resembled the structure, which has a thicker main section and several thinner branching sections.

Over large distances, galaxies can clump together into clusters, which themselves can be grouped together into larger superclusters. Astronomers have previously mapped out several of these superclusters and found that they often link together into sweeping arcs or walls, such as the Sloan Great Wall or the Laniakea supercluster, which were the previous largest structures known in the universe.

"The Quipu superstructure, end to end, is slightly longer than the Sloan Great Wall," says J. Richard Gott III at Princeton University, who helped discover the Sloan Great Wall. "Congratulations to them for finding it."

"The Quipu superstructure is a very apparent structure. It immediately catches the eye"

To find Quipu, Böhringer and his team analysed data from the German ROSAT X-ray satellite, looking at galaxy clusters several hundred million light years from Earth. They worked out which might be part of a larger structure using an algorithm that defines a maximum distance each cluster can be away from another before we consider them not linked (arXiv, DOI: arXiv.2501.19236). "This was a very apparent structure," says Böhringer. "It immediately catches the eye."

Past discoveries of such large structures have caused arguments among cosmologists, who say that they are so large they violate one of our fundamental assumptions about the universe, called the cosmological principle. This says that, at very large distances, the universe should appear to be evenly spread out in every direction.

Cosmic superstructures, clumping together in uneven ways, would appear to violate this. But Böhringer sees no such problem, instead arguing we just need to consider the universe on even larger scales, and that similar structures can be found in the most accurate cosmological simulations. "Making observations in a too small part of the universe, which has been done earlier on, can be misleading," he says.

Part of the confusion comes from an ambiguous definition of the cosmological principle, says Alexia Lopez at the University of Central Lancashire in the UK. "There is not yet one definition of the cosmological principle that every cosmologist agrees on," she says.

Though the structure appears to be a single object, it is unclear whether the clusters in it are actually gravitationally bound together, says Seshadri Nadathur at the University of Portsmouth in the UK, which could prove problematic as the universe expands. "Some of those galaxies may drift apart from each other instead of collapsing in on themselves, in which case, according to some interpretations, it's not really a bound structure," he says. ▮

Technology

Prosthetic hand is able to open jars with ease

A LIGHTWEIGHT prosthetic hand that can move almost as freely as a human hand can help wearers carry out intricate tasks, such as tying knots, combing hair, opening jars and playing chess.

To replicate the dexterity of a human hand, most commercial prosthetics use electric motors or compressed air systems, which can make the system heavy and uncomfortable to wear for too long.

Now, Shiwu Zhang at the University of Science and Technology of China and his colleagues have developed a voice-controlled prosthetic hand that weighs just 220 grams – about half the weight of a typical human hand, but it can move in nearly as many directions.

To move its fingers and joints, the hand uses a shape memory alloy, a metal that changes shape when heated and then returns to its original form when it cools (*Nature Communications*, doi.org/n5nh).

"The shape memory actuators mimic the function of human muscles, enabling finger and wrist movements," says Zhang. "The prosthetic hand also employs a closed-loop control system that senses joint angles in real-time, facilitating precise and coordinated movements."

This alloy helps the hand's fingers to move in more complex ways, such as spreading fingers apart, which means they can do intricate movements that other prosthetic hands struggle with, like opening an elastic band with three fingers or manipulating a piece of string.

HAO YANG/USTC

A woman who tried the hand for 5 hours reported no discomfort

A woman with a right arm amputation trialled the prosthetic over 5 hours and was able to carry out tasks like writing, playing chess and combing her hair, without reporting discomfort.

"One of the main criticisms of prosthetic hands is how weighty and heavy they are and [the researchers have] managed to reduce the weight of their hand, which is great," says Cheryl Metcalf at the University of Southampton, UK. ▮

Alex Wilkins

Zoology

Songs of humpback whales follow language patterns

James Woodford

TONY WU/NATURE PICTURE LIBRARY/ALAMY

Male humpback whales sing, possibly to attract mates

HUMPBACK whale songs have statistical patterns in their structure that are similar to those in human language. While this doesn't mean the songs convey complex meanings like our sentences do, it hints that whales may learn their songs in a similar way to how human infants start to learn language.

Only male humpback whales (*Megaptera novaeangliae*) sing, and the behaviour is thought to help attract mates. The songs are constantly evolving, with new elements appearing and spreading in the population until the old song is replaced by an entirely new one.

Jenny Allen at Griffith University in Gold Coast, Australia, and her colleagues looked for innate structural patterns in these songs that may be similar to those seen in human language. They analysed eight years of whale songs recorded around New Caledonia in the Pacific Ocean.

The researchers started by creating alphanumeric codes to represent every song from every recording, including around 150 unique sounds in total. "Basically, it's a different grouping of sounds, so one year they might do grunt grunt squeak, and so we'll have AAB, and then another year they might have moan squeak grunt, and so that would be CBA," says Allen.

Once all the songs had been encoded, the team used an analysis technique that applies to how infants discover words, called transitional probability.

"Speech is continuous and there are no pauses between words, so infants have to discover word boundaries," says team member Inbal Arnon at the Hebrew University of Jerusalem. To do so, they learn which sounds are more likely to occur together as part of the same word. For example, in the phrase "pretty flowers", a child can intuitively recognise that the syllables "pre" and "tty" are more likely to go together than "tty" and "flow".

> **"Amazingly, it followed the same distribution found across all human languages"**

Using the alphanumeric versions of the whale songs, the team calculated the transitional probabilities between consecutive sound elements, making a cut when the next sound element was surprising given the previous one. "We then looked at their distribution and found, amazingly, that they follow the same distribution found across all human languages," says Arnon.

In this pattern, the prevalence of less common words drops off in a predictable way. The other striking discovery is that the most common whale sounds tend to be short, just as the most common human words are (*Science*, doi.org/g836sc).

Nick Enfield at the University of Sydney, who wasn't involved in the study, says it is a novel way of analysing whale song. "What it means is that if you analyse *War and Peace*, the most frequent word will be twice as frequent as the next and so on – and the researchers have identified a similar pattern in whale songs," he says.

"I'll never forget the moment that graph appeared, looking just like the one we know so well from human language," says team member Simon Kirby at the University of Edinburgh, UK. "This made us realise that we'd uncovered a deep commonality between these two species, separated by tens of millions of years of evolution."

However, the researchers emphasise that this statistical pattern doesn't lead to the conclusion that whale song is a language that conveys meaning as we would understand it. They suggest the commonality could be because both whale song and human language are learned culturally. ▮

Physics

The perfect boiled egg takes more than half an hour to cook

Alex Wilkins

COOKING the best boiled egg involves moving it repeatedly between pans at different temperatures for at least half an hour – according to physicists.

"Many people have tasted [the egg cooked in this way], and they were amazed by the taste and the texture," says Ernesto Di Maio at the University of Naples, Italy. "This is how to properly do an egg."

Evenly boiling an egg is tricky because the yolk and white cook at different temperatures: the white requires heating at 85°C (185°F) for optimum consistency, but this can result in a hard yolk, which only needs 65°C (149°F).

Di Maio and his colleagues calculated the way energy spreads from the shell to the centre of an egg over time and found that switching it between boiling water and 30°C (86°F) water every

PELLEGRINO MUSTO/ERNESTO DI MAIO

Behold, the perfect boiled egg

2 minutes for 32 minutes would let the two parts cook separately.

When the researchers looked at eggs cooked in this way using spectrometry and an MRI-like scanner, they found that proteins in the egg yolk were less denatured and in the white they were more denatured, in each case meaning that part was better cooked than in soft-boiled eggs (*Communications Engineering*, doi.org/n5h6).

People who tasted the eggs said the white was slightly sweeter and the yolk less sweet than when cooked in other ways. The white's texture was described as similar to a soft-boiled egg, while the yolk was like a sous vide egg. ▮

Perpetual lunacy

The extraordinary new **C1 Moonphase** from Christopher Ward. A watch that tracks the moon for 128 years – without missing a beat. With an aventurine glass dial infused with copper oxide to represent the night sky. And a 3D 'moon' sculpted from Globolight© – a luminous ceramic – that precisely follows the real moon's journey across the sky. A watch this advanced can cost up to £45,000. But the C1 Moonphase starts from less than £2,000. As someone once said, you don't have to be mad to work here...

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Love in the time of AI

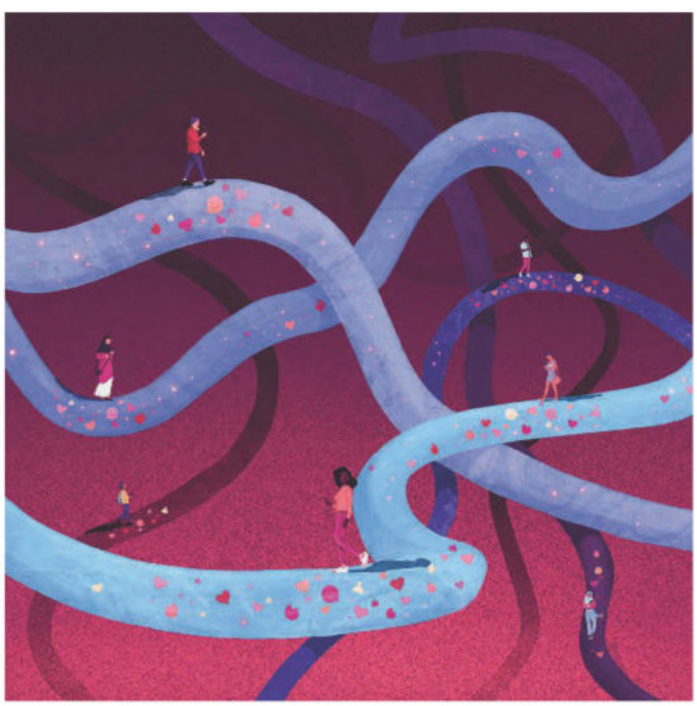
Dating apps have warped how we view romantic connections. Adding artificial intelligence could make things worse, argues **Luke Brunning**

FROM lawsuits to fumbled advertising campaigns, are we falling out of love with online dating? Recent Ofcom data showed a decline in UK users, and Gen Z seems to increasingly hanker after in-person romantic spontaneity. More broadly, the rise of online dating has been accompanied by growing social isolation and loneliness, as well as polarisation of attitudes between younger men and women on topics like the value of feminism or ideals of healthy masculinity.

To understand these changes, we need to recognise that dating apps have transformed how we connect in two ways: they make our search for intimacy radically private, and they widen our pool of compatible dates. The ability to interact with many people, free from scrutiny, makes the search for intimacy more calculating.

As dating apps have become less stigmatised, companies have gamified their platforms, making them instantly gratifying with "likes", "pings" and the sense romance could spark at any time. This keeps us on the apps and enables our attention to be a source of revenue. But gamified environments can become alienating as we hanker for new matches rather than deepening our existing relationships.

The desire for an advantage in the game of love leads many to purchase expensive tiered memberships. Yet most dating apps are frustratingly opaque about their algorithms and pricing. Is it really the case that paying £44.99 for a month's membership to Hinge means we will "go on 3x as many dates"? Where does that figure come from?



SIMONE ROTELLA

Worryingly, the premise that you get what you pay for in online dating may contribute to expressions of male entitlement to female attention, which are often seen on dating apps, as money is spent but dates fail to materialise.

It's easy to think we would be better off without dating apps. But the industry remains buoyant. It thinks the answers to issues like loneliness lie in more tech, not less, with hopes that generative AI will help. This includes Match Group, owner of Hinge, Tinder and other dating platforms, suggesting AI will help "daters curate their photos and bios to better showcase who they are".

As someone who co-runs an academic network exploring the ethical impact of online dating, this approach seems mistaken. Dating apps arguably have a social role in facilitating genuine intimacy, but they must recognise their contribution to the loneliness crisis, address the harmful sides of privacy, commercial opacity and gamification, and be wary of creating new hazards.

One such hazard lies in neglecting the risks posed by AI, especially for vulnerable young people. Widespread use of AI to write dating bios and prompt conversations may turn apps into deeply inauthentic spaces where manipulation is easier than ever, worsening existing social biases, and leading to harmful expectations about body image.

If dating apps were less gamified, or we were nudged to take breaks, we would be better able to spend our attention on deepening our connections, not increasing matches. Apps should also be designed beyond the yes/no binary of swiping left or right, providing ways for the unsure or curious to connect. Unexpected connections may stem from more dynamic and explorable online spaces that give us more creative ways to express ourselves.

Dating app users pay too much to be lonely and frustrated. Before embracing generative AI, dating apps must solve the problems they created by innovating to connect us with more transparency and agency. They may be unwilling to do so, since their current design means the more we swipe, the more they earn, but if they don't, they are unlikely to survive rising apathy towards online dating. ▮

Luke Brunning co-runs the Centre for Love, Sex, and Relationships at the University of Leeds, UK

Future Chronicles

Payback time By the 2030s, a wave of litigation led by artificial intelligence was forcing Big Oil firms to pay billions in damages for their emissions, says our guide to the future, **Rowan Hooper**

Rowan Hooper is *New Scientist*'s podcast editor and the author of *How to Spend a Trillion Dollars: The 10 global problems we can actually fix*. Follow him on Bluesky @rowhoop.bsky.social

In Future Chronicles, he explores an imagined history of inventions and developments yet to come.

FOSSIL fuel companies were never going to voluntarily admit to their role in the climate crisis. By the late 2020s, people turned to two methods to force the issue. Illegal means involved sabotage, destruction of oil infrastructure and more. Legal methods focused on litigation to force governments to comply with emissions targets and on corporations to pay reparations for past damage. If the energy policies of the 47th US president, Donald Trump, were "drill, baby, drill", the reply of climate lawyers was "sue, baby, sue".

The problem at first was that Big Oil firms deployed armies of lawyers to challenge every aspect of a case brought against them. Most plaintiffs simply couldn't afford to continue, or else became bogged down in litigation for years.

The solution came when artificial intelligence was used to build and prosecute cases. Big Oil may have had extensive human representation, but AI lawyers were even more numerous, faster, consumed evidence more comprehensively and never slept. They could be deployed on behalf of people who couldn't afford a lawyer, bringing cases based on novel and arcane aspects of law.

The use of an AI tool in law started in earnest in 2023, with the release of a ChatGPT-based AI called Harvey. The take-up of Harvey by human lawyers grew rapidly and it helped litigation by suggesting legal precedents and strategies.

Climate cases fell into three categories. First, challenging disinformation. A 2021 investigation by the US House of Representatives oversight committee found that Big Oil companies had engaged in extensive greenwashing and misinformation campaigns – but holding the firms to account was difficult. Second, action against governments for failing to protect their citizens. A key case establishing precedent for this was when Urgenda, an environmental group, successfully sued the Dutch government in 2015 to force action on climate change.

The third category was around liability for the cost of climate damage. A vital development came as the science of climate attribution improved. It hadn't previously been possible to draw a line connecting emissions from individual firms to the financial impacts of global warming, such as floods. When, in the mid 2020s, it became possible to determine the financial and humanitarian impact of climate change, litigation became feasible. For example, work by Friederike Otto's World Weather Attribution team showed that floods in Pakistan in 2022 that killed at least 1500 people and caused over $30 billion in damage were made 50 to 75 per cent worse by the climate crisis.

"AI litigation won cases by showing that corporations hadn't prepared for the effects of climate change"

AI lawyers were deployed on all three strands. Local laws around the world were scoured by AI to identify avenues for litigation. One source of inspiration was a case that began in the 2010s in Peru. Human lawyers in Germany thought of using the German neighbourhood law, which allows nuisance behaviour by neighbours to be challenged in court. Since climate change affects everyone around the world, the crisis makes us all neighbours. Carbon emissions, the lawyers argued, fall under the neighbourhood law.

German energy giant RWE, determined by a report from Climate Mitigation Services to be responsible for 0.47 per cent of historical greenhouse gas emissions, was sued for 0.47 per cent of the cost of a dam and drainage system built to protect farms and villages from melting glaciers in the Peruvian Andes.

Non-human lawyers helped in cases that were bogged down in the courts. In the US at the start of the 2020s, dozens of lawsuits were brought against the fossil fuel industry. Many were held up by the defendants challenging every aspect of the legal arguments. By 2028, AI lawyers were able to instantly fight back on such challenges and, trained on the latest science and with access to millions of documents from Big Oil companies, could overcome the human resistance. AI litigation successfully prevented new pipelines and infrastructure being built and won cases by showing that corporations hadn't prepared for the effects of climate change.

Energy giants found themselves facing multiple lawsuits in dozens of countries. Their legal departments were overwhelmed. Just as Big Tobacco companies had eventually agreed to pay billions of dollars in damages, by the 2030s, Big Oil corporations were forced to start paying up.

The wave of litigation helped speed the transition to renewable energy, and forced the fossil fuel industry to pay billions of dollars to climate finance funds for lower-income countries. Climate justice – the redistribution of oil wealth to countries most affected by climate change – was seen to be done. ▮

This column appears monthly. Up next week: Chanda Prescod-Weinstein

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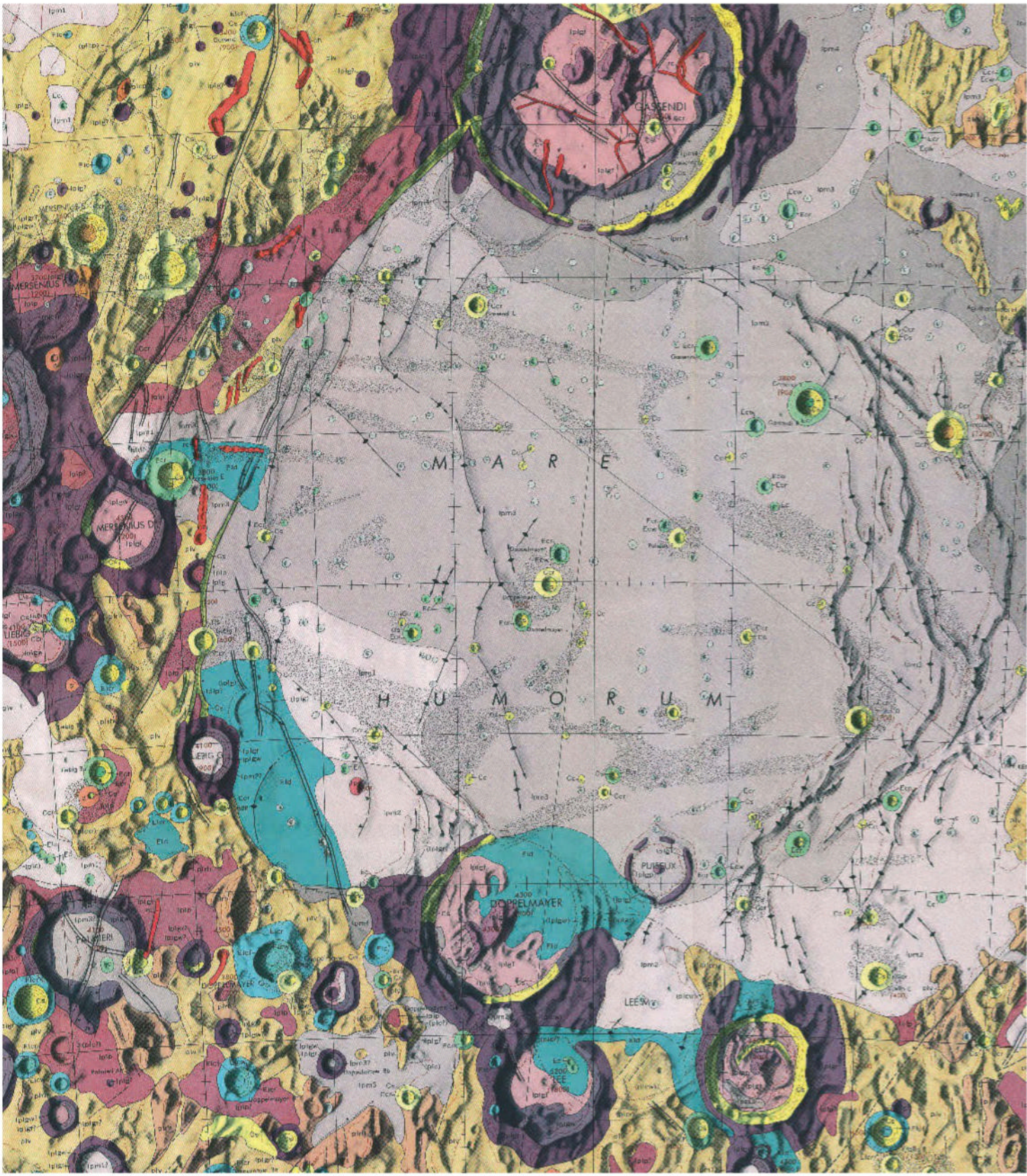

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Looking up

Thames & Hudson

WE WILL never stop thinking and talking about the moon, says Matthew Shindell, a curator at the National Air and Space Museum in Washington DC. "In cities where there is a lot of artificial light that tends to make it hard to look at the stars, the moon still shines very brightly above us," he says. "The moon still is this very constant presence in our nighttimes, no matter where we are."

Lunar: A history of the moon in myths, maps and matter, which Shindell edited, tells the story of this coexistence between humanity and the celestial body through a series of insightful essays, striking images and detailed maps of the moon's geological features. In these maps, the moon is divided into 144 sections called quadrangles, some of which were named as early as the 1600s, when cartographers started sketching what they saw through newly developed telescopes. In the 1960s and 70s, images captured by NASA astronauts during the Apollo moon missions offered a new perspective on our planet. The next few years will add chapters to the centuries-long story of our obsession with the moon: in 2025 alone, almost a dozen spacecraft teams plan to visit the lunar surface.

Clockwise from far left: the Sea of Humors, or Mare Humorum, quadrangle; Buzz Aldrin uses a lunar surface camera to take a close-up of his fellow astronaut's shoe, 1969; a view of Earth from the moon, captured by the Apollo 8 crew in 1968; and Edgar Mitchell and Alan Shepard during a lunar surface simulation training at the Kennedy Space Center in Florida, 1970.

Karmela Padavic-Callaghan

Spinning gold from fragments

Ancient Mesopotamia comes alive in a must-read history, cleverly wrought from tablets written in the world's oldest script, says **Emily H. Wilson**

Book

Between Two Rivers
Moudhy Al-Rashid
Hachette (UK, 20 February); W. W. Norton (US, 12 August)

A NEW and spellbinding book tells the history of the very ancient past of Mesopotamia, the land between the rivers Euphrates and Tigris. *Between Two Rivers* by Moudhy Al-Rashid, a researcher at the University of Oxford, weaves together the many strands of the story of the region, which covers much of what is now Iraq.

Ancient Mesopotamia has languished in obscurity, at least compared with the better-known Greek, Roman and Egyptian civilisations. So many world firsts, including the development of writing and literature, the invention of the wheel and scientific study, can be credited to it. And yet most would struggle to point to the region on a map.

One problem is that children aren't routinely taught about it at school. The sheer number of names of the area's various civilisations – Sumer, Akkadia, Assyria, Babylonia – can also serve to confuse. For security reasons, the sights of ancient Mesopotamia aren't on many tourists' itineraries, and even if they were, there is nothing so well-preserved as the Colosseum or Acropolis to be found.

What the region does have, though, is thousands of clay tablets, which have survived since antiquity. They may not glitter like gold, but they are covered in the most ancient writing system known to humankind, cuneiform, and they provide an astonishing amount of information about the dawn of the modern world.

In this new history, Al-Rashid takes full advantage of this to paint a fresh and very human portrait of the region. She shows how successive civilisations looked back on the history of these lands and used it for their own gain, with deep links to the past lending credibility to their institutions.

> "Cuneiform script helped bind the civilisations of Mesopotamia together across millennia"

Through her clever sifting of the texts, we see how cuneiform, and the formal languages associated with it, Sumerian and Akkadian, helped to bind these civilisations together across millennia. We see how official roles, for example the job of a high priestess to the god of the moon in Ur, persisted for thousands of years, and how, across civilisations, the duties of a king remained astonishingly constant.

We also discover, in Al-Rashid's vivid rendering of the texts, very moving details from the lives of real people in Mesopotamia over the ages. There is the couple forced to sell their children, and – mirroring that – a freed slave who goes to court in a bid to have her children join her in freedom. We are also furnished with details of everyday life for city schoolchildren and princesses alike.

We learn about midwifery, the struggles of merchant traders, the origins of the scientific method and also the use of war and propaganda to keep the powerful in power.

Al-Rashid's academic background gives her a wonderful confidence as she roves around the literary and archaeological evidence. She is also a gifted storyteller, able to spin a yarn of gold from the very fragmentary sources available.

In one of my favourite passages in the book, Al-Rashid records the last time we know of cuneiform being used in ancient times. I had known that the writing system was still in use until about the time of Christ, but Al-Rashid is more specific than that.

In about 80 BC, an astronomer wrote down the cuneiform sign for "king", and that is the last evidence we have for the script being used until it was decoded again in the 1850s. How utterly extraordinary, that a writing system that bound kings and queens across 3000 years would end (so far as we know) in that way.

This is a delightful book, and a must-read for anyone interested in these civilisations. I hope it serves to shine a larger spotlight on this extraordinary period in humanity's past. ▮

Right: An Assyrian stone carving
Below: The Great Ziggurat of Ur, in present-day Iraq

MOHAMMED AL ALI/ALAMY; ABOVE: SHUTTERSTOCK/VIACHESLAV LOPATIN

Emily H. Wilson is the author of *Inanna* and *Gilgamesh*, two novels set in ancient Mesopotamia. The third in the series, *Ninshubar*, will be published on 5 August

Post-human partners

Scott opts to be a cyborg; Susanna copes by filming the effects on their marriage. Is this modern love, asks **Bethan Ackerley**

Film

My Husband, the Cyborg
Susanna Cappellaro
Available to buy digitally from 14 February

STRIKE MEDIA

Pre-implant couple Scott Cohen and Susanna Cappellaro getting married

AROUND a decade ago, music industry executive Scott Cohen made a decision that rocked his marriage. His wife, actor and filmmaker Susanna Cappellaro, wasn't a fan of the two titanium piercings near his sternum – but they weren't the problem. Cradled by metal bars in his chest but not permanently anchored was a small circuit board Cohen co-developed that vibrated whenever he faced north. NorthSense, he said, would enhance his perception of the world and make him a cyborg.

Unnerved, Cappellaro decided to make a documentary about Cohen's post-human ambitions and how their relationship had been affected. For obvious reasons, *My Husband, the Cyborg* isn't an objective account of a relationship in turmoil. Instead, it is an intimate look at marital discord, captured in low-fi, often handheld footage.

At the outset, Cappellaro says Cohen has put a piece of technology between them. In that context, the documentary feels like an attempt at asserting herself. "To keep filming was my way to be part of this journey," she says. If he is to conduct this controversial experiment, she must be free to process it artistically.

Cohen seems to accept this, initially. It's an outré version of the uneasy trade-offs couples make all the time: one for you, one for me. But it isn't an agreement that always holds. Cohen seems deeply self-involved, yet he calls the documentary narcissistic. After his body repeatedly rejects the bars that secure his NorthSense, it becomes painful for the couple to hug, a problem that lasts for years. When Cappellaro says she misses their physical intimacy, Cohen simply tells her to adapt or outright denies anything has changed.

Cappellaro hits back often, particularly through the medium of the documentary. She volleys Cohen's accusations of narcissism back at him with gusto, and insists on filming as he nervously tells his parents about the project. Worse, she is careless about hugging or touching him despite his pain. There is plenty of ugliness on both sides.

Much of the time, the film focuses on Cappellaro as she debates whether to follow her husband down this post-human road. If she doesn't, could they support each other on separate, complementary joureys, holding hands across the divide, or does the only value of a marriage come from the things you share?

It is a complex question and the film barely scratches the surface. It would help if we knew what exactly was keeping the two together. We don't learn what they find attractive or compelling about each other. All we see are the clear cracks.

To understand her husband's decision, Cappellaro researches post-humanism, and interviews its proponents. This wins little credit. She buys Ray Kurzweil's 2005 *The Singularity is Near*, an influential text on artificial intelligence and post-human futures Cohen often references. He isn't keen to discuss its themes, only to disparage her taste for paper books. What's more, discussions she has with Cohen's fellow cyborgs are more fruitful and respectful than any with him.

Looking through Cappellaro's eyes, it is uncertain how responsible each party is for the breakdown in communication. What is clear is that Cohen doesn't just see his wife's experience of the world as different from his, but as lesser. He thinks she isn't ready to embrace her cyborg future – sensing north is like seeing in colour while his wife sees in black and white. She finds this silly, as, I think, will many viewers.

At times, *My Husband, the Cyborg* feels like being trapped at a dinner party with the most exhausting couple you know. But the longer the experiment runs, the better the film gets. This very modern (and very strange) love story makes for fraught and fascinating viewing.

New Scientist *recommends*

Chelsea Whyte
US editor
New York

Recently, at the **Brooklyn Botanic Garden** in New York, I had a dream come true. I got a whiff of one of the world's stinkiest plants: a corpse flower called *Amorphophallus gigas* (pictured), cousin of *Amorphophallus titanum*, which grabs headlines whenever one blooms.

The *A. gigas* I saw was standing about 2 metres high in a suffocatingly hot greenhouse. As I entered and took my first sniff, I must admit I was underwhelmed. It smelled only mildly unpleasant, a bit mildewy, certainly not the stench I had expected.

But corpse flowers give off their odours – meant to attract carrion-eating insects – in waves, and the next surge hit me hard. It was foul, a mixture of carcass and mould with a bit of baby poo thrown in.

My stomach turned and I had to rush outside to get some fresh air. That's one item off my bucket list!

Corpse flowers bloom infrequently, but they have been cultivated all over the world, so check local universities and gardens if you would like to smell one yourself.

CHRIS SPRINDIS/BROOKLYN BOTANIC GARDEN

The burden of proof

Turning rape into a crime that could be proved forensically is only possible because of one unsung woman, finds **Vijaysree Venkatraman**

Book

The Secret History of the Rape Kit

Pagan Kennedy

Vintage Books

JACLYN NASH/NATIONAL MUSEUM OF AMERICAN HISTORY

Rape kits are used to collect evidence of sexual assault for testing

WHILE writing *Inventology*, a book on inventions that create social change and the people behind them, Pagan Kennedy became fascinated by what she describes as "a piece of technology designed to hold men accountable for brutalizing women": the rape kit.

But who invented it? Newspaper reports credited Chicago police sergeant Louis R. Vitullo at the city's crime lab, but a few accounts mentioned a woman he collaborated with. Kennedy investigated, and the result is a cogent narrative about a feminist technology and its inventor. *The Secret History of the Rape Kit* is a gripping book on a grim topic, written with exemplary grace.

In 1972, activist Martha "Marty" Goddard, a volunteer for a Chicago teenage crisis helpline, realised that many of the runaways she encountered had fled home after being sexually abused. Goddard spoke to rape survivors, lawyers and hospital workers to gain insights into a crime that can leave people feeling hopeless, even responsible for their assault.

What if rape could be proved definitively? After much brainstorming, Goddard devised a forensic aid: a box with items such as swabs to collect fluids, a comb to pick up hair and envelopes to store biological evidence, which police labs could use to identify the attacker. At last, Kennedy writes, sexual assault could join the ranks of investigatable crime.

Not quite: "When Goddard gave a written description of the kit [to Vitullo], Vitullo 'threw her out of this office,' a source recalls," writes Kennedy. A few days later, she continues, "he presented her with a full model of the kit. It was exactly what she had described."

Goddard knew the kit needed Vitullo's imprimatur to succeed, so she threw herself into the work needed to ensure its widespread use. Everyone in the chain of investigation – hospital staff, crime lab personnel, police – had to be trained to use the kit and treat survivors with dignity. The public also needed to know about the right to forensic investigation.

> **"Could rape survivors use telemedicine to perform sexual assault examinations safely at home?"**

By the end of 1979, some 3000 rape kits were filed with the Chicago police, writes Kennedy. That same year, in a first for the "Vitullo Evidence Collection Kit", as the box had become known, an abducted bus driver testified against her rapist. He was sentenced to 60 years in prison.

DNA fingerprinting started to gain ground in the 1980s. It was a technology so accurate that "it could transform a murky allegation of sexual assault into a slam-dunk case", writes Kennedy. Already collected in the rape kit, the attacker's DNA gained greater weight as evidence. From 1998, US police could use a national database to hunt for matches to genetic material from other crime sites and identify offenders.

While all this increased the value of her invention, Goddard remained unrecognised because of her lack of credentials. She became depressed and dependent on alcohol. When she died in 2015, the number of untested kits in the US was estimated at 400,000.

Goddard had both succeeded and failed, writes Kennedy. Survivors of rape were coming forward in greater numbers to be tested, but at over $1000 per kit, testing was expensive, so police departments warehoused the kits. From 2010, when newspapers began writing about the backlog, women's advocacy groups stepped in to raise awareness and funds. In 2016, the US government allotted federal grants for testing, leading to identification and convictions.

But, Kennedy asks, what of the millions of rape kits that were never even filed? She acquaints us with new activists re-imagining the system. Could survivors use telemedicine to perform sexual assault examinations safely at home, avoiding long hospital waits that can traumatise people?

Like a detective on a cold case, Kennedy has done the legwork to paint a vivid picture of Goddard, whose invention brought hope to survivors of sexual assault. This compelling book could win fresh support to her cause: ensuring justice by convicting rapists. ▮

Vijaysree Venkatraman is a science journalist based in Boston, Massachusetts

Editor's pick

Fading diaper disgust or just plain, simple relief?

18 January, p 15

From Lerida Arnold, Swanage, Dorset, UK

A reduction in parental disgust as an infant develops isn't surprising, since breastfed babies tend to produce huge, explosive poos, which are like runny, yellow cottage cheese and can easily escape the nappy to coat the child, as well as their parent and surroundings. This often happens at inconvenient times, such as while at airport boarding gates.

Once weaned, babies make poos that usually emerge in more solid lumps that can be wrapped in loo paper and flushed away. Quick, easy and less urgent. I think the findings of the study you covered have less to do with disgust habituation and more to do with sheer relief!

Now for *Severance: The documentary*

25 January, p 30

From Maggie Cobbett, Ripon, North Yorkshire, UK

Like Bethan Ackerley, I am completely hooked by the TV drama series *Severance*. People I have discussed it with are mostly horrified by the concept of workers having their brains altered so their office/home life memories are strictly partitioned, but I confess that I can see the attractions.

While trying to balance the demands of work with those of a young family, I constantly worried that time necessarily given to either would be to the detriment of the other. The ability to switch off totally from one role when in the other might have been a blessing.

On the causes of depression

18 January, p 28

From Beth Morrell, Raleigh, North Carolina, US

Even if depression isn't caused by low serotonin, as Joanna Moncrieff sets out in the book you reviewed, I am glad to see some researchers have pointed out that this doesn't mean SSRIs, drugs commonly used to treat it, are ineffective.

In my view, the most obvious explanation for depression in the modern world is that we are in an environment grossly mismatched to the one we evolved for.

Smell and taste could be considered a single sense

25 January, p 23

From Sam Edge, Ringwood, Hampshire, UK

When it comes to the importance of our sense of smell, perhaps the majority of the taste of food and drink is predicated upon the aromas we experience before and during the act of consumption. This is why anosmia can lead to nutritional deficiencies, when all food seems too bland. In fact, one could argue that smell and taste should be considered a single sense since they are so closely related, both in terms of the sensory apparatus and the brain systems that process the data.

How to experience a good read at bedtime

25 January, p 32

From Geoff Harding, Sydney, Australia

Disappointingly, due to the disruptive effect of lighting, sleep experts discourage reading in bed, which no doubt many find the only time for this enjoyable pursuit. Perhaps the best solutions are ebooks with a blue-light-blocking mode or the audio version of *New Scientist*. In the latter case, a potential problem is the highly worrying content of some articles, for example concerning climate change or possible pandemics, which may give one a sleepless night.

The space race is using up much-needed resources

25 January, p 12

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

Rocket launches are deemed environmentally OK if hydrogen is used as rocket fuel, because it doesn't add to the carbon dioxide burden. However, the world must cut the total energy it consumes, and so any non-fossil fuel, such as hydrogen, ought to be used to replace fossil fuels in everyday life, not for a new space race.

Mars colony: Fiction may become reality

Letters, 25 January

From Nick Hunn, London, UK

Harm Schoonhoven raises the concern that people in a Mars colony would never be able to return to Earth. This eventuality was covered by *The Hitchhiker's Guide to the Galaxy*. In essence, its message was that those chosen to colonise a new world are those the home planet never wants to see again. Could history be about to repeat fiction?

Space-time's true nature is a bit baffling

25 January, p 10

From Denis Watkins, St Just in Roseland, Cornwall, UK

While the idea that the possible underlying structure of space-time could be to do with a strange geometric entity is fascinating, I suggest this raises another issue for many: the impossibility of comprehending the reality behind such descriptions.

Cheaper vanadium makes for a good flow battery

18 January, p 19

From Simon Goodman, Griesheim, Germany

Considering redox flow batteries, you state that they rely on "metals like lithium and cobalt, which are in short supply". In fact, many such batteries use cheap and common vanadium salts. This makes them attractive bulk electricity storage systems.

Glad to see the back of many worlds

11 January, p 32

From Ton Smit, Utrecht, Netherlands

I always found it hard to believe in the many worlds version of the multiverse that is proposed to explain quantum behaviour.

In essence, it says that a person, living on a tiny speck in the universe, measuring an even tinier subatomic particle that was in superposition, would create a new universe: a new Earth, sun, Milky Way, Andromeda nebula, etc. What's more, any intelligent alien on some distant rocky planet billions of light years away doing the same thing would create another me-reality. It is ridiculous in my view. Sorry.

Getting the measure of ultimate precision

25 January, p 17

From Phil Eden, Sheffield, UK

Your article on gauging vast distances with extreme precision says the 113 kilometres between two labs was measured to within 82 nanometres. I was wondering, was the measurement from the top of the grains of sand on the bricks or the bottom?

For the record

Efforts to rewild the Scottish Highlands with lynx are being led by the Lynx to Scotland Project (1 February, p 22)

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NASA

The universe on pause

A bold new idea suggests cosmic history contains hidden periods of stillness. If correct, it could explain the origins of dark matter and much more, says **Miriam Frankel**

ASK someone how the universe began and they will probably reply with those three familiar words: the big bang. But as recently as the 1960s, cosmologists hotly debated this matter. On the other side of the argument to the big bang was the idea of an unchanging "steady state" universe, the density of which was kept the same by continually adding new matter as it expanded.

In the end, observations ruled out the idea of a steady state universe and cemented the place of the big bang in the canon of cosmology. That primordial explosion started a process of continual expansion, and today cosmologists view the universe as a place of constant flux.

But now a bold group of cosmologists is questioning all that. To be clear, this isn't a return to the steady state universe, but something altogether more intriguing. The researchers are proposing that the universe's history may have been punctuated by spells of eerie stillness. These periods of cosmic stasis could arise in such a way that they replace whole epochs of conventional cosmic history or become spliced within that timeline.

Bold is certainly the word for this hypothesis. "It's pointing to a whole different family of possibilities that before this we didn't realise could happen," says Adrienne Erickcek at the University of North Carolina at Chapel Hill, who wasn't involved in the work. But if these static periods do exist, they could solve all manner of conundrums, including what dark matter is made of. Even more exciting, these ideas may soon be testable.

Before we write alternate histories of the universe, let's first lay down the traditional timeline. The big bang kicked things off some 14 billion years ago, causing space to balloon. As it continued, this expansion caused the universe's energy to shift its distribution between different forms. Today, cosmologists think of the history of the cosmos as being divided into a series of epochs, each of which is dominated by a different form of energy (see "History rewritten", overleaf).

The first was the inflation epoch, a period of rapid acceleration lasting a tiny fraction of a second. This was dominated by a form of energy intrinsic to the vacuum of space-time,

generated by a hypothetical elementary particle called the inflaton. After inflation, the universe underwent a reheating epoch, during which this vacuum energy was converted into matter, which then decayed to radiation. This led to the radiation epoch, so called because at first there was much more energy – in the form of radiation, such as photons – than matter. But as the universe expands, radiation dilutes quicker than matter, so, after about 50,000 years, this turned into the matter epoch.

Over the next 10 billion years, matter evolved in complexity from atoms and molecules to stars, galaxies and vast cosmic webs. But as the universe continued to grow, it eventually became dominated by another kind of mysterious vacuum energy called dark energy, which doesn't dilute as space-time expands. We live in this dark energy epoch, often considered to be the final era, in which the cosmos expands ever faster while matter incessantly dilutes.

In the eyes of most cosmologists, the passage between these epochs is an inevitable, unceasing march. "This has been standard lore since the beginning of [modern] cosmology," says Keith Dienes at the University of Arizona.

But the consensus that the universe's energy continually transmutes is now being challenged by Dienes and his collaborators: Lucien Heurtier at King's College London, Fei Huang at the Weizmann Institute of Science in Israel, Tim Tait at the University of California, Irvine, and Brooks Thomas at Lafayette College in Pennsylvania. In a slew of recent papers, the team raises the striking possibility that novel epochs characterised by stillness could have arisen for extended periods in our cosmic past – and may come about again in the future.

A balancing act

In these epochs of cosmic stasis, the amount of energy in the form of matter, radiation and even dark energy remains fixed, even though the universe is expanding. There is no single kind of energy dominating during periods of cosmic stasis. Instead, a peculiar kind of balancing act exists between them all.

It may seem forward to suggest rewriting cosmic history in this way, and to be fair, it wasn't originally the researchers' intention. They were initially investigating ideas to do with as-yet undiscovered particles. Specifically, they were interested in the idea of "towers" – sets of particles related to each other by certain properties, such as their masses. These could be the heavier "superpartners" of known particles predicted by a hypothesis called supersymmetry, for example, or a family of dark matter particles hiding in extra dimensions, such as "axion" particles manifested by string theory, which suggests everything is made up of vibrating one-dimensional strings. Axions are a possible explanation for dark matter, dark energy and inflation, among other puzzles.

It isn't clear if any of these ideas is right, but many physicists reckon there must be undiscovered particles of some description. "Dark matter is definitely a sign that the standard model of particle physics is incomplete," says Erickcek. "There are more particles out there than we thought".

In the spring of 2020, while working with Dienes, Heurtier simulated whether such towers of particles would affect inflation or its aftermath because of how matter decayed. "I started building a code, putting a lot of different particles in there," he recalls. "And we were always seeing in the simulation that matter and radiation would balance each other in a weird way." Whatever type of particle tower they began with, the simulation naturally evolved towards at least one extended period of stasis. "We literally ›

"It is even possible that we are entering or leaving a period of stasis now"

fell upon it – this is what the universe does if there are towers of particles," says Dienes.

In 2022, the five collaborators published the recipe for static epochs of matter and radiation. A year later, they showed that stasis still occurs if you add dark energy to the mix: matter, radiation and dark energy could all share the energy density of the universe in fixed proportions, without one taking over. They found that epochs of cosmic stasis may replace existing epochs or find themselves spliced within the orthodox timeline.

Why does this happen? Ultimately, stasis occurs because heavier particles in these towers decay into lighter ones, emitting radiation in the process. As described earlier, when the universe expands, radiation dilutes faster than matter. But in this new view, the shortfall in radiation is filled in by new radiation from decaying particle towers. Similarly, all those extra particles mean that matter doesn't dilute as quickly relative to dark energy, allowing the universe to also have a balance. "The idea that you could 'pause' the universe is really interesting," says Erickcek. "Usually expansion [means] evolution. Stasis is a counterexample to that: you can still be expanding and not change the energy balance of the universe."

There are many ways stasis can happen. Exactly when and how it appears depends on which ideas from beyond the standard model of particle physics you use, as that determines how many particles are in the towers, what the masses of those particles are and their rates of decay to lower levels in the towers.

It is even possible that we are entering or leaving a period of stasis now, says Heurtier. We know that the energy mixture of the universe has changed in relatively recent history because dark energy currently dominates, but a few billion years ago the universe was mostly made up of matter. Simulations show that large fluctuations like this can happen at the beginning or tail end of stasis periods, says Heurtier.

If we are leaving a period of stasis, or if stasis emerged during the matter-dominated epoch, this may help resolve a cosmological puzzle called the Hubble tension. This is a small but significant mismatch between how quickly we measure the universe to be expanding now and how quickly we expect it to be expanding. The expectation is calculated by taking measurements of the cosmic microwave background (CMB), an afterglow emitted 380,000 years after the big bang, and then winding the clock forwards until today. However, that calculation depends on assumptions about what the energy content of the universe was immediately before, during and after the CMB was produced. "Perhaps this extrapolation is wrong because the traditional models haven't taken into account periods of stasis during which different kinds of energy coexist," says Heurtier.

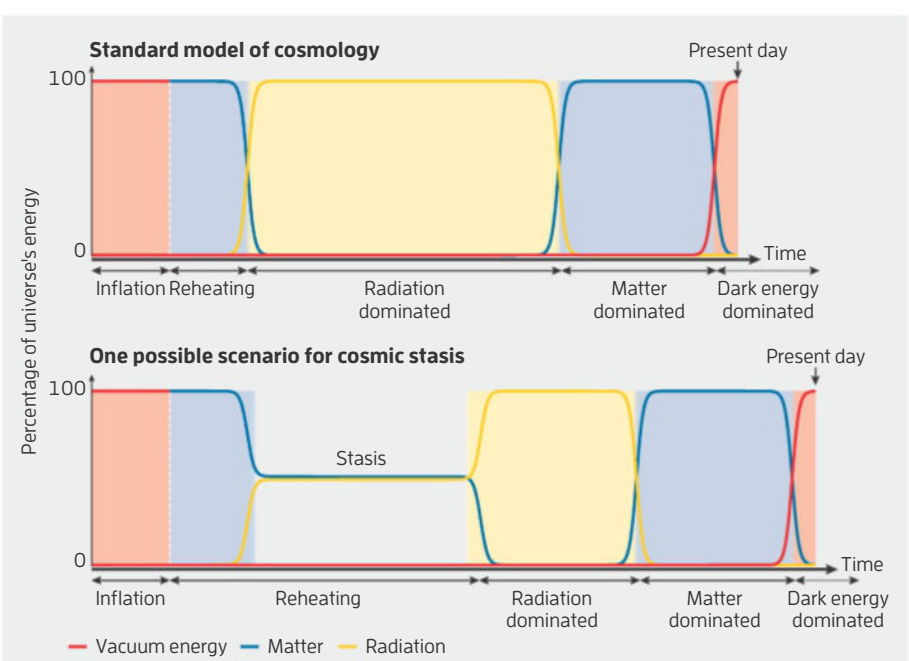
What we do know is that stasis can't happen in the period just before the CMB was emitted. Astrophysicists have made very precise measurements of this radiation, which neatly aligns with radiation measurements from an even earlier period, when light atomic nuclei such as helium were first created, called the big bang nucleosynthesis. All radiation is accounted for within this window of time, but stasis, by definition, requires the production of new radiation, either from decaying matter or, in some models, from dark energy. So these measurements rule out stasis epochs between 1 minute and 380,000 years after the big bang, says Erickcek.

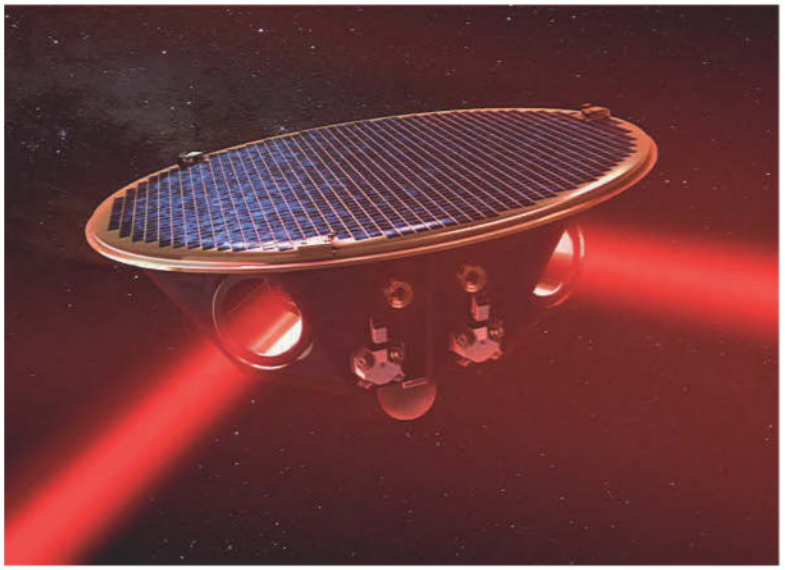
This means a period of stasis is more likely to come about during that first minute before big bang nucleosynthesis – a pause after the big bang, if you will. "That is when we're imagining these things would have occurred," says Dienes. Although that sounds like just the briefest flash in time, this first minute was exceptionally consequential.

That becomes clear when you think of the past in cosmologists' preferred measure of time: the "*e*-fold". This way of thinking allows us to talk about the universe's age in terms of how quickly it expands, with each *e*-fold corresponding to the universe's volume increasing by a factor of roughly 2.718 – meaning it expands exponentially according

History rewritten

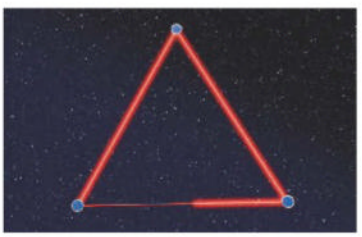
In conventional cosmology (top), the universe's history is divided into five epochs in which one form of energy dominates. But new research suggests that our past includes periods of stasis (below), where energy in the form of matter, radiation and vacuum energy were held in balance





AEI/MM/EXOZET; GW SIMULATION: NASA/C. HENZE

Wobbles in the lasers of the upcoming LISA telescope array may offer evidence of cosmic stasis



AEI/EXOZET EFFECTS

to the mathematical constant *e*. The universe's entire history has taken place over about 120 e-folds, but this first minute of existence would correspond to about 50 to 60 of those *e*-folds. In that sense, this period accounts for about half of the universe's history – any new stasis epochs that arise here may substantially alter the universe's age in *e*-folds.

We still know very little about what happened before the big bang nucleosynthesis, including how inflation and reheating took place. "We really don't have data about that," says Dienes.

In standard models of inflation, energy stored in the inflaton field starts the expansion. But it isn't clear exactly what this field is and why, after a tiny fraction of a second, it comes to an end. To explain that, physicists have to make a lot of assumptions, adding very specific features to the mysterious field. What's more, traditional inflation automatically dilutes both matter and radiation, leaving the universe cold and empty when it ends. To get around that, we have to assume that some sort of reheating process took place that populated the cosmos with matter and radiation again. Then, somehow, this period transitions to the radiation-dominated epoch of the traditional timeline.

If all that sounds like rather a post-hoc rationalisation, it is. Towers of particles which necessarily cause periods of stasis, however, could smooth things over. For example, particle towers produced during reheating would populate the universe with matter and radiation as they decay. Then, after the entire tower has decayed, only radiation would remain. "From this point forward, we would rejoin the standard timeline," says Dienes.

Similarly, decaying particle towers can naturally lead to a universe that contains a large proportion of vacuum energy. This would rapidly accelerate the expansion of the universe for a sustained period of time. In other words, according to the team's latest paper from June 2024, which is yet to be peer-reviewed, inflation could actually be a period of cosmic stasis.

Unlike conventional models of inflation, stasis explains how inflation ended without having to make extra assumptions. When the tower of particles has decayed, inflation ends of its own accord. And at that point, there would be loads of radiation present, so there is no need for reheating.

Proving the pause

Exploring periods of stasis is worthwhile, says string theorist Joseph Conlon at the University of Oxford. However, he points out that many of these models entail towers with very heavy particles that decay too quickly to have a cosmological impact. On the other hand, if the particles involved were light, they would produce large extra dimensions – and since those haven't yet been spotted, that is a mark against the hypothesis.

Still, there are several ways in which near-future observations could find evidence of cosmic stasis in its various forms, one of which involves gravitational waves. We now routinely detect these ripples in space-time, typically produced by the collision of massive objects such as black holes. And in 2023, a fainter hum called the gravitational wave background was detected. This lower-level oscillation of space-time may have been initiated during inflation, among other possibilities. In the next decade, space telescopes such as the Laser Interferometer Space Antenna (LISA) plan to map this background hum in detail in order to decipher its origin.

Dienes and his team are now figuring out how these observations would be affected by epochs of cosmic stasis. Adding new *e*-folds of time into the inflation epoch would change the predictions made by existing models, says Erickcek. Meanwhile, other periods of stasis would leave a unique imprint on the gravitational wave background, says Huang.

Another possibility is that early periods of cosmic stasis would alter how matter is structured on small scales because the presence of radiation tends to prevent matter from clumping. This means lumps of dark matter would be smaller than those predicted by standard cosmology.

Astrophysicists are becoming adept at detecting these slight differences by observing how dark matter warps the light from stars behind them, an effect called microlensing. Likewise, timing arrays based on pulsars, astronomical objects that emit bright bursts of radiation at well-defined intervals, can detect small changes due to gravitational tugs from lumps of dark matter. "It's hard – but there's hope," says Erickcek.

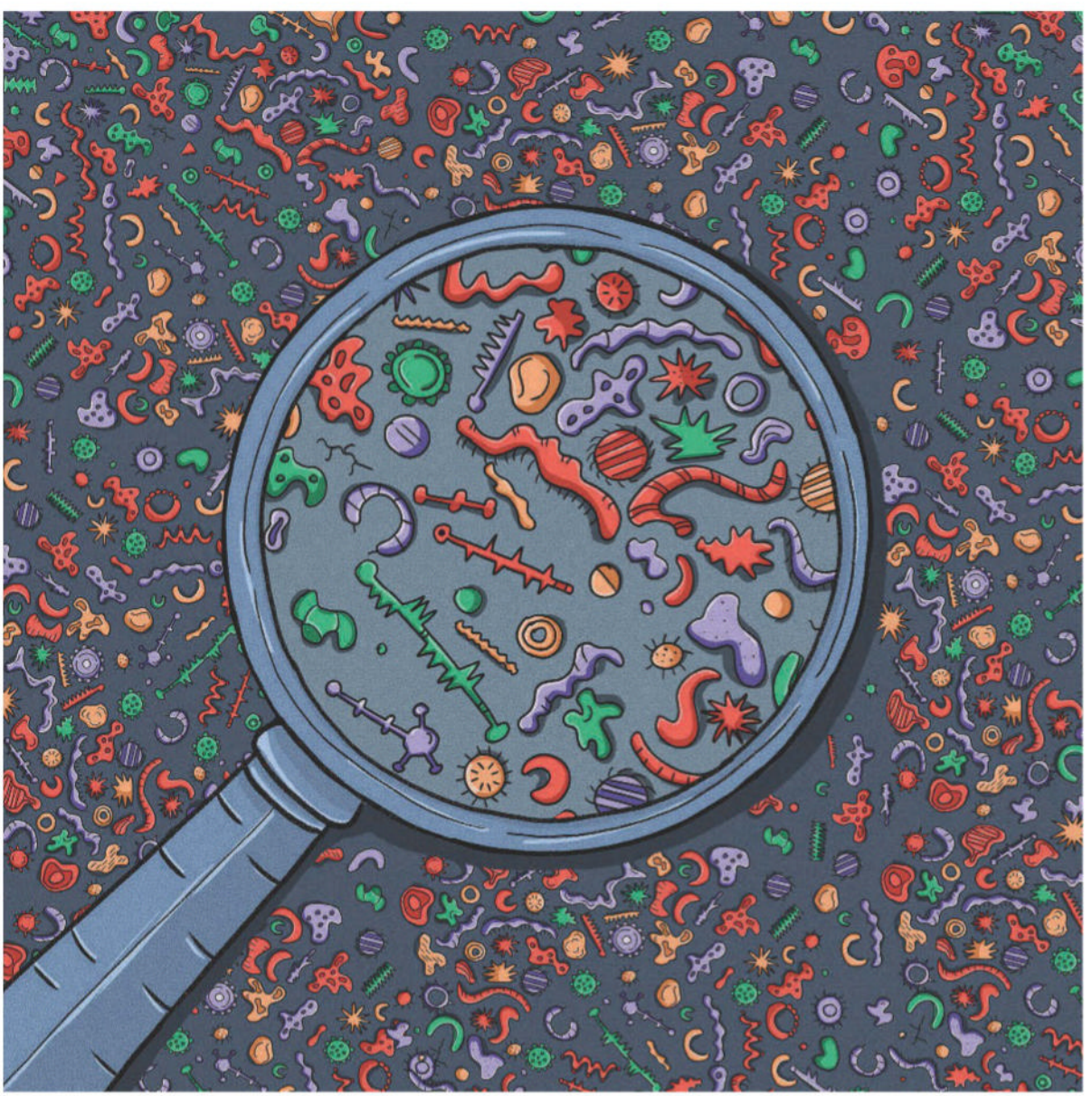
Already, others are beginning to explore the new paradigm of cosmic stasis. In August 2024, James Halverson and Sneh Pandya at Northeastern University in Massachusetts found that cosmic stasis arises from decaying towers of axions within models of string theory known as the axiverse.

Less than a century ago, the big bang seemed counterintuitive to most cosmologists. Now, the team who stumbled upon stasis hope that other researchers will embrace the unexpected once again and see that stillness may be as innate a part of the universe as change. Assuming that towers of particles exist, says Thomas, "some kind of stasis is likely going to be a part of nature". ▮

Miriam Frankel is a freelance science journalist and author based in London

Small wonders

Biologists are discovering microscopic entities even tinier than a virus. **Michael Marshall** delves into the boundary between life and non-life



NATALIA KOKKINOS

THEODOR DIENER had a problem. It was 1967, and he and a colleague had successfully isolated the infectious agent causing potato spindle tuber disease, which devastates crops. But it wasn't like anything they recognised. Although they called it a virus, it didn't behave like one.

It took Diener four years to demonstrate that the mysterious entity was something even simpler than a virus: a single "naked" molecule that could infect the cells of potato plants and thereby reproduce. He suggested calling it a viroid. It was the smallest replicating agent ever identified. At a stroke, Diener had expanded our understanding of life in the microscopic world.

You might think that such a dramatic discovery would go, er, viral. Yet hardly anyone noticed. Apart from a few other plant pathologists, the scientific world largely forgot about viroids for half a century. So obscure were they that, in 2020, when Benjamin Lee at the National Center for Biotechnology Information in Bethesda, Maryland, was advised to try looking into viroids, he had never even heard of them.

Since then, thanks to Lee and others, there has been an explosion of discoveries. We now know of thousands of viroids and viroid-like entities, with exotic names like obelisks, ribozyviruses and satellites. They appear to be everywhere, in a huge range of organisms and microorganisms. We have no idea what most of them are doing, including whether they are benign or dangerous. But these simplest-possible replicators raise fundamental questions about what it means to be alive. They may even date back to the origins of life.

Part of the story of biology over the centuries has been the quest to find smaller and smaller life forms. It began in the 1670s when Antonie van Leeuwenhoek, a master of microscopes and lenses, observed tiny "animalcules" living in rainwater. Biologists eventually realised that these were single-celled organisms, which include bacteria and yeast. The most minuscule are just a few micrometres across, but they are incredibly intricate, containing hundreds of different kinds of molecules – including the DNA that carries their genes.

Smaller and smaller

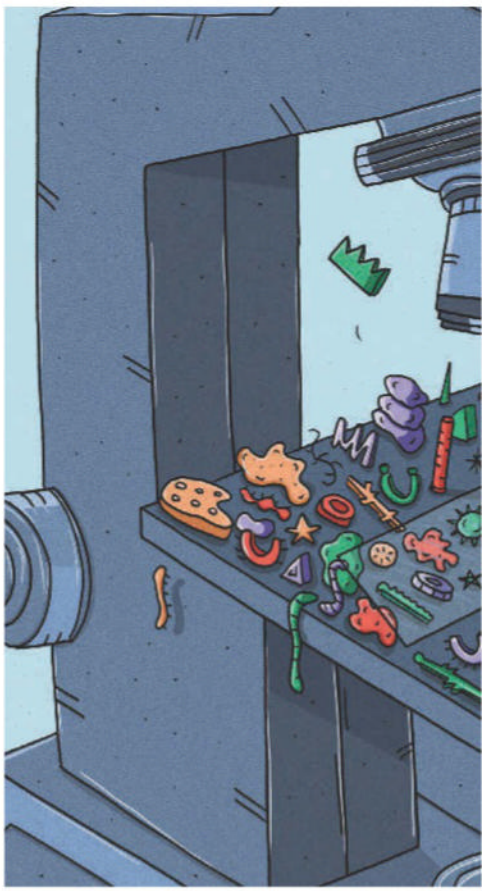
It would be more than two centuries before botanist Dmitri Ivanovsky discovered something even tinier. In an attempt to find out what was causing another disease in potato plants, he managed to catch the culprit using an incredibly fine filter. In 1898, microbiologist Martinus Beijerinck gave this kind of infectious agent a name: virus. Viruses consist of a piece of genetic material – either DNA or a similar molecule called RNA – encased in a shell, or capsid, made of protein. They are often a tenth of a micrometre across and some are even smaller. On their own, they can't multiply. But if they infect a living cell, they can take over its internal machinery and use it to make thousands of new viruses. The cells are destroyed in the process, explaining why viruses can cause serious illness.

Viruses pushed the limit of how small a living thing can be. But, seven decades later, with Diener's discovery of viroids, the envelope began to expand (see "Denizens of the invisible realm", p 37). Viroids consist of a strand of RNA without even a capsid. Like viruses, they replicate by entering a host cell and subverting its systems. But the precise mechanism is different because the RNA of a viroid is circular. The viroid takes over an enzyme that the host uses to make its own RNA, which then "walks" around the circular RNA, copying it as it goes to create a long, ticker-tape-like strand of RNA with many repetitions of the viroid sequence. This is cut into pieces, each one holding a single copy of the viroid's RNA, and these then form loops. Electron microscopes sometimes show viroids as rod-shaped, indicating that the loop of RNA is further twisted and folded.

The way viroids work is unique and their tiny size unprecedented. But for decades, nobody paid them much notice. Even within biology, they were a niche subject. Viroid research proceeded at a glacial pace for 50 years, says Zasha Weinberg at Leipzig University in Germany. He suspects that the lack of interest was partly because viroids seemed only to infect plants. However, in 2021, Weinberg and his colleagues published a study that changed everything.

The irony is that they weren't even looking for viroids. They were compiling information about ribozymes – RNA molecules that can also act as enzymes to speed up biochemical reactions – and were particularly interested in a group called hairpin ribozymes. Named after the shape the RNA strand is folded into, hairpin ribozymes were discovered in the late 1980s, yet until 2021 only four types were known. When the researchers trawled through a huge volume of genetic sequence data, both DNA and RNA, collected from different species over the years, they found 941 new ones – expanding the diversity more than 200-fold. On closer examination, these ribozymes were all found within circular RNA sequences, just like viroids. But there was something distinct about them: their genetic sequences varied wildly in length, from 381 to 5170 nucleotides, whereas previously known viroids spanned just a few hundred nucleotides.

"5000 is crazy," says Weinberg. "There's something really different going on here." What's more, these "viroid-like entities" weren't confined to plants. Weinberg's team had found them in several ›



"Are viroids and their ilk alive? Should we view them as biological or chemical?"

fungi, narrow-headed ants, a marine sponge and a bristle worm.

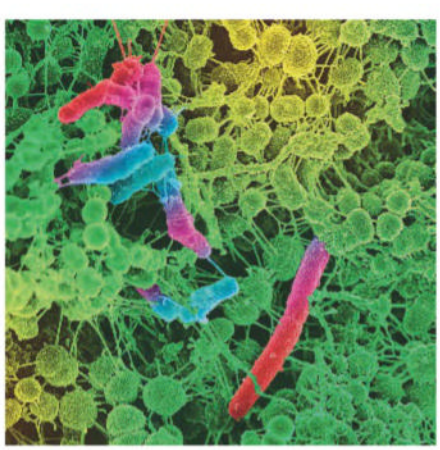
More discoveries followed over the next two years. When a new system designed to examine enormous volumes of genetic sequence data uncovered more than 100,000 new RNA viruses, it also found other strange entities called satellites. Although known about since 1960, satellites remain enigmatic. Superficially, they resemble viruses: a bit of genetic material is surrounded by a protein shell. But a satellite can only infect a cell if it pairs up with a specific virus.

Meanwhile, Lee and his colleagues had been actively searching genetic sequence data for evidence of new viroids. In 2023, they reported finding more than 11,000 viroid-like circular RNAs. Some of them appear to be classic viroids while others are probably satellites. The set also includes some "ribozyviruses" – these have circular RNA and replicate like a viroid, but also have a gene that codes for a protein shell, blurring the line between viroids and viruses.

In the same year, a team that included Beatriz Navarro at the Institute for Sustainable Plant Protection in Bari, Italy, and Lee reported new entities called ambiviruses, which they described as "hybrids of RNA viruses and viroid-like elements". Unlike classic viroids, they have a gene coding for the enzyme that copies their own RNA. Nevertheless, they are still reliant on a host to replicate – the team found them in fungi.

Last year, researchers discovered perhaps the oddest things so far. A team led by Andrew Fire at Stanford University in California identified entities in the human gut microbiome that, like viroids, are circular RNAs, but folded into a rod-like shape – earning them the name obelisks. Also unlike classic viroids, their genomes code for proteins, dubbed oblins, that bear no resemblance to any known protein, and whose function is a complete mystery. The researchers found 29,959 distinct types of obelisks.

Despite the sudden discovery of all these viroid-like entities, we have almost no information about whether most of them harm their hosts. Some viroids are known to naturally infect plants, resulting in crop losses. And in 2022, a team led by Wenxing Xu at Huazhong Agricultural University in Wuhan, China, reported viroid-like RNAs infecting a fungus, which, ironically, is itself a pathogen of plants. The researchers called them mycoviroids. Obelisks also seem to enter cells: Fire's team found some in bacteria called *Streptococcus sanguinis*, which live in our mouths. But, to date, very few actual experiments have been done with viroid-like entities – partly because interest in them is so recent and restrictions caused by the covid-19 pandemic have limited the time available for such work. "You can't rule out that there could be viroids that would infect humans," says Weinberg. But neither is there any evidence that they do.



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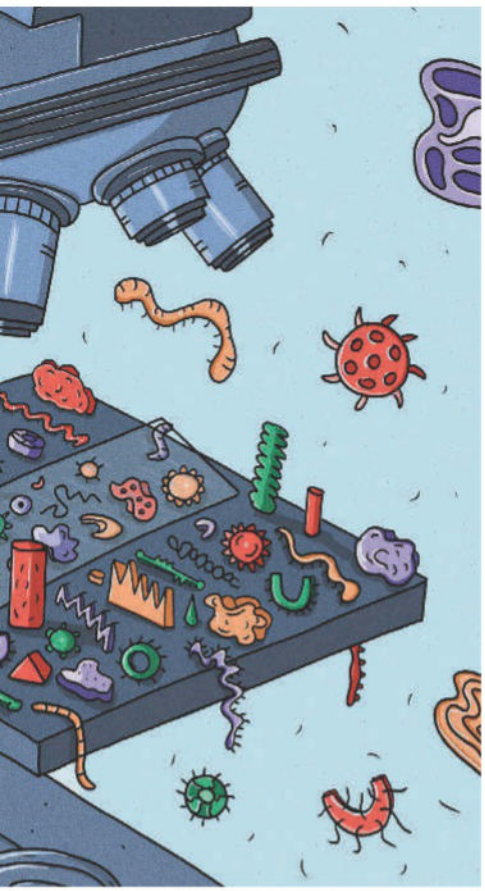
Bacteria in our mouths can contain viroid-like obelisks (not visible)

What this series of discoveries makes very clear, however, is that there are life-like entities that are even tinier than viruses – and they are everywhere. We don't know how many there are, not least because the available search tools work by looking for familiar genetic sequences, so they won't pick up entities with more peculiar kinds of RNA. "I think we're only scratching the surface," says Lee.

The flurry of findings has also created a lot of confusion. How can we subdivide all these different little things? Existing categories such as viroid and satellite don't capture the full variety. To add to the complexity, what starts as a viroid doesn't necessarily stay that way. "It's very likely that there can be transitions between categories of viroid-like entities," says Lee. For instance, a viroid could gain the gene for a protein, becoming a satellite or virus, then later revert back. The RNA sequences concerned are so short that they can readily be swapped around or evolve at random in a large population of viroids.

It is even unclear how we should think about the members of this sub-viral world. Are they



Denizens of the invisible realm

VIRUS: One or more strands of DNA or RNA, often wrapped in a protein shell, or capsid

VIROID: A circular strand of RNA, but without a capsid

SATELLITE: A viroid-like entity that is dependent on a true virus to replicate

RIBOZYVIRUS: A satellite with a circular strand of RNA encoding a single, specific type of gene

OBELISK: A circular strand of RNA folded into a rod shape, which produces mysterious proteins called oblins

VIROID-LIKE ENTITY: An umbrella term covering viroids, satellites, ribozyviruses, obelisks and more

alive or not? Should we view them as biological or are they just complicated chemistry? After all, many biologists baulk at the idea that viruses are living. "I personally believe that the definition of life should be dramatically expanded to include viruses and viroids, but that's by no means a consensus view," says Lee. "They're clearly biological replicators subject to evolution by natural selection and that's what matters for biologists."

The deeper issue is that nobody has yet managed to come up with a definition of life that a majority of biologists can get behind. "It maybe depends on the context of what scientific question you are asking," says Weinberg. But these strange little entities might help. There has been a growing move to treat life as a spectrum rather than a yes-no phenomenon. In which case, viroids and their ilk are at the base of things – they are more alive than rocks, but not as alive as bacteria or elephants.

Another obvious question is where all these viroids and viroid-like entities come from. There are two main possibilities. The first is that they form spontaneously inside living cells. Because viroids are short sequences of RNA, and all cells produce huge volumes of RNA all the time, it isn't inconceivable that viroid-like entities could form by sheer chance, says Weinberg. Lee and his colleague Eugene Koonin have argued that this is the most likely explanation, pointing to sequences in plant genomes called retrozymes that resemble viroids. "A replicator might basically grow legs and walk away," says Lee.

If this is true, many viroid species may have quite recent origins – even if the general phenomenon is ancient. However, Lee and Koonin wrote their paper before all the recent discoveries. "A lot of that was predicated on the fact that viroids were only found in plants," says Lee. We now know that isn't true. Instead, it seems viroids and viroid-like entities are universal. This suggests a second possibility, that they may be truly ancient, dating back to the dawn of life. "They have all the characteristics to be the first entities that replicate," says Navarro. They are small, making them easier to replicate without too many mistakes. Furthermore, "they are stable, because they are compact", she says.

Quite how life began on Earth is a profound mystery, despite decades of research into the question. One much-discussed hypothesis is that its origins lie in a so-called RNA world. This idea was prompted by the discovery of the first ribozymes in the early 1980s: the finding that RNA could act as an enzyme as well as storing genetic information made the molecule a good contender for the simplest form of life. Navarro and her colleagues believe viroids may be relics of that time. "Our hypothesis is that they are fossils of the precellular RNA world," she says.

Living fossils?

However, the idea remains unproven, and Lee says it has some major issues. Perhaps the biggest is that nobody has ever found a ribozyme in nature that can increase the size of RNA molecules – which would have been essential for a primordial viroid to self-replicate. Nevertheless, this has been achieved in the lab. Gerald Joyce at the Salk Institute in La Jolla, California, has used artificial evolution to modify ribozymes. In 2016, he and his colleague David Horning created one that could copy short RNA sequences. And in March last year, they evolved one that was able to copy an RNA sequence that included a ribozyme. "Those are demonstrably pretty easy to evolve," says Weinberg.

But if a ribozyme like this was essential at the dawn of life, asks Lee, why isn't it still around? He accepts that it could simply have died out, but also notes that life is both diverse and thrifty, so it is odd that we haven't found something like this clinging on anywhere.

For now, the question of whether viroid-like entities are living fossils from the dawn of life remains wide open. But, in a pleasing instance of circularity, this is exactly what Diener, the discoverer of viroids, suggested back in 1989. ▮

Michael Marshall is a science writer based in Devon, UK

Hello world

Advances in infant brain imaging are opening a door to the inner worlds of newborns, revealing that consciousness may arise earlier than expected, finds **David Robson**

MY FIRST memory is of my family moving house when I was 3 years old. I can picture the removal van at the gate with my brother in the front seat, and I remember worrying about how his pet rabbit would fare on the journey.

Before this moment, my autobiography is a blank page. At some point between my conception and that morning we moved house, I must have gained the ability to think, with an awareness of my body and its surroundings all knitted together into something we loosely call consciousness – but I have no idea when that occurred.

Most parents would assume that their newborn is conscious from the moment they hold them in their arms, but how do we really know? It is a problem that has been troubling philosophers for decades. "There's this general issue of, when did we begin? When did this stream of consciousness first emerge, if I can't remember it?" says Tim Bayne at Monash University, Australia.

The answers, however, haven't been forthcoming, with some researchers claiming it is already present at birth and others arguing it arises after our first year or later. Now, improvements to infant brain imaging are bringing clarity to the debate – suggesting an early origin of consciousness, perhaps even emerging just before birth.

Besides helping us imagine what life is like during those first moments of infant awareness, these insights help us to understand what consciousness is. "If you know when consciousness emerges, you can know what type of brain structures are necessary and sufficient," says Claudia Passos-Ferreira, a bioethicist at New York University.

First, some definitions. The inner life that you are experiencing now as a waking adult is a fusion of many different elements, including a sense of self. This is often assessed through the mirror test. A parent may put a little mark on a baby's nose, for instance, and place them in front of a shiny surface. If the child notices the mark and rubs it off, they have succeeded in recognising their own reflection – a sign that they have a sense of self.

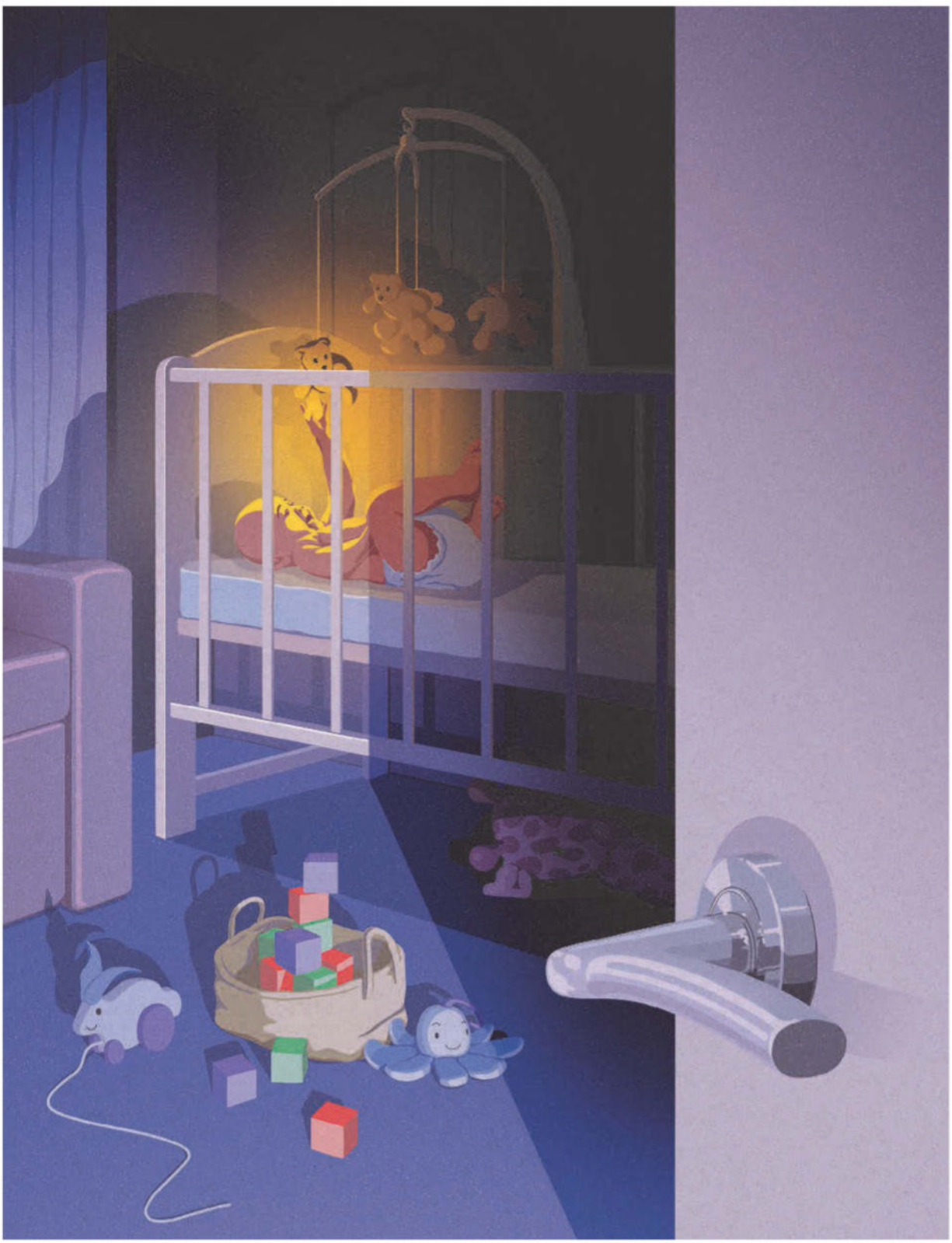
Most babies fail this test, while toddlers between around 18 months and 2 years of age can generally identify the mark successfully. Clearly, some of the experiences of consciousness that we take for granted need time to develop, even after we have been born.

Bayne and his colleagues are more interested in the origins of primary, or "core", consciousness. They define this as a subjective perspective comprised of distinct experiences of phenomena such as the taste of coffee or the scent of lavender. Crucially, the contents of each conscious moment are integrated into a single experience. When watching a violinist, for example, we experience the sight and sound together rather than feeling that they are part of two separate perspectives.

The origin of this core consciousness occurs when we start to be aware of any events inside and outside our bodies – such as the pain of colic or the calming sound of a parent's voice – and are able to distinguish between them.

For most of us, the point at which this happens may seem obvious. Babies cry when they are hungry and sleep when they are content. But in the not-so-distant past, the medical profession treated infants as if they had no inner world. Until the 1980s, for instance, surgeons would operate on babies without any analgesic or anaesthetic. The assumption was that painkillers weren't necessary, since babies couldn't truly feel discomfort. The protocol has now changed – but the question of when conscious awareness appears remains unresolved.

This is largely because we can't really know about a baby's inner life until they can talk and tell us what they are thinking or feeling. We can try to draw inferences from observation, such as the fact that newborn babies are more likely to turn their heads towards their mother's voice, compared with a stranger's. To some, this is evidence that consciousness has an early onset – but others remain sceptical that this reflects anything more than an automatic reaction, without any awareness. ›



PETER REYNOLDS

REUTERS/SWOAN PARKER

Understanding infant consciousness informs approaches to neonatal healthcare

"Babies have an annoying habit of wriggling, which degrades the quality of brain images"

Bayne and his colleagues suggest a practical approach to settle the debate. They point to recent research identifying four patterns of brain activity and behaviour associated with conscious awareness in adults. While none of these consciousness markers can, by itself, guarantee the presence of an inner life, taken together, they give a strong indication that someone is aware of their surroundings. And if we can identify the same markers in babies, then we might assume that they also possess core consciousness.

"We may, in the fullness of time, develop a kind of crucial test that can act like a thermometer for consciousness," says Bayne. "But we're a million miles away from that right now, and so I think the best way to go is to look for lots of different tests, and if they all point in roughly the same direction, then you know you're onto something."

The first consciousness marker that Bayne and his colleagues considered concerns the ways that different brain regions temporarily link up into working networks. Brain scans reveal that, when we are at rest and daydreaming, the default mode network (DMN) takes over. If something captures our attention, the executive control network (ECN), which is a set of brain areas responsible for goal-oriented thinking, comes online in combination with the dorsal attention network (DAN). People who are asleep and dreaming, which is considered by most to be a conscious state, show this ebb and flow of activity between the DMN and the ECN and DAN, but those under anaesthesia don't – leading Bayne and his colleagues to select it as a marker of consciousness.

Measuring brain activity in babies is no mean feat. In the past, fMRI scanners required the subject to sit very still, but babies have an annoying habit of wriggling. "Movement degrades the image quality," says Lorina Naci at Trinity College Dublin, Ireland. Improved algorithms, however, allow scientists to correct for the baby's motion, resulting in a much better view of their brain activity.

Asleep but aware

In 2022, Naci and her colleagues analysed brain images of more than 280 full-term newborns as they slept in an fMRI scanner, finding that the hallmarks of the DMN, DAN and ECN – and the reciprocal activity between them – were already in place. Interestingly, this was also true of preterm babies once they had reached the equivalent age, but not before. "There was a lower limit," says Naci. This suggests that, in a typically developing fetus, the networks may develop in the very last stage of pregnancy.

The mere presence of these networks doesn't reveal much about the contents of a baby's awareness or the way they are perceiving the world. This comes from the team's second marker, which concerns the neural activity associated with a shift in attention. A core element of conscious awareness is the ability to move our focus from object to object in our surroundings. Measuring this is simple – just observe the changes in participants' gaze as they look at different stimuli. In adults, the shift tends to correspond to heightened activity in the frontal cortex, a brain region responsible for many higher-level cognitive functions. Crucially, in 2021, researchers found very similar activity in 3 to 12-month-olds.

Bayne and his colleagues' third marker is "multisensory integration". Our brains often combine incoming information from different organs, meaning that signals from one sense can influence the conscious perception of signals from another. In experiments with adults, for instance, participants were asked to watch a video of someone saying one sound (such as "ba-ba") but listen to the audio of them saying another (such as "ga-ga"). Most people perceive "da-da" as a mental compromise between the conflicting stimuli – a phenomenon known as the McGurk effect.

It is trickier to do this test on babies as they can't tell us if they are perceiving "ba", "ga" or "da". But they often show a preference for sounds that feel familiar and remain focused on the source of such sounds for longer. So, if an infant experiences the McGurk effect, this should increase the familiarity of the "da" sound – enhancing their attention when it is played. In 2004, Denis Burnham at Western Sydney Univesity and Barbara Dodd at the University of Queensland, both in Australia, used this method to show that babies don't differentiate between the illusory "da" sound and the real thing. This strongly suggests that their brains are integrating the information from the different senses into a single, unified experience.

Bayne and his team's final marker of consciousness comes from an experiment using the oddball paradigm, which tests the mind's ability to keep track of patterns. It involves playing a series of tones, with intermittent variation over both short and longer periods. If you imagine it as a simple musical score, you might have a series of bars with three Cs, for example, followed by a D. That bar is then repeated multiple times until, one time, you have a new bar of four Cs – the oddball.

"There is a question mark over whether fetuses are conscious in late pregnancy"

Research in 2009 found that awake adults show a signature brainwave travelling across the cortex around 300 milliseconds after the short and long-term patterns have been violated with the oddball. This so-called P300 response to both pattern violations suggests the brain is keeping track of these sound sequences, and only appears to occur when people are conscious of what they are hearing.

To find out if young babies show the same neural reaction, Julia Moser at the University of Tübingen in Germany and her colleagues placed 20 newborns in a cradle of magnetic sensors that were able to measure small fluctuations in their brain activity as they listened to the sequence tones. Quite remarkably, they showed a neural response that was very similar to the P300, although the time lag between the oddball and the brainwave was longer than in conscious adults.

In a recent paper, Bayne and his colleagues argue that, taken together, these four lines of evidence would certainly seem to suggest that very young babies have conscious awareness. "The critical networks involved in consciousness were present and seem to be active much earlier than anyone had thought," says Bayne.

If consciousness is present at birth, it is reasonable to speculate whether it might also be present during the last few weeks of gestation. There is limited evidence supporting that idea. Using very sensitive magnetic sensors, it is possible to detect brain activity in the uterus. One study suggests that 35-week-old fetuses do seem to respond to oddball tests – although there are enough differences from the patterns seen in conscious adults that this conclusion remains controversial. Either way, the research has few implications for the debate on abortion, as interventions so late in pregnancy are rare.

Passos-Ferreira is open to the possibility that consciousness arises before birth, though she suggests the fetus might be sedated by chemicals within the protective amniotic fluid. These may inhibit neural activity without necessarily eliminating conscious awareness of external stimulation entirely. "My best bet is that they are conscious at birth, but there is a question mark over whether they have the capacity for consciousness in late pregnancy," she says.

Emergence of experience

The debate is far from settled, however. In a published response to Bayne and his colleagues' paper, philosopher Henry Taylor and psychologist Andrew Bremner, both at the University of Birmingham, UK, question whether it is fair to focus solely on the indicators of basic perceptual awareness without considering more sophisticated mental abilities. These might include intentionality, which is the capacity to complete an action in order to meet a goal, and explicit memory – the ability to recall an event and then replay it at a later point.

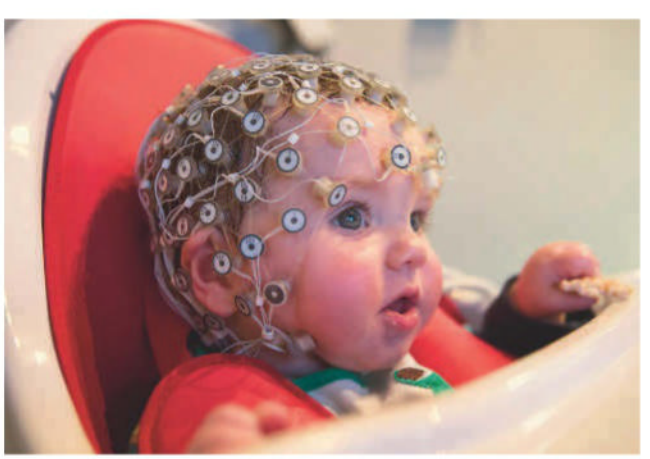
"If you think that consciousness is linked to some high-level cognitive abilities, which quite a lot of people believe, then you can make the case that newborn infants are unconscious," says Taylor. Unsurprisingly, your view on when consciousness emerges depends on how you define consciousness in the first place.

To try to find a more objective set of consciousness markers, Taylor and Bremner suggest looking more closely for correlations between the different markers. It could be that certain markers are present or absent independently of the others, which would suggest that they are less reliable as an indicator of consciousness, so can be discounted.

Alternatively, we may find that two markers always appear together, or that the emergence of one strongly predicts the development of others at an older age. This might reveal consciousness to be a gradual process, with the building blocks slotting together as the child's brain develops. "I'm pretty convinced that when you disambiguate all those different kinds of consciousness, you're going to find them coming online at different times," says Taylor.

Such investigations may help refine our definitions and theories of consciousness more generally. Integrated information theory (IIT), for instance, argues that subjective experiences emerge from the way data is processed and combined in the brain, so that the integrated total is more than the sum of its parts. Although the idea remains controversial, some researchers argue it is possible to estimate the amount of information that is being integrated from measures of neural activity – including those of young babies. Comparing this with the other markers of emerging consciousness and seeing how they change as a baby ages, could offer evidence for IIT – or indeed for competing ideas of consciousness, which abound.

Such advances may allow us to better understand what a baby's experience feels like. The research so far suggests that, if they have conscious experience, it may be very different from our own. Whereas adults have a very fine focus of attention, that of babies may be much more diffuse. In the words of the developmental psychologist Alison Gopnik at the University of California, Berkeley, it may be more like a "lantern" than a "spotlight", with a conscious experience that comprises a huge amount of sensory detail distributed more evenly across their environment. Or in other words, suggests Bayne, "perhaps everything's conscious all at once". ▮



OLI SCARFF/GETTY IMAGES

Caps with EEG sensors can record brainwaves associated with consciousness in infants

David Robson is the author of *The Laws of Connection: 13 social strategies that will transform your life*

Debunking gardening myths

Dissolve in water

James Wong had always dismissed the idea aspirin was beneficial to plants. But digging into the science brought some surprises

James Wong is a botanist and science writer, with a particular interest in food crops, conservation and the environment. Trained at the Royal Botanic Gardens, Kew, in London, he shares his tiny flat with more than 500 houseplants. You can follow him on X and Instagram @botanygeek

MOST of us will probably have heard of the 1980s tip of popping a soluble aspirin into the vase water of cut flowers to extend their life. Or, if you aren't quite as old as I am, maybe you will have come across what sounds like a hipster-era rebrand of the same idea, as an early 2010s internet "hack" for growing tastier tomatoes. Honestly, some permutation or other of this idea is all over the gardening internet.

The rationale behind this seems to be that what perks up humans must also do the same for plants, and I had always dismissed it as a far-fetched myth – along the lines of folk remedies that use similar spurious logic to claim that plant fertiliser must also make effective hair tonic. However, to my great surprise, when I looked into the science, there was a lot more to using aspirin in the garden than you might imagine.

Aspirin, or acetylsalicylic acid, is a synthetic derivative of salicylic acid, which is a natural compound found in plants. It's why extracts from willow, or *Salix*, trees, from which salicylic acid gets its name, have been used for thousands of years to relieve pain. But plants don't create this compound for our benefit. In their tissues, it serves as a trigger to set off chemical reactions that make them more resilient to environmental threats, such as attack from pests and disease, extremes of temperature and even drought. It's like the "on" switch to their equivalent of an immune system.

GAP PHOTOS/NICOLA STOCKEN

We now know that spraying or misting a wide range of crops in an aspirin solution causes them to behave just as if there were a spike in their own levels of salicylic acid, leading to a ramping up of their natural defences.

Perhaps more surprising, however, is that studies have shown aspirin doesn't just make plants more resilient, it can also improve the quality of their harvests, from tomato fruit with significantly higher vitamin C to cherries that were larger, redder and higher in antioxidants.

Although exact concentrations and application rates do vary between studies, on average it is roughly the equivalent of one 300-milligram soluble aspirin tablet dissolved in a litre of water, applied to plant leaves once every couple of weeks.

Ironically, the one thing the trial results aren't so positive about for aspirin is perhaps its most famous use: on cut flowers. While there have generally been mixed results in trials that used aspirin with a cocktail of other ingredients dissolved in vase water, when tested on its own, it usually fails to beat just pure tap water for flowers like chrysanthemums (pictured) and roses.

The moral of the story, for me at least? Plants will always surprise you, in all sorts of counterintuitive ways. So keep an open mind about even the weirdest-sounding gardening tips. ▮

Debunking gardening myths appears monthly

Next week
The science of exercise

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

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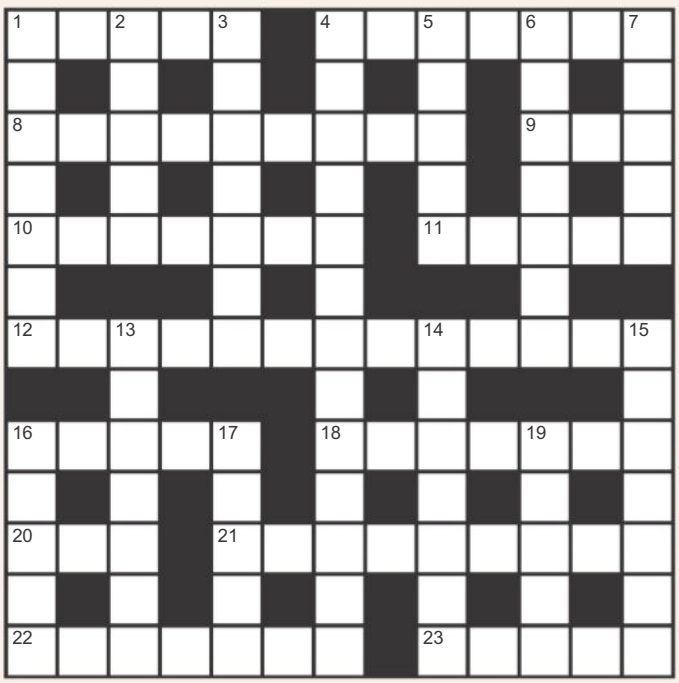
Cryptic crossword #155 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Bit of potato entertains male ape (5)
4 Fret anew about one-pound nut (7)
8 Curved pieces on car's rim cracked (5,4)
9 University invested in haemoglobin centre (3)
10 Hire leader of remarkably buff computer experts (7)
11 Gathering everyone inside railway termini (5)
12 Simple breakfast includes dude's fix relating to part of the nervous system (13)
16 Disputes part of a sentence at hearing (5)
18 Cabbage salad gets past my mentor's initial statement of resistance? (4,3)
20 Started inventory, overlooking sulphur (3)
21 Retracting error, little pest puts a lid on physicist's concern (5-4)
22 Female neighbours immure criminal element (7)
23 Excellent work put into retro merch items (5)

DOWN

1 Two-thirds of university city starting to collect material (7)
2 Myself, Oscar and Nick mostly like salt (5)
3 Upset a vat containing last of ether (7)
4 Translated oath informs Dr! (5,2,2,4)
5 Beam raised pole in concrete (5)
6 Position leech on boils (7)
7 Cat flap on vacant bakery (5)
13 College leader conceals a nuclear device (7)
14 Nursery brand used to make spam persuasive (7)
15 Look over grain specification in recipe (3,4)
16 Say, Chelsea almost entirely abandoned one on staff (1,4)
17 I post questionable hospital food (5)
19 Large mineral deposit surrounds source of Icelandic river (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #289
set by Corryn Wetzel

1 Name the key structural protein that helps form hair, skin and nails.

2 In which year did Luna 2 become the first human-made object to reach the surface of the moon?

3 What is the longest nerve in the human body?

4 Which mammal has the densest fur?

5 Who coined the term "cell" after viewing a piece of cork under a microscope?

Answers on page 47

BrainTwister
set by Peter Rowlett
#60 Say what you see

You have three cards labelled A, B and C. You shuffle them and deal them face down onto a table, saying "A, B, C" as you place each card. What is the probability that you say the name of at least one card as you deal it?

What if you add a fourth card , labelling this D, and say "A, B, C, D"?

With six cards you think of two ways to label them. You can have A, B, C, D, E, F and say in order "A, B, C, D, E, F", or have two As, two Bs and two Cs and say "A, B, C, A, B, C". Which is more likely to see you name at least one card as you deal it from a shuffled deck?

Solution next week

Nodding off

If humans needed to hibernate, how would civilisation have developed?

Hillary Shaw
Newport, Shropshire, UK
Cues to hibernate often include colder temperatures, but such biological signals are imprecise, so some individuals would go to sleep and, crucially, awaken before others. Humans are greedy and exploitative. Those in the tropics would probably not need to hibernate, so they and early spring risers in the temperate zones would have a ready source of slave labour: just kidnap and shackle those still asleep.

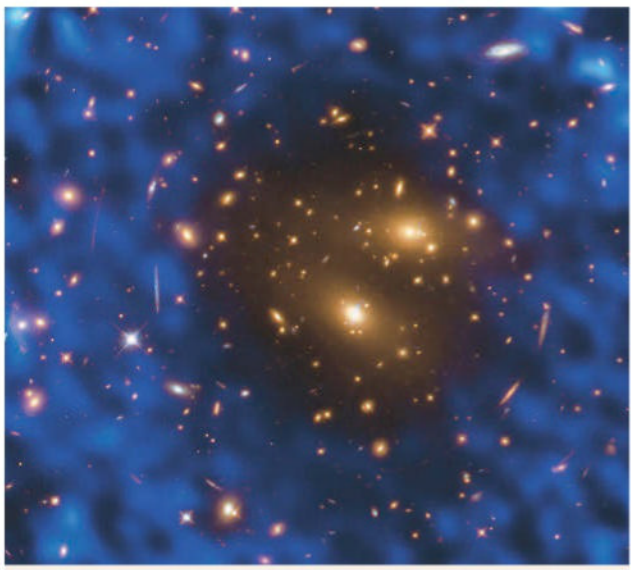
In keeping with this, civilisation might have developed more slowly in Mediterranean zones and more quickly in the tropics compared with our history. There would also have been very strong incentives to invent medication to reduce the need for hibernation, and this might have led to earlier advancements in pharmacology.

Alternatively, temperate hibernators might have tried to avoid the cold by constructing underground cities, so there could have been a boost to building techniques and artificial lighting.

"Human hibernators in temperate zones might have tried to avoid the cold by constructing underground cities"

These developments would spin off into other fields, including weaponry and transport, perhaps leading to an economy much like ours. But our winter flu jabs might also include anti-hibernatory drugs. Today, some might choose to hibernate instead.

Pat French
Longdon Upon Tern, Shropshire, UK
Sooner or later, people who could hibernate would have discovered fire. This would have given them warmth and light, and so extended their day and year. This would then eliminate the need to hibernate, enabling the development of civilisation much as we know it.



ESA/HUBBLE & NASA, T. KITAYAMA

How did the fabric of space itself come into being at the big bang?

This week's new questions

Making space **At the big bang, matter formed from the initial energy when it cooled enough for particles to form. But how was space formed?** ***Andrew Hawkins****, Peaslake, Surrey, UK*

I remember! **Sometimes a name I have forgotten pops into my head a few days later. Is my brain "processing" all that time?** ***Robert Watson****, Newcastle, New South Wales, Australia*

Further dimensions

Our eyes receive a two-dimensional image but our brains build a three-dimensional one. Could two three-dimensional images create a four-dimensional one, ad infinitum?

Simon McLeish
Lechlade, Gloucestershire, UK
Yes, it is possible to create a three-dimensional image of a four-dimensional object: a hypercube is the four-dimensional analogue of a cube, and it has a well-known three-dimensional image that looks like a cube with another cube nested inside it. It is even possible to represent this shape in two dimensions, as can easily be seen with a search online for "hypercube".

These are perspective images, and they are distorted in length and angle so that a flat painting creates the appearance of space. It seems likely that n-dimensional beings with a sense of sight could use similar distortions to make sense of n+1 dimensional objects.

More abstractly, any finite dimensional equivalent of a cube can be represented with Cartesian coordinates, where each vertex is defined by a set of numbers. A 2D square can be written as (0,0), (1,0), (1,1), (0,1), while a 3D cube would be (0,0,0), (1,0,0), (1,1,0), (0,1,0), (0,0,1), (1,0,1), (1,1,1), (0,1,1). As the number of dimensions increases, the number of coordinates required to define each point goes up.

Feeling contagious

There are good and bad bacteria, but are there any good viruses? And what would happen if all viruses disappeared? (cont.)

Mike Follows
Sutton Coldfield, West Midlands, UK
If people had been aware of the existence of bacteria and their role in causing the Black Death in the 14th century, as well as the subsequent cholera pandemics, convincing them that bacteria could be both "good" and "bad" would have been a significant challenge. Similarly, in the wake of the covid-19 pandemic, emphasising the benefits of "good" viruses might seem equally difficult. However, viruses play a positive role in medicine, ecology and biotechnology, with several important applications.

Phage therapy, which uses bacteriophages – viruses that infect and kill bacteria – has emerged as a promising treatment for bacterial infections, particularly those resistant to antibiotics. Bacteriophages can be highly specific in targeting pathogenic bacteria, leaving beneficial bacteria unharmed, which contrasts with broad-spectrum antibiotics that kill beneficial and harmful bacteria indiscriminately.

In gene therapy, researchers exploit certain viruses to deliver healthy genes into human cells to correct gene variants associated with genetic disorders such as cystic fibrosis. Furthermore, oncolytic viruses – which are engineered to target and destroy cancer cells while sparing healthy tissue – are being explored as a novel cancer treatment.

Viruses also play a crucial role in ecological systems, particularly in regulating microbial populations.

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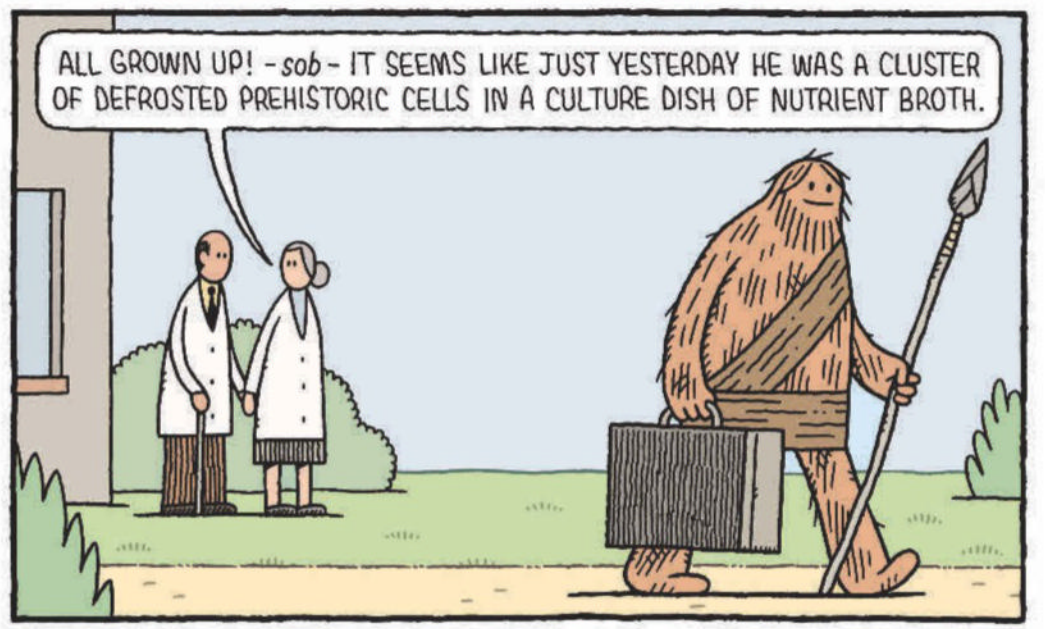
Tom Gauld
for New Scientist



By infecting and killing certain bacteria, viruses prevent any single species from dominating, and so help maintain microbial biodiversity. This also happens in the human microbiome, where viruses help control the levels of harmful bacteria, potentially reducing the risk of infections and inflammation.

In agriculture, phage therapy has been employed as a control method for plant pathogens, providing an alternative to chemical pesticides. Additionally, bacteriophages have potential in cleaning up contaminant spills, targeting bacteria that otherwise exacerbate pollution incidents.

Viruses also drive evolutionary processes through horizontal gene transfer, a mechanism by which genetic material is exchanged between organisms, leading to increased genetic diversity. This has contributed to the evolution of many different species, including humans.

If viruses were to disappear, illnesses such as influenza and covid-19 would also vanish. The loss of viruses, however, would also mean the loss of their many beneficial roles.

"Scientists have found that humans possess stereo olfaction. This involved experiments where Teflon devices were fitted to noses"

Being nosy

Why do our nostrils point down while those of most mammals point straight out from their face? (cont.)

David Muir
Edinburgh, UK
There can be benefits to nostrils that point forwards. Some animals have a stereoscopic sense of smell. This is where each nostril operates independently, sending different signals to the brain, which are then interpreted to determine which direction an odour is coming from. Forward-pointing nostrils could enhance this supersense.

Moles, for example, make up for their poor vision by using their stereo sniffing to detect food. It may come as a surprise to readers that scientists at the University of California, Berkeley, found that humans also possess a degree of stereo olfaction. This was observed in experiments where Teflon devices were fitted into the noses of research participants. I hope these devices were non-stick.

Raphael Chesterman
London, UK
Having read the interesting and probably more scientifically compelling reasons put forward for this, I conclude that humans have downward pointed nostrils because they have hands. Most animals need to take their nose to the object they want to sniff. This makes having a forward-projecting snout a necessity. Humans can hold and manipulate objects, allowing them to raise them up to their smelling device. In this way the nose is now free to point down, where it is best placed to enjoy the scents of the delicious food entering the human's mouth. ▮

Answers

Quick quiz #289 *Answers*

1 Keratin
2 1959
3 The sciatic nerve
4 Sea otter (*Enhydra lutris*)
5 Robert Hooke

Quick crossword #176 *Answers*

ACROSS 5 Squirt, **7** Cohesion, **9** Jelly ear, **10** Nebula, **11** *Interstellar*, **13** Petrel, **15** Simian, **18** Kentish glory, **21** Enamel, **22** Vertical, **23** Jetliner, **24** Allele

DOWN 1 Killdeer, **2** Stress, **3** Shingles, **4** Isobar, **6** Queen bee, **7** Cortex, **8** Oily, **12** Hairtail, **14** Landline, **16** Multiply, **17** Silver, **18** Kamala, **19** Herbal, **20** Knee

#59 Seven segments *Solution*

From 04:59 to 05:00, the room will get slightly brighter: there is a change of two segments, going from 21 to 23 lit.

The brightest time is 08:08, which sees 26 segments lit, while the dimmest is 11:11, which uses just eight.

The largest change in brightness is an increase of five segments lit, which occurs between 07:59 and 08:00, going from 20 to 25.

NDCs TBC

Everything's a bit quiet in the fun world of international climate negotiations at the moment. The last big news was November's COP29 meeting in Azerbaijan, which was a roaring success – for the fossil fuel companies promoting their wares on the sidelines. Then came Donald Trump's return to the White House as US president. He promptly ordered the country to withdraw from the Paris Agreement that governs international climate action. Negotiators could be excused for being a bit shell-shocked.

Nevertheless, the wheels of the climate bureaucracy grind on. This year, Paris Agreement signatories are required to submit updated Nationally Determined Contributions (NDCs), which are essentially a list of promises to take action to deal with climate change. The deadline was 10 February, and most countries missed it. Climate strategist Ed King noted in his newsletter that "three small, hilly countries with lots of sheep" (the UK, New Zealand and Switzerland) had managed to submit theirs, but that we would have to "wait till later in 2025 for China, India and the EU".

No rush folks; you take your time. It's not like half of Los Angeles just burned to the ground. Have a cup of tea, put your feet up, live your best life. It'll be done when it's done.

The V-word

Reporter Matthew Sparkes draws our attention to the experience of one David Birch, who went online with Virgin Money to discuss some savings accounts, asking its chatbot: "I have two ISAs with Virgin Money, how do I merge them?" The chatbot responded: "Please don't use words like that. I won't be able to continue our chat if you use that language."

It seems the online assistant had been programmed to avoid certain words and phrases that had been deemed discriminatory or otherwise offensive, including "virgin". After Birch posted angrily about this on LinkedIn, there was some media coverage and Virgin Money apologised and withdrew the chatbot (which was an outdated model anyway).

This was yet another example of a recurring problem in online discussions: context is crucial. It is certainly possible to use the letter string V-I-R-G-I-N to be insulting, but it is also the name of a multinational corporation. Tools that simply filter for certain letter strings are liable to block a lot of innocuous messages, while also missing abuse that doesn't rely on obvious slurs.

The problem goes back to at least 1996, when AOL refused to allow residents of Scunthorpe in England to create accounts. The town's name contains a letter string that many people find offensive – hence the term "Scunthorpe problem" for such technological mishaps.

The "virgin" incident is just the latest example. The Wikipedia page for the Scunthorpe problem is a treasure trove of inadvertent potty-mouthed humour and, more importantly, surprises. You will probably be able to guess the issues faced by promoters of a certain mushroom with a Japanese name, but we defy readers to anticipate why the New Zealand town of Whakatāne, a software specialist and even a London museum fell foul of similar context-blind controls.

Readers are welcome to submit their own stories – but Feedback can't guarantee our email filters will let them through.

Twisteddoodles *for New Scientist*

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

Is it finally happening?

On 26 January, the website of the *Daily Express* newspaper issued a major alert: "Yellowstone warning as supervolcano could be 'gearing up to explode'". Good gravy, we thought. Could it be that the supervolcano under Yellowstone is going to cease its perennial rumbling and finally let rip, blanketing North America in ash and blotting out the sun?

Upon closer inspection, the story was merely reporting the existence of a short YouTube documentary entitled *What If the Yellowstone Volcano Erupted Tomorrow?* This was released on a channel called What If in March 2020. Feedback felt, and readers may agree, that this did not entirely justify the *Express*'s headline.

Still, it does fill pages. Feedback found a half-dozen articles from early January on exactly this theme, with headlines like "Yellowstone crater movement sparks fears of supervolcano explosion as scientists assess risk". This noted that some scientists had found "movement deep in the crater" and that this was alarming, before quietly noting that the main source was a paper in *Nature* that used a new imaging technique to determine that the volcano doesn't contain anywhere near enough magma to erupt. Others said this study "sparks new debate on where and when it will erupt", which is certainly one way of interpreting a study that says no eruption is imminent.

Lurching further back in time: on 23 July last year, there was a small hydrothermal explosion in the Biscuit Basin area of Yellowstone, essentially trapped steam blowing out debris as it escaped the ground. Cue the headline "Is Yellowstone going to erupt?" This was handily answered by a geophysicist, who explained that volcanoes only erupt if "there is enough eruptible magma... and pressure", and that "neither condition is in place at Yellowstone right now".

We tried to go further back, but after the 50th article with pretty much the same headline, Feedback's brain broke. At this point, there have been so many stories proclaiming a Yellowstone eruption is imminent, we're not sure we will believe it even if we see it go off on live TV.

Discovery Tours
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