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The answers to the biggest mysteries of the cosmos might be imprinted in its very fabric

Vol 266 No 3548
Cover image: Simon Danaher

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"When something moves through space-time, it is as if space has been imprinted with a memory"

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NS Live

Doctors by nature: How ants, apes and other animals heal themselves

Building on his own work on monarch butterflies, and taking us on a tour around the globe, Jaap de Roode will introduce you to a whole menagerie of self-medicating animals on 18 October at London's ExCel Centre. By learning how animals self-medicate, we can improve the livestock industry, save pollinators and even find new drugs to treat human diseases.

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Tour

The science of deep time in the Brecon Beacons, Wales

Witness the cosmic, geological and human forces that have shaped our lives, and understand humankind's place in the story of Earth with this short break based in the beautiful Brecon Beacons (Bannau Brycheiniog) National Park. This three-day tour starts on 1 September and costs £899.

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ANDREW RAY/ALAMY

A window into the past Explore the breathtaking Brecon Beacons

Inside the Fungarium See the world's largest fungi collection

Podcast

The world, the universe and us

The team discusses how researchers at Harvard University have created cyborg tadpoles. They also discover why we have entered a new era of warfare with Ukraine's drone attack on Russia and share some news on the economic benefits of net zero. Plus, hear a report from the Vera Rubin Observatory in Chile.

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Video

Inside the world's most important fungi collection at Royal Botanic Gardens, Kew

Fungi underpin all life on Earth, yet many species remain undiscovered. With more than 1.25 million dried specimens, the Fungarium at Royal Botanic Gardens, Kew, in the UK is the largest fungi collection in the world, as well as one of the oldest.

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Newsletter

Our Human Story

Huge amounts of research effort have gone into figuring out when and where humans first entered Europe, Asia and North America, but far less attention has been paid to our lineage's first arrivals in South America. However, that is all starting to change, thanks to a massive genetic study.

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Podcast

"The Vera Rubin Observatory will help us answer some of the biggest mysteries about dark matter"

Amazing books for aspiring young scientists

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Stupid intelligence

Put aside superintelligent AI and focus on the problematic versions we have today

SHOULD politicians ensure that AI helps us colonise the galaxy, or protect people from the overreach of big tech? The former sounds more fun, but it shouldn't be the priority.

Among the Silicon Valley set, superintelligent AI is viewed as a rapidly approaching inevitability, with tech CEOs promising that the 2030s will see a golden era of progress (see page 10). That attitude has reached Westminster and Washington, with think tanks telling politicians to be ready to harness the power of incoming AI and the Trump administration backing OpenAI's $500 billion initiative for ultrapowerful AI data centres.

It all sounds exciting, but as the great and the good dream of superintelligence, what we might call "stupid intelligence" is causing problems in the here and now. One of the questions facing the AI sector is whether hoovering up vast swathes of the internet – a necessary part of training AI – is copyright infringement.

There are reasonable arguments on both sides. Proponents say that, just as you aren't infringing *New Scientist*'s copyright by merely reading these words, AI learning should be treated the same. Detractors, meanwhile, now include entertainment giants Disney and Universal, which are suing the AI firm Midjourney for reproducing images of everything from Darth Vader to the Minions (see page 11). Only legislation can settle the matter.

> **"We are heading towards a world in which machines could kill with little human oversight"**

The battlefields of Ukraine pose another thorny AI problem. While OpenAI's Sam Altman has said he fears a superintelligent AI may one day kill us all, deadly stupid intelligence is already here. The Russia-Ukraine war is driving us towards a world in which, very soon, machines could kill with little human oversight (see page 8).

Politicians have entirely failed to get to grips with this threat. The United Nations held its first meeting on regulating "killer robots" in 2014. A decade later, we are no closer to restricting their use. If our leaders are biding their time in the hope that a superintelligence will eventually solve their problems for them, they are very much mistaken. ▮

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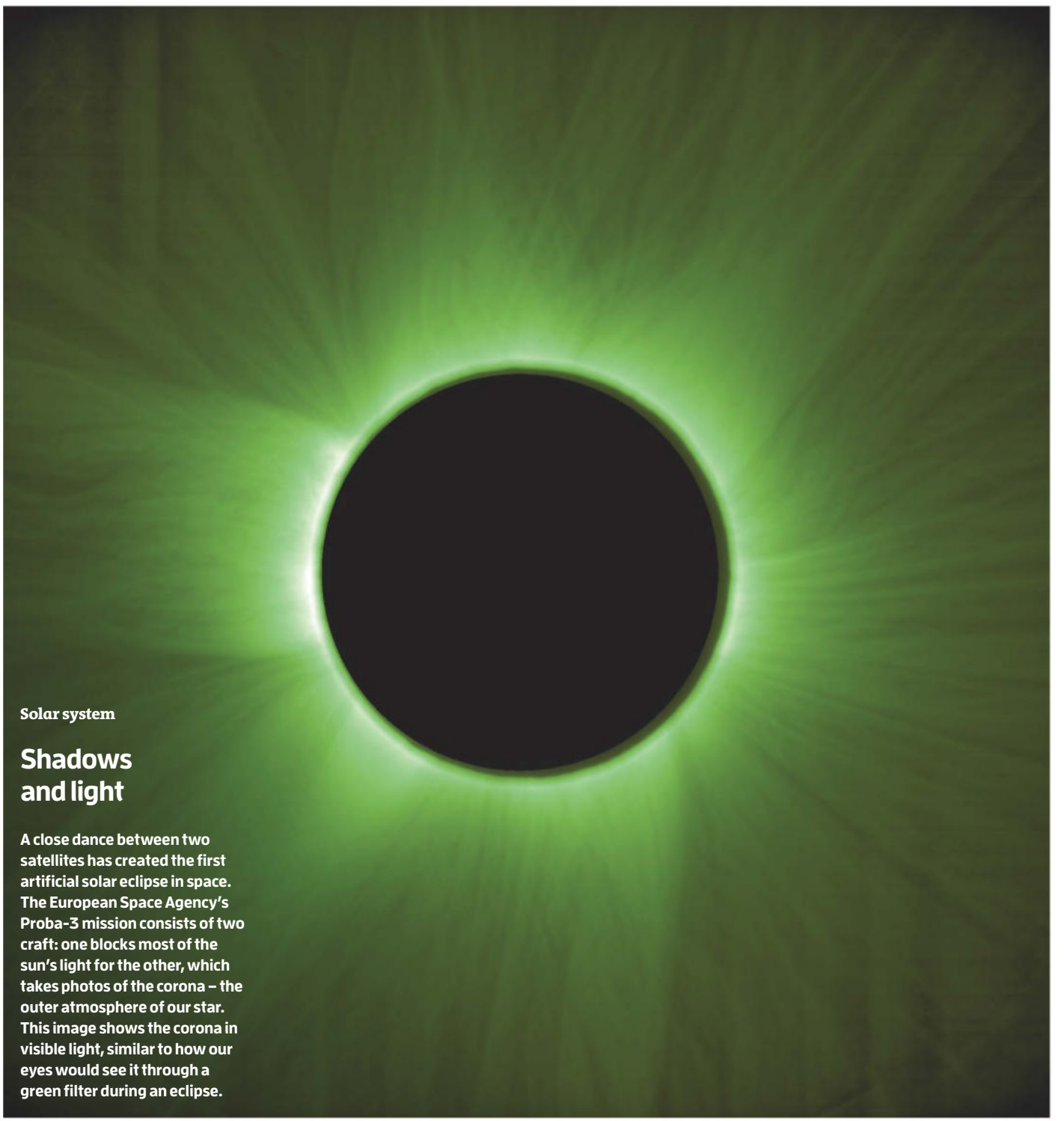


Solar system

Shadows and light

A close dance between two satellites has created the first artificial solar eclipse in space. The European Space Agency's Proba-3 mission consists of two craft: one blocks most of the sun's light for the other, which takes photos of the corona – the outer atmosphere of our star. This image shows the corona in visible light, similar to how our eyes would see it through a green filter during an eclipse.

ESA/PROBA-3/ASPIICS/WOW ALGORITHM

Space

The telescope transforming astronomy

The huge Vera C. Rubin Observatory could help us solve some of the universe's biggest mysteries, from dark matter to whether Planet Nine exists, finds **Chelsea Whyte**

ON TOP of Cerro Pachón, a Chilean mountain that reaches more than 2600 metres above sea level, the air is thin. I have to catch my breath as we climb the stairs inside the dome of the Vera C. Rubin Observatory. It is cool and quiet and enormous, a bit like a cathedral – until the entire dome booms into motion around us and opens to the sky.

Night has fallen and above us sit more stars than I have ever seen with my own eyes. The Milky Way shines brighter than usual, and I can just make out two of its galactic neighbours; the Small and Large Magellanic Clouds. However, the Rubin telescope can see far, far more. It is a behemoth, housing the largest digital camera and largest lens on Earth and weighing in at 350 metric tons. It is a reflecting telescope, gathering light via mirrors, the largest of which is 8.4 metres across – as wide as it could possibly be because a tunnel on the way up to the summit is about 8.5 metres across.

"The result will be a kind of cosmic timelapse that starts to reveal faint and distant objects"

Yet despite such heft, this telescope can move extremely fast, which will let it revolutionise what we know about our own solar system, our galaxy and the universe. Every three nights, it will complete a survey of the southern sky. Previous all-sky surveys have taken months or weeks, but the Rubin will do one in less than half a week, over and over for a decade.

"By taking the entire sky every three days, you can stack those images together to go deeper," says observatory scientist Kevin Reil. "So after 10 years, you've gone very, very deep, very, very far into the universe, very far back in time. But you're also getting the structure of the universe," he says. The result will be a kind of cosmic timelapse, one that not only captures change, but starts to reveal unbelievably faint and distant objects as multiple images get combined to bring them into view.

Understanding the structure of the cosmos is one of the observatory's missions – by finding out more precisely how dark matter warps the universe. The telescope's namesake, US astronomer Vera Rubin, started this journey. In the 1970s, her observations of galaxies rotating made it clear that visible matter makes up only a fraction of the universe. She found that stars on the outer edges of galaxies were moving too fast – according to Kepler's laws, they should have been slower than the stars close to galactic centres.

The only way to square this was to assume that there had to be more matter than we could see. This unseen stuff was named dark matter. Astronomers now believe that there is roughly five times as much of it in the cosmos as ordinary matter, and its gravitational pull shapes the universe we see.

Mapping the cosmic web

"The visible matter actually follows where the dark matter is, not the other way around," says Stephanie Deppe at the observatory. Galaxies are thought to be laid out on what astronomers call the cosmic web, comprising interconnecting filaments of dark matter that gravitationally trap the stars we can see, which themselves make up so-called stellar streams. The images from Rubin will give us our best-ever look at this web.

Mapping the web will also help us pin down the true nature of dark matter. Is it hot and made of light, fast-moving particles, or cold and made of particles that clump more easily? "You can look for little disruptions like kinks in the stellar streams," says Deppe. These will show us where clumps of dark matter busted through a filament. Understanding how big a clump would be able to do so will narrow down which type of dark matter might be out there. The structure of the cosmic web will also give us a better sense of the effects of dark energy, the propulsive force accelerating the expansion of the universe.

The excitement over this precision astronomy is palpable at the observatory. During the night I am there for observations, everyone is a little giddy. In the kitchen near the telescope's control room, I hear excited chatter. One of the telescope operators is almost bouncing as he says, "I hope we get 'on sky' tonight." That is observatory lingo for opening up the telescope's

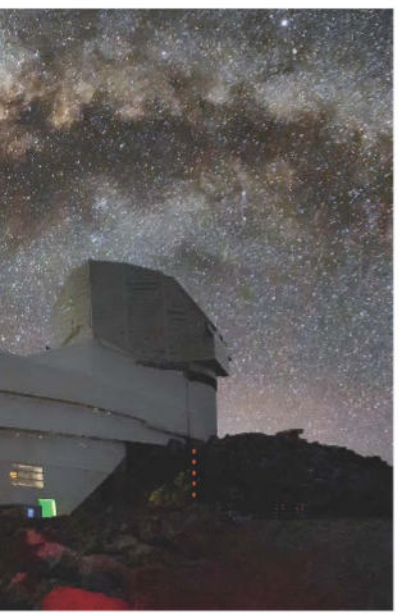
RUBIN OBSERVATORY/NSF/AURA/B. QUINT

The Vera C. Rubin Observatory sits on a summit in Chile

350
How much the telescope weighs, in metric tons

8.4
The width, in metres, of the observatory's largest mirror

10 years
How long the telescope will image the southern sky, scanning it every three days



shutter and taking images. "Oh, we will," says his colleague, smiling into a mug of tea. As the sun goes down, we all cross our fingers for the clouds to clear.

Once they do, the control room is a hive of activity. The operators are still working out the kinks with the telescope, getting the images into proper focus. Every 30 seconds or so, another one comes through, along with a whooshing sound that signals that the shutter has opened, followed by another whoosh when it has closed. The telescope takes a snapshot of part of the sky and then zips to the next spot, building up a grid that can be stitched together.

Everything is going swimmingly until suddenly there is a glitch. To make the most out of a telescope that can move so quickly, the observatory uses an automated program that chooses where to point the telescope next, based on things like weather or the phase of the moon. But for a moment, this system isn't working. The operators have a video chat with scientists at the base camp a couple of hours' drive down the mountain. Together, they dive into the system's code to find the problem. The fix is sent around 20 minutes later and they are back up and running.

Fast-moving images

"This is one of the best nights we've had; this is just cruising. This is such good data right now," says Eli Rykoff, a calibration scientist. "I hope the processing people right now are appreciating us giving them high-quality science images."

Once the images are made at the telescope, they begin a long but very quick journey across the globe. They head down the mountain along the first stretch of 103,000 kilometres of fibre-optic cables that run to either the Atlantic or Pacific oceans and then underwater to the US. The images pass through a hub in Florida and then end up at the SLAC National Accelerator Laboratory in California.

Each image is around 32 gigapixels, which is about the size of a 4K movie, and arrives within around 10 seconds, says William O'Mullane, who manages the data for the observatory. From California, the information goes to facilities in the UK and France that make the images available to scientists around the world.

Perhaps the most urgent analysis will be done on fast-moving objects. The night sky pulses, blips and changes in ways we can't always predict – and the Rubin Observatory is hot on its tail. We have never had the ability to capture these movements so quickly, and doing so will let us see those rapidly changing objects in as close to real time as you can get. The telescope will track asteroids and comets zipping across the sky, both those that make up the main asteroid belt between Mars and Jupiter and those much farther out called trans-Neptunian objects.

"Currently, we only know of a few thousand objects" in the Kuiper Belt and the Oort cloud that lie beyond Neptune, says Deppe. "Rubin's going to increase by probably 10-fold the number of objects that we know out there."

It will also help us track any potential threats from near-Earth objects, increasing the known examples of these from roughly 30,000 to around 100,000. And it could even catch fast-moving interstellar objects like 'Oumuamua, which whizzed through the solar system in 2017, or the comet Borisov that flew by in 2019.

This kind of solar system census could also answer the question of whether there is, indeed, a Planet Nine. Tantalising evidence for this world – one five to 10 times the mass of Earth in the outer solar system – comes from Kuiper Belt objects that have unusual but similar orbits. Simulations have shown a planet could be to blame, but there is no direct evidence yet.

That may soon change. "Either Rubin is going to directly find Planet Nine, it's going to find indisputable evidence for it, or it's going to totally wipe away the evidence that exists," says Deppe.

One mystery the telescope won't solve is the uncertain state of US science, which has been gutted under the Trump administration. Rubin is jointly funded by the US Department of Energy and the US National Science Foundation (NSF), the latter of which has seen its proposed budget slashed by more than half. When I asked people at the observatory what this would mean for them, none were certain. "We're going to decline to speculate on the potential impacts of the president's FY 2026 budget request," an NSF spokesperson told me when I later asked.

"Either Rubin is going to find Planet Nine or it's going to totally wipe away the evidence that it exists"

But back in the control room, funding is a concern for another day. We are nearing midnight – the scientists will take data until 3 or 4 am – but no one seems tired. Every once in a while someone shouts out something like, "Look at these beautiful images!"

The first images to be made public will be released on 23 June. In the meantime, the observatory will be snapping every three nights. "The whole idea was, could you build an observatory that would take all the data that everyone in the world would want? Because if you take a picture of the entire sky every three days, and somebody says, 'I wanted a picture over there,' just wait three days, I'll give you another one," says Reil. ▮

***New Scientist*'s US editor Chelsea Whyte inside the observatory**

Analysis Technology

Can any nation protect against a Ukraine-style drone-smuggling attack?

Ukraine's Operation Spiderweb showed the damage that small drone attacks can do, leading other nations to worry about their own defences, finds **David Hambling**

ON 1 June, Ukraine stunned the world with an audacious attack against Russian airbases. Using cheap, small drones concealed inside trucks that had penetrated deep into Russian territory, Ukraine says it was able to hit dozens of nuclear-capable strategic bombers, taking out a reported $7 billion of military hardware.

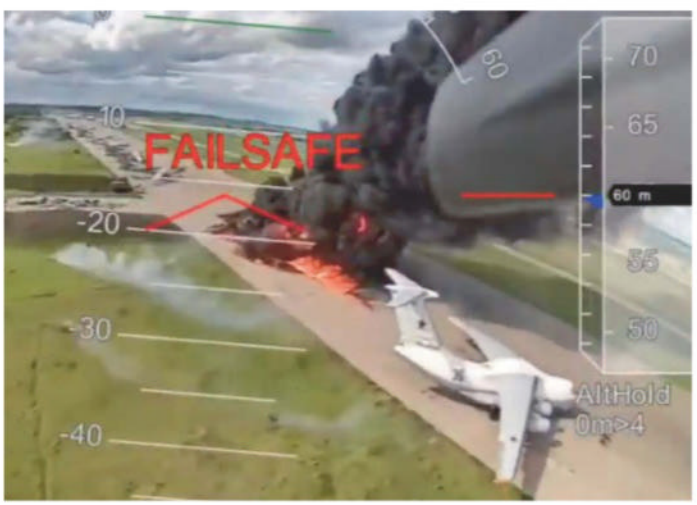
The drone-smuggling attack, codenamed Operation Spiderweb, was an incredible feat of military planning – but it also highlighted a vulnerability that has defence chiefs around the world concerned that their assets could be hit next.

"The risk potentials of small drone attacks to US or UK air bases right now are 100 per cent," says Robert Bunker at US consultancy firm C/O Futures. "You simply need a group with the intent and capability, which is a very low bar to overcome."

Ukraine's security service, the SBU, says it used 117 first-person-view drones for the attack, adapting them from racing quadcopters to carry a couple of kilograms of explosives each. The country produced around 1.5 million of these drones for battlefield use last year, costing just a few hundred dollars each. They are typically limited to a range of around 20 kilometres, but as Spiderweb shows, they can be delivered to the target area and flown remotely.

Drone defences

The attack came as no surprise to US defence analyst Zachary Kallenborn, who predicted exactly this kind of threat to strategic bomber aircraft in a 2019 paper. "Ukraine did far more in scale and impact than I could have imagined. I figured such an attack might be a small part of a far larger strike on adversary nuclear delivery



SCREENSHOT VIA MINISTRY OF DEFENSE OF UKRAINE/UPI/ALAMY

The Ukrainian military released video footage of the attack

vehicles, but Ukraine managed to destroy 34 per cent of the nuclear bomb force with an incredibly complex and coordinated operation. That's amazing," he says.

So, what can nations do to protect themselves from similar attacks? Broadly, there are three approaches: the physical, the electronic and the kinetic.

The first sounds simple – just erect a physical barrier to keep drones away. Some of the Russian planes hit by Ukraine were parked in bays surrounded by protective concrete blast walls or earthen banks designed to shield against nearby fire or explosion, but these don't stop attacks from above. Russia is now hastily building hardened aircraft shelters, but these are expensive, costing millions apiece, and are only big enough for fighters.

Anti-drone nets are a cheaper alternative, and one that is already employed by both Ukraine and Russia on the battlefield. Russian authorities have reportedly advised airbases to erect such barriers in response to Ukraine's attack, but the problem is that such nets are easy to take out.

What about electronic protections? On the front lines, both Russia and Ukraine use electronic-jamming tools to break radio links between drones and their operators. That works to some extent in a battlefield situation, but because jammers typically operate at short range, an airbase would need to be blanketed in them. "They must be deployed and monitored 24/7," says Bunker.

> **"This goes well beyond even being a major vulnerability gap. The dike is literally crumbling in front of us"**

That creates its own problems. Operation Spiderweb used commercial cellphone networks, but attackers might use any frequency to control their drones, and jamming every frequency may not be an option. "Jammers interfere with friendly signals too," says Kallenborn. "To prevent such an attack, we may need to accept greater risk to friendly operations."

In addition, the SBU says its drones were designed to anticipate jamming and were fitted with an AI backup system that guided them to targets without operator input. Such drones are essentially immune to jamming.

That leaves kinetic measures, otherwise known as shooting down the drones. The Russian airbases were well protected against conventional air attacks with surface-to-air missiles and mobile anti-aircraft units, but these couldn't detect or engage the small drones.

"Such weapons systems need advanced acquisition and targeting capabilities to have any chance of taking down an armed UAS [uncrewed aerial system]," says Bunker. "If humans are operating them, they have to be dispersed throughout a facility for defensive coverage and manned 24/7, which creates an immense personnel and economic burden."

Automated defences offer a potential solution, and Ukraine is already deploying AI-controlled anti-drone machinegun turrets to protect cities against Russian attacks using large Shahed drones. But despite costing around $100,000 each, turrets like these could easily be outmatched by the smaller, cheaper drones used in Operation Spiderweb.

In short, there are no good solutions – and yet, militaries urgently need to find a way to mitigate this imminent threat. A US Air Force general recently told a Senate committee that there were over 350 instances of unauthorised drones flying over military bases inside the US in 2024 alone.

All of this means a repeat of Operation Spiderweb, in Russia or elsewhere, is looking very possible. "This goes well beyond even being a major vulnerability gap," says Bunker. "The dike can't be plugged. It's literally crumbling in front of us and will soon burst." ▮

Space

‘Impossible’ particle that hit Earth may have been dark matter

Jonathan O’Callaghan

AN EXTREMELY high-energy particle that was spotted tearing through Earth and was thought to be an unusual neutrino may be something even wilder: a particle of dark matter travelling across the cosmos.

The KM3NeT detector, off the coast of Italy, spotted this “impossible” neutrino in 2023 while it was under construction. The particle in question was 35 times more energetic than any seen before. Where it came from remains a mystery, with possible sources including a galaxy with a very active central black hole known as a blazar, or a background source of high-energy neutrinos pervading the universe.

Bhupal Dev at Washington University in St. Louis, Missouri, and his colleagues suggest the event might not have been a neutrino at all, but instead a dark matter particle crashing into our planet that originated from a blazar (arXiv, doi.org/prf2). “It opens up a new way you can really test dark matter,” he says. “We can convert these neutrino telescopes into dark matter detectors.”

Neutrino detectors already have a difficult job to do because these particles are extremely tiny and nearly massless, rarely interacting with matter as they traverse the cosmos. When they arrive at Earth, they can occasionally crash into atoms, producing a particle called a muon that can be picked up by neutrino detectors like KM3NeT and IceCube at the south pole.

“Everybody would be pretty thrilled if neutrino detectors could also study dark matter”

IceCube has seen evidence for hundreds of cosmic neutrinos since 2011, but never something as energetic as KM3NeT’s discovery. That was confusing, because whatever source KM3NeT was seeing, IceCube should have seen it too.

Dev says that if the incoming particle was dark matter and not a neutrino, it could explain this mystery. The shallow predicted path of the incoming particle meant it had to travel through more of Earth to reach KM3NeT than IceCube, increasing the chance of it being scattered into a muon. “The dark matter goes through lots of Earth’s matter,” says Dev, “and we can explain why IceCube didn’t see it.”

The particle would have been produced in a blazar and then fired towards Earth in a beam. Dev favours this idea because high-energy protons in a blazar more efficiently transfer their energy into dark matter than neutrinos, he says.

“From an Occam’s razor perspective, this is probably just an ordinary neutrino that’s exceptional in energy,” says Dan Hooper at the University of Wisconsin-Madison. However, if correct, it would allow us to find and study dark matter particles, which have never previously been detected. “Everybody would be pretty thrilled if these machines can study not only neutrinos but also dark matter,” says Hooper.

Shirley Li at the University of California, Irvine, says the idea could be tested in future, as any incoming dark matter particle should produce two muons in the detector when it hits Earth, not just one, but the detectors currently lack the precision to distinguish two particles from a single signal. “That’s potentially testable, but at these energies, muon reconstruction is very difficult,” she says. ▮

Zoology

Cryopreserved sea star larvae could save vital species

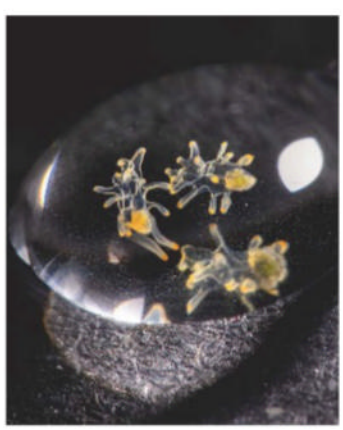
SEA star larvae have been successfully cryopreserved and then reactivated – an important milestone that could help re-establish a critically endangered keystone species.

Beginning in 2013, sea star wasting syndrome spread along the west coast of North America, wiping out populations of species including sunflower stars (*Pycnopodia helianthoides*) and giant pink stars (*Pisaster brevispinus*). The loss of these predators led to a big expansion of sea urchins, which contributed to northern California losing 97 per cent of its kelp forest canopy.

Sunflower stars are now functionally extinct in California and intense efforts are under way to raise them so they can be reintroduced to the wild.

When giant pink stars spawned at the Aquarium of the Pacific in Long Beach, California, in January, vials of the 2-day-old larvae were shipped to the San Diego Zoo Wildlife Alliance. There, they were submerged in liquid nitrogen and stored at –200°C for the next month before being transported around 700 kilometres north to Sunflower Star Laboratory in Monterey Bay in February.

Next, the giant pink star larvae were carefully thawed and resumed their development, reaching the stage when they settle on the seabed and change into their juvenile form. “Nobody had ever taken a sea star, frozen it at the larval stage and successfully settled it, which has tremendous implications for their conservation,” says Reuven Bank at Sunflower Star Laboratory.



PATRICK WEBSTER

Sea star larvae resumed their development after being frozen

Being able to raise cryopreserved larvae brings conservationists closer to returning genetically diverse sunflower stars to the waters of California. “The giant pink star has a similar larval cycle to sunflower stars, and we’re moving on to sunflower stars next,” says Bank.

Over the past 15 years, marine ecosystems in the North Pacific have faced a convergence of environmental threats. “When you’re telling the story of climate change, marine heat waves and ecosystem collapse, it’s grim,” says Andrew Kim at Sunflower Star Laboratory. “But with the *Pycnopodia* recovery, there’s a sliver of hope.” ▮

Becci Jewell

Artificial intelligence

Is superintelligent AI nearly here?

Tech CEOs are promising utopian visions of the 2030s, powered by "superintelligence", but the most advanced AI systems can still struggle with simple puzzles, finds **Alex Wilkins**

IF YOU take the leaders of artificial intelligence companies at their word, the coming decade will be quite unlike any in human history: a golden era of "radical abundance", where high-energy physics is "solved" and we see the beginning of space colonisation. But researchers working with today's most powerful AI systems are finding a different reality, in which even the best models are failing to solve basic puzzles. So, whom should you believe?

Sam Altman and Demis Hassabis, the CEOs of OpenAI and Google DeepMind, respectively, have both made claims that powerful, world-altering AI systems are just around the corner. In a blog post, Altman writes that "the 2030s are likely going to be wildly different from any time that has come before", speculating that we might go "from a major materials science breakthrough one year to true high-bandwidth brain-computer interfaces the next year".

Hassabis, in an interview with *Wired*, said that in the 2030s, artificial general intelligence (AGI) will start to solve problems like "curing terrible diseases", as well as finding new energy sources. "If that all happens," said Hassabis, "then it should be an era of maximum human flourishing, where we travel to the stars and colonize the galaxy."

This vision relies heavily on the assumption that large language models (LLMs) like the one powering ChatGPT get more capable the more training data and computer power we throw at them. This "scaling law" seems to have held true for the past few years, but there have been hints of it faltering. For example, OpenAI's recent GPT-4.5 model, which is likely to have cost hundreds of millions of dollars to train, achieved only modest improvements over its predecessor GPT-4. And that cost is nothing compared with future spending, with reports suggesting that Meta is about to announce a $15 billion investment in an attempt to achieve "superintelligence".

Stands to reason

Money isn't the only attempted solution to this problem, however. AI firms have also turned to "reasoning" models, like OpenAI's o1, which was released last year. These models use more computing time and so take longer to produce a response, feeding their own outputs back into themselves. This iterative process has been labelled "chain-of-thought", in an effort to draw comparisons to the way a person might think through problems step by step. "There were legitimate reasons to be concerned about AI plateauing," Noam Brown at OpenAI told *New Scientist* last year, but o1 and models like it meant that the scaling law could continue, he argued.

Yet recent research has found these reasoning models can stumble on even simple logic puzzles. For example, researchers at Apple tested Chinese AI company DeepSeek's reasoning models and Anthropic's Claude models, which work like OpenAI's o1-family of models.
The researchers wrote that they have "limitations in exact computation: they fail to use explicit algorithms and reason inconsistently across puzzles".

The team tested the AI on several puzzles, such as a scenario in which a person has to transport items across a river in the fewest number of steps, and Tower of Hanoi, a game where you must move rings one by one between three poles without placing a larger ring on top of a smaller one. Though the models could solve the puzzles at their easiest settings, they struggled when the number of rings or items to transport was increased. While we would take longer to think about a more complex problem, the researchers found that the AI models used fewer "tokens" – chunks of information – as the complexity of the problems increased, suggesting that the "thinking" time the models displayed is an illusion (arXiv, doi.org/prw2).

"The damaging part is that these are [easily solvable] tasks," says Artur Garcez at City, University of London. It is possible that these newer systems can be fixed and improved to eventually be able to reason through complex problems, but this research shows it is unlikely to happen purely through increasing the size of the models or the computational resources given to them, says Garcez.

"OpenAI's recent GPT-4.5 model achieved only modest improvements over its predecessor"

Meanwhile, other research is showing that increased "thinking" time can actually hurt an AI model's performance. Soumya Suvra Ghosal and his colleagues at the University of Maryland tested DeepSeek's models and found that longer chain-of-thought processes led to decreased accuracy on tests of mathematical reasoning (arXiv, doi.org/prw3).

For example, for one mathematical benchmark, they found that tripling the amount of tokens used by a model can increase its performance by about 5 per cent. But using 10 to 15 times as many tokens again dropped the benchmark score by around 17 per cent.

In some cases, it appears the chain-of-thought output produced by an AI bears little relation to the answer it provides. When testing DeepSeek's models on the ability to navigate simple mazes, Subbarao Kambhampati at Arizona State University and his

BOB HENRY/UCG/UNIVERSAL IMAGES GROUP VIA GETTY IMAGES

AI models like DeepSeek have some issues with problem-solving

colleagues found that even when the AI solved the problem, its chain-of-thought output contained mistakes that weren't reflected in the final solution (arXiv, doi.org/prw4).

Wrong chain of thought?

What's more, feeding the AI a meaningless chain-of-thought could produce better answers.

"Our results challenge the prevailing assumption that intermediate tokens or chains-of-thought can be semantically interpreted as the traces of internal reasoning of the AI models, and caution against anthropomorphising them that way," says Kambhampati.

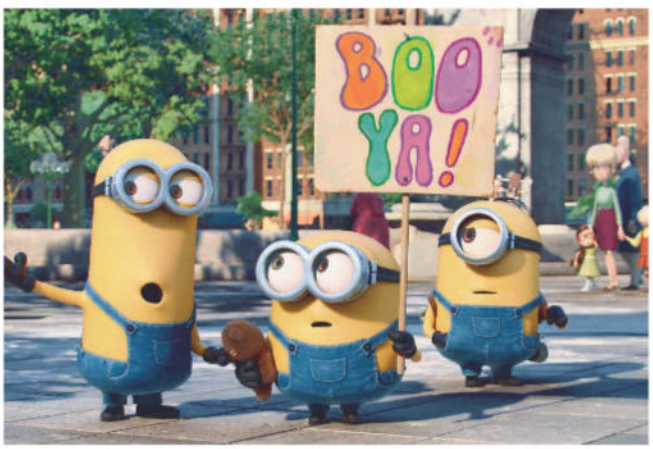
Indeed, all of the studies suggest that "thinking" or "reasoning" labels for these AI models are a misnomer, says Anna Rogers at the IT University of Copenhagen in Denmark. "For as long as I've been in this field, every popular technique I can think of has been first hyped up with some vague, cognitively-sounding analogy, which [was] then eventually proved wrong."

Andreas Vlachos at the University of Cambridge points out that LLMs still have clear applications in text generation and other tasks, but says the latest research suggests we may struggle to ever make them tackle the kind of complex problems promised by Altman and Hassabis.

OpenAI disagrees, however. "Our work shows that reasoning methods like chain-of-thought can significantly improve performance on complex problems, and we're actively working to expand these capabilities through better training, evaluation and model design," says a spokesperson. DeepSeek didn't respond to a request for comment. ▮

Disney and Universal lawsuit may be killer blow in AI copyright wars

Two Hollywood giants entering this legal fight could be a watershed moment, finds **Chris Stokel-Walker**



MAXIMUM FILM/ALAMY

The Minions are some of Universal's many characters

DISNEY and Universal have filed a lawsuit against AI image generator Midjourney alleging mass copyright infringement that enables users to create images that "blatantly incorporate and copy Disney's and Universal's famous characters". The action could be a major turning point in the legal battles over AI copyright infringement being negotiated by book publishers, news agencies and other content creators.

Midjourney's tool, which creates images from text prompts, has 20 million users on its Discord server, where users type their inputs.

In the lawsuit, the two movie-making giants share examples in which Midjourney is able to create images that uncannily resemble characters each company owns the rights to, such as the Minions, controlled by Universal, or the Lion King, owned by Disney.

The companies allege those outputs could only be the result of Midjourney training its AI on their copyrighted material. They also say Midjourney "ignored" their attempts to remediate the issue prior to taking legal action.

In the complaint, the firms say that "Midjourney is the quintessential copyright free-rider and a bottomless pit of plagiarism." Midjourney did not immediately respond to *New Scientist*'s request for comment.

The lawsuit has been welcomed by Ed Newton-Rex at Fairly Trained, a non-profit organisation that promotes fairer training practices for AI companies. "This is a great day for creators around the world," he says. "Governments have shown worrying signs they might bend to big tech's intense lobbying by legalising intellectual property theft – Disney weighing in makes this that much less likely."

"It's now very easy to produce pretty much any character you can imagine"

Newton-Rex claims Midjourney engineers once told him their actions were justified because art is "ossified". "Thankfully, this ludicrous defence wouldn't stand up in court," he says.

Legal experts are equally forthright about Midjourney's likelihood of success defending the case.

Andres Guadamuz at the University of Sussex, UK, points out that Disney's general approach to legally protecting its intellectual property – rarely, but firmly when it does – highlights the importance of its intervention. The movie companies acted months after other organisations, including news publishers, pursued AI firms over the alleged use of their proprietary creations. Many of those cases have been settled after licensing agreements were reached between the AI companies and copyright holders.

"Media conglomerates are more interested in infringing outputs. The models are getting so much better that it's now very easy to produce pretty much any character you can imagine," says Guadamuz. He thinks Disney waited because "unlike publishers, they're not looking for licensing agreements to survive".

The involvement of two titans of the creative industry is revealing in itself and marks a watershed moment for AI and copyright, Guadamuz reckons. "The fact that they're going after Midjourney is telling," he says.

The company is a minnow compared with larger AI firms because it specialises in image generation. "This is a message to the larger players to get their act together and start implementing stronger filters, or they'll be next."

A less likely alternative is that Disney, which made $91 billion in revenue last year, is seeking to get money from Midjourney. "This could also be a message to come to the table and start negotiating. AI isn't going away, so Disney may be setting this as a marker that they're open for business," says Guadamuz. ▮

Geology

Earth's mantle may have 'ghost plumes'

James Dinneen

A SECTION of Earth's mantle beneath Oman appears to be unusually warm, in what may be the first known "ghost plume" – a column of hot rock emanating from the lower mantle without apparent volcanic activity on the surface.

Mantle plumes are mysterious upwellings of molten rock believed to transmit heat from the core-mantle boundary to the Earth's surface, far from the edges of tectonic plates. There are a dozen or so examples thought to occur under the middle of continental plates – for instance, beneath Yellowstone and the East African rift. "But these are all cases where you do have surface volcanism," says Simone Pilia at King Fahd University of Petroleum and Minerals in Saudi Arabia. Oman has no such activity.

Pilia first came to suspect there was a plume beneath Oman after he began analysing new seismic data from the region. He observed the velocity of waves generated by distant earthquakes slowed down in a cylindrical area beneath eastern Oman, indicating the rocks there were less rigid than the surrounding material due to high temperatures.

Other independent seismic measurements showed key boundaries where minerals deep within the planet change phases in a way consistent with a hot plume. These measurements suggest the plume extends more than 660 kilometres below the surface (*Earth and Planetary Science Letters*, doi.org/prw5).

"The more we gathered evidence, the more we were convinced that it is a plume," says Pilia, who named the feature the "Dani plume" after his son.

"It's plausible" that a plume indeed exists there, says Saskia Goes at Imperial College London, adding the study is "thorough". However, she points out that narrow plumes are notoriously difficult to detect.

If it does exist, however, the presence of a "ghost plume" beneath Oman would suggest there are others, says Pilia. "We're convinced that the Dani plume is not alone."

"It has implications, potentially, for the evolution of the Earth if we get a different estimate of how much heat comes out of the mantle," says Goes. ▮

ALEXEY STIOP/ALAMY

A hidden plume was found underneath the surface of Oman

Neuroscience

Cyborg tadpoles are teaching us about our brains

Sally Adee

HOW does our brain, which is capable of generating complex thoughts and actions, grow out of essentially nothing? An experiment using an electronic implant inside tadpoles may have got us closer to an answer.

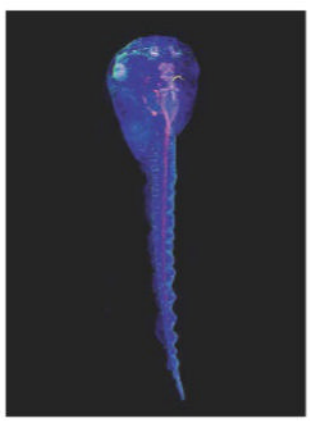
Past attempts to peer into neurodevelopmental processes have relied on tools like functional magnetic resonance imaging or hard electrode wires stuck into the brain. But the imaging resolution was too low to be useful, while hard wires damaged the brain too much.

Now, Jia Liu at Harvard University and his colleagues have identified a type of perfluropolymer whose softness and conformability matches that of brains. They used it to build a soft, stretchable mesh around ultrathin conductors that they then placed onto the neural plate – a flat, accessible structure that forms the neural tube, the precursor to the brain – of African clawed frog (*Xenopus laevis*) embryos (*Nature*, doi.org/prmk).

"This is a great tool that could allow biologists to measure neural activity during development"

As the neural plate folded and expanded, the ribbon-like mesh was subsumed into the growing brain, where it maintained its functionality while stretching and bending with the tissue. When the researchers wanted to measure brain signals, they wired up a part of the mesh sticking out of the skull to a computer, which displayed the neural activity.

The implant appeared to neither damage the brain nor elicit an immune response, and the embryos developed into tadpoles as expected. At least one went on to grow into a normal frog, says Liu.



HAO SHENG ET AL. 2025, JIA LIU LAB/HARVARD SEAS

The tadpoles had electronic implants inserted as embryos

"This is a great tool that could potentially advance fundamental neuroscience by allowing biologists to measure neural activity during development," says Christopher Bettinger at Carnegie Mellon University in Pennsylvania.

The team has two main takeaways from the research. First, the patterns of neural activity changed as expected as the tissue differentiated into specialised structures responsible for different functions. According to Liu, it hasn't previously been possible to track how a piece of tissue self-programs into a computational machine.

The second was how a regenerating animal's brain activity changes after amputation. A long-standing idea was that the electrical activity returns to an earlier developmental state, which the team confirmed by using its implant in an experiment involving axolotls. ▮

Boost for lab-grown blood vessels

By reprogramming skin cells, scientists grew blood vessels that could one day be used to prevent tissue damage or help develop mini-organs for research, finds **Carissa Wong**

TINY balls of lab-grown blood vessels helped restore blood flow to injured tissue in mice, minimising necrosis. This approach could one day be used to reduce the damage caused by things like blood clots.

Researchers have previously made clumps of lab-grown blood vessels, known as organoids, by immersing human stem cells in a cocktail of chemicals. But this method takes a few weeks and often produces vessels that poorly mimic those in the body, says Juan Melero-Martin at Harvard University.

In an alternative approach, Melero-Martin and his colleagues genetically engineered human stem cells that were made by reprogramming skin cells. They gave the stem cells a genetic sequence that causes them to develop into blood vessels in the presence of the antibiotic doxycycline. "We managed to get blood vessel organoids in just five days," says Melero-Martin. The vessels also had protein and gene activity levels that were highly similar to those found in the human body, he says.

Restored blood supply

To test whether the organoids could treat injured tissue, the researchers surgically cut off the blood supply to one leg of several mice to less than 10 per cent of normal levels. One hour later, they implanted 1000 organoids at each of the injury sites.

When imaging the mice two weeks later, the team found that the implanted blood vessels had fused with those already in the animals, restoring blood supply to 50 per cent of normal levels.

This is a substantial amount, says Oscar Abilez at Stanford University in California. "For example, in a heart attack situation, if you can restore that much blood flow to tissue, in a reasonable time, that would be significant for reducing tissue damage."

"In a heart attack, if you can restore blood flow, that would be significant for reducing tissue damage"

After treatment, about 75 per cent of the mice had minimal levels of dead tissue, says Melero-Martin. In contrast, most of the leg tissue died in around 90 per cent of the mice that were injured and not given the implanted blood vessels (*Cell Stem Cell*, doi.org/g9p93w).

In another experiment, the researchers used the organoids to treat mice with type 1 diabetes, where damage to the pancreas causes blood sugar levels to get too high. They found that implanting the organoids into the mice alongside transplants of pancreatic tissue substantially improved their blood sugar control, compared with transplanting pancreatic tissue alone.

But further studies in larger animals such as pigs are needed before this method can be tested in people, says Abilez. Melero-Martin says the team hopes to do this, adding that human studies could realistically take place within five years.

Besides treating tissue injury, the findings could help the development of lab-grown mini-organs that better mimic what is happening in the body, or even mini-tumours that scientists can study and test treatments on in the lab.

"Until recently, those organoids can only grow to a certain size, because they don't have blood vessels – so, after a certain size, a few millimetres, they start to die," says Abilez. "This study offers a way to add blood vessels to those organoids so that they better represent the physiology of a human and are more useful for developing treatments." ▮

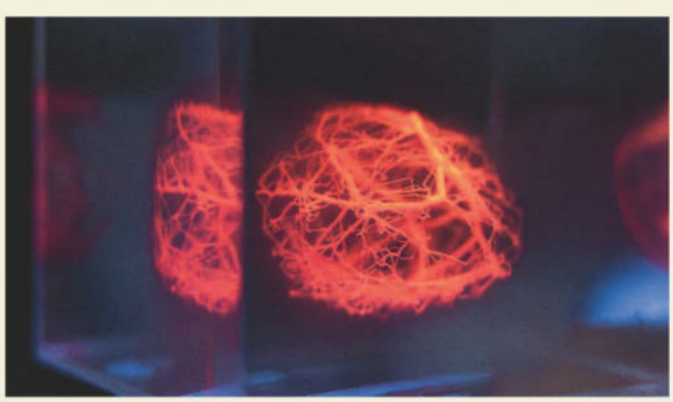
3D-printed blood vessels could pave way for artificial organs

A computational model that can rapidly design a blood vessel network for any 3D-printed organ may take us a step closer to transplanting artificial organs without the need for a donor.

People with organ failure often require transplants, but only 10 per cent of global demand is being met. To help, scientists are developing ways to 3D print organs in the lab, but these require blood vessel networks to stay alive. Creating them is hard (see main story) and the design itself can take weeks.

To address the latter point, Alison Marsden at Stanford University in California and her colleagues built a computational model that can design these networks for any organ based on a mathematical law that describes how blood vessels branch into smaller ones in the body.

They tested their approach by having the model design a network of 25 vessels for a 1-centimetre-wide ring-shaped structure that had been 3D printed from kidney cells, which it did in a few minutes.



This blood vessel network was designed by a computational model

ANDREW BRODHEAD

The team then printed the vessel network into the ring using cold gelatin particles, before heating it to 37°C (98.6°F), which melted the gelatin and left a network of hollow, 1-millimetre-wide channels that mimicked blood vessels. The researchers then continuously pumped a liquid containing oxygen and nutrients through the channels to simulate normal blood flow.

A week later, there were around 400 times more living cells in the ring compared with an identical ring of kidney cells without the vessels, which the team had also bathed in the blood-like fluid (*Science*, DOI: 10.1126/science.adj6152).

Physics

Fluid-like light simulates space-time

An experimental breakthrough could help us better understand the behaviour of black holes

Karmela Padavic-Callaghan

BY MANIPULATING light into a fluid-like form, then using it to simulate space-time, researchers hope to unlock new insights on the nature of black holes.

Supermassive cosmic objects, such as black holes, are very difficult to study directly, but researchers can construct useful analogues in the laboratory using quantum effects. For example, researchers previously simulated space-time – the fabric of our physical reality – using extremely cold atoms, then populated it with the equivalents of black holes.

Now, Kévin Falque at the Kastler–Brossel Laboratory (LKB) in Paris and his colleagues have used light to create a well-controlled space-time analogue.

To do so, they confined light in a small cavity made from a reflective semiconductor material, where it bounced between the layers of the material and interacted with electric charges within it. During this process, quantum interactions ultimately turned the light into a liquid-like state of matter.

"This opens the door for observations of a variety of new phenomena, including how black holes vibrate"

The researchers could use lasers to control the properties of this fluid and sculpt it to have the same geometry as space-time. They could also manipulate it to create structures equivalent to the horizon of a black hole – the edge that objects can fall over but never return from (*Physical Review Letters*, doi.org/prkv).

Because their light-based "universe" could be controlled extremely well, Falque and his colleagues could create not only event horizons but also similar, less steep, space-time structures.

They hope to use this unique simulation to test how Hawking radiation, which emanates from black holes, changes with the steepness of the event horizon. To get there, however, they will have to make their experiment colder and more isolated, which will boost the quantum effects within it.

"The work is an impressive experimental tour de force," says Juan Ramón Muñoz de Nova at the Complutense University of Madrid. He says it opens the door to observations of new phenomena, including how black holes vibrate.

One of the most extreme outcomes of this experiment could be that we discover some observed black holes are actually impostors, says team member Maxime Jacquet, also at LKB. The first image of a black hole, taken by the Event Horizon Telescope, certainly looks like the real thing – but looking like a black hole isn't the same as being one, he says.

In theory, there might be objects that bend light like black holes but lack event horizons, and these experiments could explore the idea further, says Jacquet.

"We need to be super careful. Even though we have these analogues – there's a fluid and there's a black hole – these objects are super different," says Falque. "But what we are doing in this experiment is testing and playing with the theory that is used for black holes." ▮

For more on space-time, turn to page 32

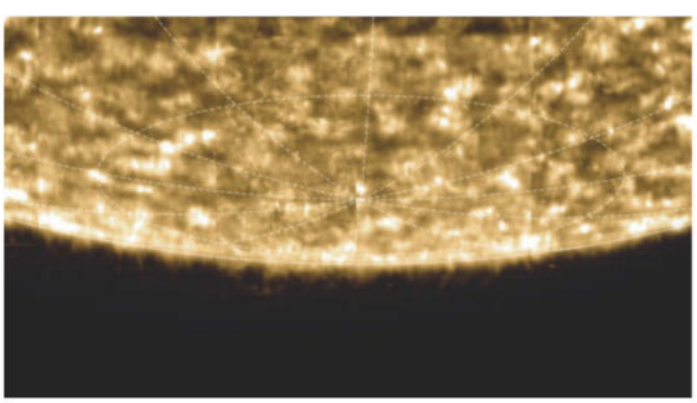
Solar system

The sun's south pole is caught on camera for the first time

OUR understanding of the sun could be about to change, thanks to some never-before-seen images of its south pole taken by the pioneering Solar Orbiter spacecraft.

Taking a picture of the solar poles is harder than it sounds, because to do so a spacecraft must leave the ecliptic plane, a flat disc around the sun in which almost every object in the solar system orbits. The Solar Orbiter, a joint mission between the European Space Agency and NASA, has done just that. Launched in 2020, it has gradually been tilting its orbit and has now reached a sufficiently steep angle to glimpse the sun's polar regions.

ESA has now released the first pictures of the sun's south pole, taken between March, when the spacecraft was orbiting at an angle 15 degrees below the ecliptic plane, and June, when it reached 17 degrees below.



ESA & NASA/SOLAR ORBITER/PHI TEAM, J. HIRZBERGER (MPS)

Studying the sun's poles will help us better forecast space weather

Seeing the images for the first time felt special, says Lucie Green at University College London, who helped develop the Solar Orbiter. "It felt like we're at a privileged time that these previously hidden areas are now available to us."

The Solar Orbiter has also taken measurements of the magnetic fields and high-energy radiation spilling out of the sun's south pole, which ESA has now released.

Being able to make measurements of the magnetic fields at the sun's south pole will help us better understand the solar cycle, which rises and falls in intensity in roughly 11-year periods, says Green.

"It might seem counterintuitive, but one of the most critical regions on the sun for forecasting space weather at Earth is the one place we can't get a good look from Earth: the solar poles," says Mathew Owens at the University of Reading, UK.

For space weather forecasting, knowing the magnetic structure of the poles at solar minimum, the period of lowest solar activity due in three to four years time, will be particularly valuable, says Owens.

The Solar Orbiter has also caught a glimpse of the sun's north pole, but ESA is waiting for the data to be returned to Earth. ▮

Alex Wilkins

Space

Volcano discovered on Mars, and we may have samples from it

Jonathan O'Callaghan

A VOLCANO seems to have been identified near the rim of Jezero crater on Mars, which is being explored by NASA's Perseverance rover.

Perseverance landed in the crater in 2021 and has gradually made its way to the western rim, driving up a dried-up river that is thought to have flowed about 3 to 4 billion years ago.

The vehicle has been collecting samples that were intended to be returned to Earth as part of the Mars Sample Return mission in the 2030s, although that is now threatened by the Trump administration's proposed sweeping cuts at NASA.

Some of the material it has gathered was thought to be volcanic, including signs of lava flows. Now, James Wray at the Georgia Institute of Technology in Atlanta and his colleagues have found a possible source – a dormant volcano on the south-eastern rim of Jezero named Jezero Mons (*Communications Earth & Environment*, doi.org/g9p6m5).

High-resolution images from Mars orbiters have revealed fine-grained material on the mountain, consistent with ash from a volcano. The size and shape of Jezero Mons – 21 kilometres wide and 2 kilometres tall – also matches some volcanoes on Earth.

By counting craters near the volcano, Wray and his team have estimated that Jezero Mons may have last erupted as recently as 1 billion years ago, possibly flinging ash, lava and rocks into Jezero crater, even as far as Perseverance's landing site.

That means the rover might have collected samples from Jezero Mons. If so, and if they could be returned to Earth, scientists would be able to precisely date the activity of a volcano on another planet for the first time. ▮

Health

How you breathe could reveal a lot about your health

Helen Thomson

SANDY HUFFAKER/CORBIS VIA GETTY IMAGES

Breathing exercises could help treat health conditions

FORGET facial recognition – there could be a new way to identify you. Researchers have discovered that we all seem to have a "respiratory fingerprint", a unique way of breathing that could revolutionise how we diagnose and treat various health conditions.

The breakthrough comes from Timna Soroka at the Weizmann Institute of Science in Israel and her colleagues, who have developed a wearable device that captures the subtle nuances of how we breathe.

The idea that breathing patterns contain health information isn't new. But without a wearable device that could record nasal breathing data as a person moves around, research was limited to data collected from hospital patients, who tend to have their breathing monitored for less than an hour.

To get around this, Soroka and her colleagues created a wearable device and gave it to 97 people who wore it for 24 hours. They then trained an algorithm to recognise unique combinations of 24 parameters – everything from the volume of air breathed in to how often breath-holding occurred. The algorithm could identify the participants with almost 97 per cent accuracy, and this signature remained stable over a two-year follow-up period (*Current Biology*, doi.org/prkr).

Nevertheless, "don't expect to have a nasal airflow recording next time you go to the bank", says team member Noam Sobel, also at the Weizmann Institute. The goal isn't to use the device for biometrics, he says, but for valuable health information.

> **"It's not hard to imagine a future where all patients are given a nasal airflow monitoring device"**

For instance, a person's body mass index (BMI) could be predicted by a combination of parameters of the nasal cycle, the rhythm in which each nostril alternates between being more or less open than the other.

This cycle is governed by the balance of your sympathetic nervous system, which prepares the body for a "fight or flight" response, and the parasympathetic system, which calms the body, says Sobel. "So by measuring airflow in your nostrils, you're actually gaining a measure of your sympathetic arousal, and that seems to be a predictor of BMI."

This raises an intriguing possibility, says Sobel: rather than weight gain causing breathing changes, could breathing patterns influence weight? "If that's true, we'll find the breathing pattern that makes you thin and our whole group will retire and go live on an island," he says.

The respiratory data also revealed correlations between aspects of breathing and levels of anxiety and depressive symptoms, such as people with high levels of depressive symptoms inhaling faster.

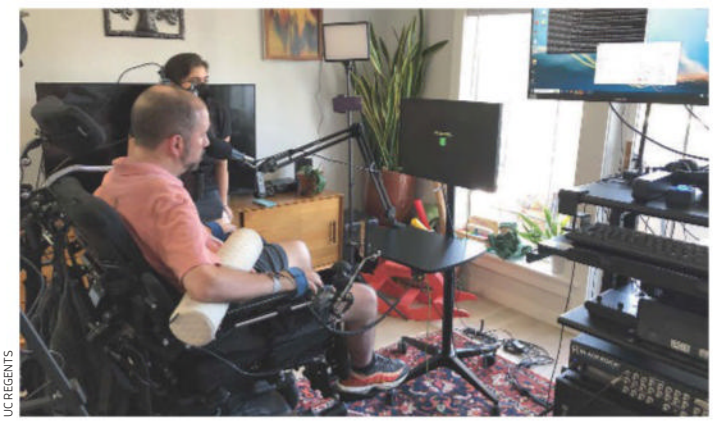
The team is now investigating whether breathing patterns actually cause these symptoms, to see whether they can be used to diagnose some common mental health conditions, which could then potentially be treated via breathing exercises.

"It's not hard to imagine a future where every patient is given a nasal airflow monitoring device that tracks treatment, provides feedback and predicts outcomes for a range of disorders," says Torben Noto at Osmo in New York, an AI firm aiming to give computers a sense of smell. "It has the potential to have a huge impact on human health." Noto came up with the 24 breathing metrics the team used, but wasn't involved in the study. ▮

Neuroscience

AI turns brainwaves into instant speech

Christa Lesté-Lasserre



UC REGENTS

An AI system helped a paralysed man speak with specific intonations

A MAN who lost the ability to speak can now hold real-time conversations and even sing through a brain-controlled synthetic voice.

The brain-computer interface reads the man's neural activity via electrodes implanted in his brain and then instantaneously generates speech sounds that reflect his intended intonation.

"This is kind of the first of its kind for instantaneous voice synthesis – within 25 milliseconds," says Sergey Stavisky at the University of California, Davis.

The technology needs to be improved to make the speech easier to understand, says Maitreyee Wairagkar, also at UC Davis. But the man, who lost the ability to talk due to amyotrophic lateral sclerosis, says it makes him happy and that it feels like his real voice, according to Wairagkar.

Speech neuroprostheses that use brain-computer interfaces already exist, but these generally take several seconds to convert brain activity into sounds. "It's like having a phone conversation with a bad connection," says Stavisky.

To synthesise speech more realistically, Wairagkar, Stavisky and their colleagues implanted 256 electrodes into the parts of the man's brain that help control the facial muscles used for speaking. Then, across multiple sessions, they showed him thousands of sentences on a screen and asked him to try saying them aloud, sometimes with specific intonations, while recording his brain activity.

Next, the team fed that data into an artificial intelligence model that was trained to associate specific patterns of neural activity with the words and inflections the man was trying to express. The machine then generated speech based on the brain signals, producing a voice that reflected both what he intended to say and how he wanted to say it (*Nature*, doi.org/prgs).

The researchers also had him try to sing simple melodies using different pitches. Their model decoded his intended pitch in real time and adjusted the singing voice it produced.

"He's a very articulate and intelligent man," says team member David Brandman, also at UC Davis. "He's gone from being paralysed and unable to speak to continuing to work full-time and have meaningful conversations." ▮

Space

Starlink's leaking radio waves may affect astronomy

Alex Wilkins

SPACEX'S Starlink satellites are unintentionally emitting radio waves to such an extent that it could threaten our ability to study the early universe.

Interference from the thousands of Starlink satellites in orbit, where they provide a global internet service, has been a concern for astronomers, who say that the radio emissions from the craft could affect sensitive telescopes that observe distant, and faint, radio sources. SpaceX has tried to prevent this interference by switching off their internet-transmitting beams when they fly over key telescopes, but that isn't enough.

Steven Tingay at Curtin University in Australia and his colleagues have tracked the signals from nearly 2000 Starlink satellites using a prototype telescope from the Square Kilometre Array-Low observatory (SKA-Low) in Australia. This planned collection of more than 100,000 small, linked telescopes is currently under construction to study the early universe, but the researchers found that Starlink signals are affecting up to a third of the data taken at some frequencies (arXiv, doi.org/prfg).

They also found that the satellites were emitting signals at two frequency ranges that are protected for use in radio astronomy by the International Telecommunication Union (ITU). However, it is thought that these satellite transmissions are unintentional. The leaking emissions are 10,000 times stronger than the faint radio signals that existed when the first stars began to form.

"These signals are comparable to the brightest natural radio sources in the sky"

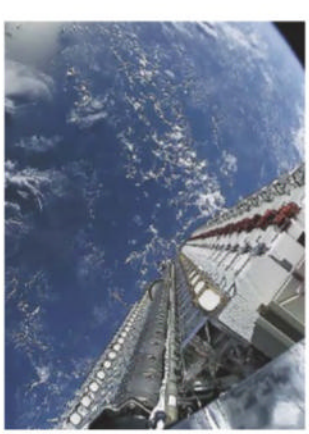
"If you look at the signal strength produced by these unintended emissions, it's not unusual for them to be comparable to the brightest natural radio sources in the sky," says Tingay.

The emissions are probably coming from onboard electronics that are accidentally transmitting signals through the satellite's antenna, says Tingay. "No one is breaking any rules from SpaceX or Starlink," he says, as the ITU regulations only cover intentional emissions. The ITU declined to comment.

"These findings are consistent with previous studies we've conducted, but more work is needed to have a clearer picture of the impact on low-frequency observations," says a spokesperson for SKA-Low.

The team has shared the results with SpaceX and says that the firm has been open to a dialogue on ways to reduce emissions. SpaceX didn't respond to a request for comment. ▮

SpaceX Starlink satellites sent into orbit atop a Falcon 9 rocket



SPACEX

Health

CRISPR takes on kidney damage

Gene editing could counter some of the effects of "irreversible" polycystic kidney disease

Michael Le Page

THE damage to the body caused by the most common type of inherited kidney disease was thought to be irreversible. But now, animal studies suggest that correcting the responsible mutations via CRISPR gene editing can reverse at least some of it.

Polycystic kidney disease (PKD) causes extensive changes to the kidneys over time. "It really seemed unlikely that you could change that even if you correct [the mutation]," says Michael Kaminski at the Charité – Berlin University of Medicine in Germany. "But now it seems that the disease might be more plastic than somehow previously appreciated."

PKD leads to fluid-filled cysts that grow larger over time, forming in the kidneys and often also in the liver. These organs eventually fail, meaning people need dialysis or a transplant to stay alive. But even before the kidneys fail, their damaged and swollen state can cause many other issues, from high blood pressure and infections to pressure on other organs.

With the adult form of the disease, which is estimated to affect 12 million people worldwide, cysts may not grow large enough to cause symptoms until people are in their 30s, during which time there could have been extensive changes to their kidneys and liver.

Now, Kaminski's team has used a form of CRISPR called base editing to correct a mutation in a gene called *Pkd1* that causes the disease in mice.

The methods his team used meant the mutant gene was mainly corrected in the liver, and the number and size of cysts there declined after the treatment (bioRxiv, doi.org/prd5). There were also signs of improvement in the kidneys, says Kaminski.

Separately, Xiaogang Li's team at the Mayo Clinic in Rochester, Minnesota, did a similar study using methods that better target the kidneys (*Journal of the American Society of Nephrology*, doi.org/prd6). This suggests that the number and size of cysts there can also be reduced, says Li.

12 million

The number of adults worldwide affected by polycystic kidney disease

Both sets of researchers used viruses to deliver the gene-editing machinery. This could be an issue if repeat doses are needed, as the immune response to viruses can stop treatments from working. "That's a concern," says Li. "But so far, based on the animal model, the immune response is very limited."

Replacing the viruses with lipid nanoparticles, like those used in mRNA vaccines, would avoid the potential immune issue, but these particles can't penetrate deep enough into the kidneys via blood to be effective, says Kaminski.

"But I think an approach where you would deliver [lipid nanoparticles] through the urethra could be more realistic," he says.

Another issue is that base editing can correct only single-letter mutations and so wouldn't work for people whose disease is caused by longer mutations. But Li says he has achieved similar results with a technique called prime editing, which can correct longer mutations.

This work will be published in a scientific journal soon, he says, after which he aims to move to tests in people. "When our paper is published, I will try to organise a small clinical trial," he says. ▮

Technology

Turning Death Valley's arid air into a source of water

A SMALL panel managed to extract a glassful of clean water from the bone-dry air of Death Valley in California, which suggests that the device could provide this vital resource to arid regions.

The atmosphere over extremely dry land can hold large volumes of water, but extracting this in significant quantities without power is difficult. In the past, researchers have come up with innovative ways to tap into this reservoir, such as fog-catching nets made from simple mesh fabrics or spider silk-like artificial fibres, but they have struggled to make them work effectively in real-world conditions.

MIMI DITCHIE PHOTOGRAPHY/GETTY IMAGES

Death Valley in California has an incredibly dry climate

Now, Xuanhe Zhao at the Massachusetts Institute of Technology and his colleagues have developed a power-free water-collecting device that is about 0.5 metres tall and 0.1 m across. It is composed of a glass panel that contains an absorbent hydrogel, a jelly-like substance made from long-chain polymers, and lithium salts that can store water molecules.

The hydrogel, which was folded into an origami-like structure to increase its surface area, absorbs water at night. This then evaporates when the sun shines on the glass panel in the day. The device's interior is coated in a cooling material, where the evaporated water collects and drips into storage below.

Zhao and his team tested their device for one week in Death Valley, where humidity can reach as low as 5 per cent. For comparison, London's year-round average is around 70 per cent. The researchers found that the device extracted up to 160 millilitres of water per day, enough to fill a small glass (*Nature Water*, doi.org/prfd).

They estimate that eight of these panels could supply an average adult's daily drinking water needs, which may be particularly useful in arid areas. ▮ AW

OWN YOUR MIND BUSINESS

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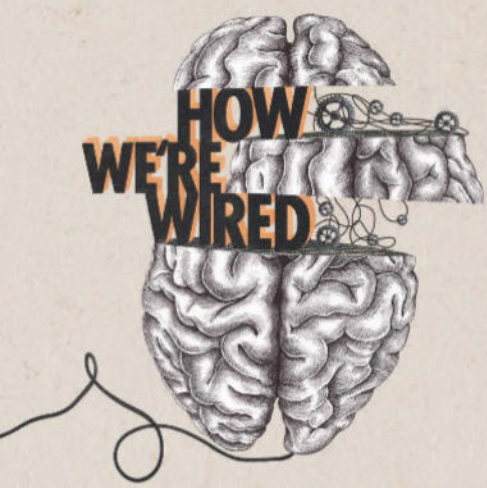

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Views

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Alone in a crowd

The "immersive entertainment" boom takes user-centred experiences to new heights, but what are we losing as a result, asks **Arwa Haider**

SIMONE ROTELLA

WHAT are you doing later: roaming through Van Gogh's landscapes, time-travelling to ancient Egypt or maybe catching a posthumous gig from a musical hero? These are the kinds of "immersive" experiences we are increasingly flooded with, spanning dizzying possibilities that each promise to place us at the centre of their story. The immersive entertainment market globally was valued at around $114 billion in 2024, and it is predicted to almost quadruple to roughly $442 billion by 2030.

As a journalist and life-long pop culture fan, I am simultaneously captivated and unsettled by immersive entertainment. My most memorable experiences of it were intensely personalised and powerfully emotive; they have made me exhilarated, tearful, even "cybersick". When we are wrapped up in a narrative, particularly one relayed through a headset, we are removed from real time – arguably part of the allure.

It isn't the escapism that fazes me, though – great culture liberates us from everyday constraints – it is the insularity. Immersive events elevate the subjective viewpoint, often at the expense of the communal energy that fuels social atmosphere, so even packed-out immersive shows can seem like solitary pursuits, with human companions resembling NPCs (non-playable videogame characters).

The cultural academic Keren Zaiontz coined a sharp term for our consumption of immersive entertainment: "narcissistic spectatorship". One study found VR use induced dissociative symptoms in 83.9 per cent of participants. The long-term effects remain nebulous, but research, including a study of VR tourist experiences, has highlighted recurring themes of addiction to the experience and isolation.

Over at London's Barbican Centre, Feel the Sound is a new immersive exhibition whose installations offer imaginative personalised features, including *Your Inner Symphony*'s "sensing stations", which generate unique visuals by tracking our bodily reactions to music. Luke Kemp, who heads up the Barbican's immersive programming, says these experiences respond to our need for "playful" cultural spaces, accessible regardless of prior knowledge: "It allows the audience to have agency, and to feel part of something."

Robyn Landau at Kinda Studios, co-developer of *Your Inner Symphony*, points out the link to interoception – our awareness of our body's inner senses. "When we have these transformative experiences individually that connect us to ourselves, they actually transform how we show up in the world and the way we connect to others," she says.

According to psychologist Sophie Janicke-Bowles, immersive experiences create scenarios where our "processing power is challenged just enough to keep us interested". This "can have an incredible recovery effect on our psyche, where we can detach from our everyday concerns and cognitively, emotionally and even physiologically get absorbed into something different", she tells me.

Having grown up clubbing, I am struck by how many immersive experiences evoke the dancefloor; the extraordinary *In Pursuit Of Repetitive Beats,* a multi-player VR homage to the UK rave scene in which networked headsets allow groups to interact in real time, is also at the Barbican.

But for me, there is still a curious tension at play in immersive entertainment, and I am torn about where the rapidly developing scene is taking us. It does give us an opportunity to tune into ourselves, but I am less convinced it amplifies our bond with those around us. If we remain fixated by our own reflections, then we are missing the bigger picture. Immersive entertainment might make VIPs of us all, but culture should also bring us together. ▮

Arwa Haider is a culture journalist based in London

No planet B

A tangled web From spiders to scorpions, some 1000 different invertebrate species are traded globally as pets. This is bad for biodiversity – but there is a silver lining, says **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *Mustn't Grumble: The surprising science of everyday ailments*. You can follow him @grahamlawton

Graham's week

What I'm reading
Many Things Under a Rock: The mysteries of octopuses *by David Scheel.*

What I'm watching
The Survivors *on Netflix.*

What I'm working on
The York Festival of Ideas is on this week, so I've been going to talks and events looking for... er... ideas.

This column appears monthly. Up next week: Annalee Newitz

WHEN I was about 7 or 8 years old, my biology-professor dad brought me a present home from work: a jar of sticks. Or at least that's what I thought it was. When some of them started moving he explained that they were stick insects. I kept them for a while and found them fascinating. They weren't cute and cuddly but they had something else: they were cool.

Seems I was ahead of my time. Last month, two Belgian teenagers were released from jail in Kenya after paying a fine for wildlife piracy. Their crime, to which they pleaded guilty, was attempting to smuggle 5000 ants out of the country. Smuggled ants often turn up in what reports describe as a "booming" global trade in exotic invertebrate pets. Their haul included giant African harvester ants (*Messor cephalotes*). A colony of these highly prized mini-beasts sells for around £170 in the UK.

Ants are by no means the only invertebrate group being traded and kept as pets. The menagerie also includes spiders, scorpions, mantises, beetles, cockroaches, grasshoppers, snails, slugs and, of course, stick insects.

A recent review found that almost 1000 invertebrate species are being traded on the exotic pet market. Some are traded legally, but others are contraband. Giant African harvester ants, for example, are a protected species in Kenya.

Keeping invertebrates as pets may seem like a harmless hobby, but it can have serious consequences for biodiversity. Putting firm numbers on any of this is difficult, but an estimated two-thirds of the arachnids on the market are poached from the wild. In Mexico, overharvesting of *Brachypelma* tarantulas has caused significant population declines. In the limestone karsts under the Dinaric Alps of south-eastern Europe, poachers of troglobionts – animals adapted to living in caves – have helped to push several already-endangered insects closer to extinction.

Unsustainable harvesting also damages the wider ecosystem. Invertebrates are an important food source for many vertebrates, and they supply vital ecosystem services such as decomposition and nutrient cycling.

Poaching destroys habitats directly. Many prized tarantulas live in vase-shaped plants called bromeliads, which also provide a home to frogs and other animals.

"In Mexico, the overharvesting of tarantulas has caused significant population declines"

According to Caroline Sayuri Fukushima at Tarantupedia, an online taxonomic database of large spiders, the poachers just chop the plants down, killing them and their captive ecosystems. In the Balkans, the poachers set pitfall traps that kill thousands of non-target species.

Exotic invertebrates are also a threat to the locations where they end up. Indeed, 57 ant species known to be traded are classed as invasive by the International Union for Conservation of Nature (IUCN), and 13 of them are among the top 20 worst global ant invaders.

Stopping the trade will be very difficult. The Kenyan judges – who sentenced the Belgians to either a fine of 1 million Kenyan shillings (£5700) or a year in jail – reportedly said they wanted to send a strong message that trafficking of all protected wildlife is unacceptable. But people must be getting away with it. I found several websites advertising giant African harvester ants, which live only in East Africa.

The Belgian teenagers were caught red-ant-handed, but according to the authors of a 2022 survey of the global arachnid trade, smuggling invertebrates is relatively straightforward, at least compared with smuggling vertebrates. They are small and easily concealed, and aren't picked up by X-ray machines or thermal cameras at airports. Protected species can also be laundered as legally tradeable ones, as customs officers lack the taxonomic expertise to tell them apart.

It's the same old story of greed, exploitation and destruction. But it doesn't have to be like this. According to biologists who study it, the trade in invertebrates can be a force for good. Sustainable harvesting of wild species can support the livelihoods of some of the world's poorest people, while also diverting them away from more harmful acts such as illegal logging. Increased recognition of the trade is stimulating much-needed research on wild populations of target species and their conservation status. It is also getting organisations such as the IUCN to pay attention to a group of animals they have historically neglected.

As for the collectors themselves, they are obviously interested in the amazing variety of life on this planet, and could also be recruited into the fight to save it. I think they should be allowed to indulge their hobby, albeit within a well-regulated system of sustainably harvested or captive-bred, non-invasive invertebrates. I won't be getting any more stick insects, but they certainly helped to stimulate my interest in the natural world.

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Hope from the embers

When Science Finds a Way, a podcast from Wellcome, uncovers inspiring stories of scientific innovation and community collaboration

THIS year, California experienced some of its worst wildfires in history, killing 30 people, destroying over 16,000 structures and harming the health of thousands. Indigenous communities, closely tied to the land, have been hit hard.

But wildfires and their management are not new – across North America and beyond, droughts and rising temperatures caused by climate change are increasing the frequency and destructiveness of these blazes.

"If we're going to solve this wildfire crisis, we need to be working together," says Cody Desautel, a firefighter with 30 years' experience and executive director of the Colville Tribe in North Central Washington State in the US. Desautel has witnessed wildfires become an escalating threat, fuelled by climate change and short-sighted land management practices.

Yet indigenous knowledge may also hold the solution. For centuries, communities like Desautel's have practiced "cultural burning" to manage forests and support biodiversity. This traditional practice, long side-lined, is now being re-examined as scientists and local communities join forces to fight fire.

Urgent issues

This story, highlighting the intersection between local communities and science, is one of many featured on *When Science Finds a Way*, a podcast from Wellcome. Hosted by botanist-turned-actor Alisha Wainwright, the show explores the incredible stories of people on the forefront of discovery science, research solving urgent health challenges, and the huge impact science has on all of us.

Wainwright brings her science background and love of storytelling to the role. "We have a treasure trove of research projects to explore, and it gives listeners a real sense that amazing science is being done and that it is effective."

Desautel's story features in her favourite episode, which explores how traditional "cultural burning" can help prevent wildfires – an approach that Nicole Redvers, a member of the Deninu Kųę First Nation, in the Northwest territories of Canada, and researcher at Western University says Western science is only just embracing.

"Short-sighted forest management practices have really contributed to the increasing destructiveness of wildfires," Redvers told Wainwright.

Natural firebreaks

One common practice is to use the weed-killer glyphosate on forests to kill deciduous trees and encourage the more profitable coniferous forest growth. But this removes natural firebreaks and increases risk of wildfire.

The health impacts are stark – particularly for Indigenous communities who often lack air conditioning and other measures to protect against smoke. Fine particulate matter in wildfire smoke is linked to asthma, heart attacks, cardiovascular disease, cancers, as well as mental health issues.

Cultural burning can offer a way forward – setting small, deliberate fires guided by intergenerational knowledge about how the brush grows, when vegetation is thriving, and how animals move through the forest.

Studies comparing people's blood and lung function show smoke from these beneficial burns is less harmful than wildfire smoke. "With beneficial fire, you could barely pick up the smoke particles [in the blood]", says Kari Nadaeu, at Harvard School of Public Health. Nadeau and her colleagues took the data to the World Health Organization and now policymakers are using it to incorporate beneficial fires back into land management.

Yet true progress isn't about bringing Indigenous people to a Western table and asking how to assimilate their knowledge into their systems, says Redvers. "Why are we not thinking about how we integrate Western systems to Indigenous systems?"

MEET THE PODCAST HOST: ALISHA WAINWRIGHT

Before becoming an actor, Alisha Wainwright studied botany and became a tropical biologist working at the Smithsonian Tropical Research Institute in Panama. While considering post-doctoral programs, she decided to take a year off. "I thought maybe I could work in enology, the chemistry behind wine," she says. Instead, she leaned into the arts, which turned into a career in TV where she is best known for her role in the Netflix superhero series Raising Dion. Describing herself as still that "curious, science-minded, analytical dork" she jumped at the chance to host Wellcome's podcast *When Science Finds a Way*. "I used to only talk about science over a drink with my friends, so now I get really emotional that I get to talk about it on a much wider platform."

KARA CAPALDO/ISTOCK

Wildfires are an escalating threat, fuelled by climate change

This theme – putting communities at the heart of science – is consistent across the podcast. Another favourite episode of Wainwright's features Scott O'Neill, founder of the World Mosquito Program and his work to combat dengue fever using a naturally occurring bacterium called *Wolbachia*, which reduces the mosquitoes' ability to carry and transmit viruses like dengue. O'Neill's work has been supported by Wellcome for more than a decade.

Viral load

The *Aedes aegypti* mosquito is responsible for almost all the world's dengue transmission, infecting around 390 million people each year, killing thousands. To combat this, O'Neill's group introduced *Wolbachia* into the mosquito. Released into the wild, the *Wolbachia*-infected mosquitoes spread the bacterium as they breed, reducing the transmission of the dengue virus to humans.

Elegant it may be, but implementation wasn't easy. "We can't just go into these communities and say, 'this is good for you, you should accept it'," says O'Neill. In Bello, Columbia, Joanny Rendon, a community volunteer played a role in spreading the word to her neighbours. "We went from house to house, churches, supermarkets, informing people on why it was important." When someone from your own community tells the story, people listen, she says. As a result, seasonal peaks of dengue fell by more than 90 per cent.

Wainwright hopes listeners come away inspired by the podcast. Other episodes in season two explore cholera prevention in Kenya, equitable access to genomics, and even stories from people using digital avatars to regain control over psychosis. Each one reinforcing Wellcome's goal of creating a healthier future for everyone, through scientific innovation.

"When I read the news, I feel hopeless and frustrated," says Wainwright. "What I love about each episode is that I never come away feeling disappointed in the world."

"What I love about each episode is that I never come away feeling disappointed in the world"

Alisha Wainwright

Season two of *When Science Finds a Way* is available now on all podcast platforms

Rich waters

Vivian Wan
Earth Photo 2025

RESTORING a way of life is at the heart of this photograph by Vivian Wan, part of a series that won the New Scientist Editors Award in the Earth Photo 2025 competition.

It shows members of the Indigenous Yurok community working with biologists and technicians to set up rotary screw traps on the Trinity river, a major tributary of the Klamath river in California. The team uses fish traps to study the animals' health and migration patterns.

The Klamath basin is at the heart of Yurok life, with its rich waters providing large Chinook salmon (*Oncorhynchus tshawytscha*), which hold deep cultural and spiritual significance to the community. But two centuries of colonisation have depleted resources in the region.

Climate change and diverted water further pushed the fish to the brink. In 2002, new irrigation policies resulted in tens of thousands of Chinook salmon in the Klamath river dying. This added urgency to a decades-long fight to remove the river's dams. Last year, the fourth of the dams on the Klamath river was dismantled.

For Wan, the aim was to explore how Indigenous communities lead the battle for environmental justice. "I hope viewers come away with a deeper sense of respect for the Yurok people's strength, culture and fight to protect [the] Klamath basin," she says.

All winners in the Earth Photo competition were chosen by a panel including *New Scientist*'s picture editor, Tim Boddy, and head of editorial video, David Stock. See the Earth Photo 2025 exhibition at London's Royal Geographical Society until 20 August, before it tours the UK.

Liz Else

A dish best served cold

A recovering "revenge addict" makes the case for retaliation to be understood as an addiction, but **Elle Hunt** isn't persuaded

Book
The Science of Revenge
James Kimmel Jr.
Harmony Books

FEW people may readily own up to thirsting for revenge – yet it is undeniable that some of us do.

From US President Donald Trump's fixation on score-settling to the "cancel culture" of policing on social media, and maybe even the felling of the iconic Sycamore Gap tree in the UK – possibly an attempt at payback due to one of those found guilty being at risk of eviction – revenge may be more plausible than love as the force that makes the world turn. Could we even go so far as to call it an addiction?

James Kimmel Jr. argues passionately that we can – and we must, if the world is ever to become a more compassionate place. His new book *The Science of Revenge: Understanding the world's deadliest addiction – and how to overcome it* reflects his efforts, over more than a decade, to improve our understanding of the neurology driving revenge and to recognise its deadly toll.

You can't deny Kimmel's credentials: he is a lecturer in psychiatry at Yale University, where he leads studies into motive control, and a lawyer. As a former civil litigator, resolving non-criminal disputes, he saw how the law could be abused to progress personal grievances and punish perceived enemies, especially by the wealthy and powerful.

He also understood the impulse, he writes. Growing up in rural Pennsylvania in the early 1980s, he was bullied and his family intimidated. Their dog was even shot dead. After their mailbox was blown up, the teenage Kimmel ended up pulling a gun on his tormentors – but not the trigger.

Still, Kimmel writes, his unresolved grievances ended up leading him into law – "the professional revenge business". After a mental breakdown, he began researching his pet theory of "revenge addiction", pivoting to psychiatry to progress it.

Today, Kimmel points to himself as a "recovering revenge addict", as well as to years of scientific inquiry, to make the case for "compulsive revenge seeking" to be understood as an addiction and a brain disease.

He argues that the desire for revenge registers in the brains of some individuals in much the same way as narcotics, activating cravings, overriding impulse controls and "satisfying the same brain-biological desire for relief of pain and hedonic reward".

"Kimmel says the desire for revenge registers in some people's brains in much the same way as narcotics"

If borne out, writes Kimmel, this idea could not only explain "the desire to hurt and kill", but also present a possible path for preventing violence. He suggests that by identifying people with a tendency to feel victimised, nurse perceived grievances and ruminate on retaliation, it may be possible to stop mass shootings and other deadly outbursts in their tracks.

To make his case, he references much credible research about reward, revenge and forgiveness. He is up front about the limits of their application or relevance to his concept of revenge addiction, and includes sceptical expert voices alongside those who agree there may be something to it.

However, his eagerness to credit revenge as the cause of "all the wars, murders, and physical and psychological assaults throughout human history" may put readers off as much as it persuades them.

Kimmel doesn't deny the relevance of "genetic factors, early trauma, or psychosocial and environmental circumstances", and says revenge addiction isn't intended to excuse people who commit violent crimes. But that is often the impression he creates, such as when he likens experiencing a bout of potentially murderous "revenge cravings" to a heart attack.

This is both confusing and clumsy. Kimmel is most compelling when he tells the stories of people who escaped lives shaped by hate, such as a former Ku Klux Klansman who now helps others. But his fixation on revenge as the root of all evil risks pushing nuance and other contributing factors (such as misogyny or childhood sexual abuse) to the side.

His analyses of mass murderers' manifestos and the psychologies of Adolf Hitler, Joseph Stalin and Mao Zedong via the narrow (at best) lens of revenge addiction sit particularly uncomfortably. Revenge may be under-acknowledged as a motivating force throughout history, but Kimmel may be too close to his subject. ▮

Elle Hunt is a writer based in Norwich, UK

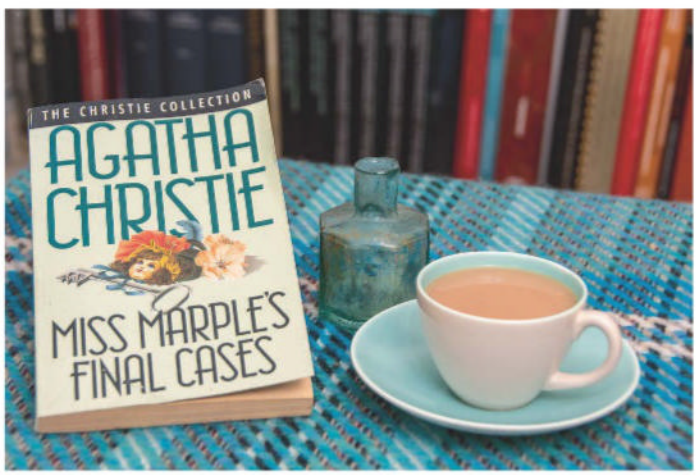
Was the UK's iconic Sycamore Gap tree felled in an act of revenge?

VAUGHAN/EPA-EFE/SHUTTERSTOCK

Killer queen

Agatha Christie had a deep knowledge of toxicology, making her murder mysteries all the more compelling, finds **George Bass**

Book
V Is for Venom
Kathryn Harkup
Bloomsbury Sigma



SHUTTERSTOCK/DOODEEZ

A talent for murder: Agatha Christie is one of the world's bestselling writers

AGATHA CHRISTIE'S five-decade writing career saw her poison dozens of her characters, supplying the killers in her stories with an assortment of deadly chemicals, including poisons and venoms produced by living organisms and delivered via injection.

Chemist Kathryn Harkup has visited their use before in 2015's *A Is for Arsenic. V Is for Venom: Agatha Christie's chemicals of death* looks at "the more unusual means of chemical killing that [make] Agatha Christie a true 'Queen of Crime'."

Christie's murders were made all the more authentic due to her scientific background: she was a pharmaceutical dispenser before she became a bestselling writer, and she furthered her knowledge of toxicology while volunteering as a nurse during the first world war. Harkup presents a detailed but never overwhelming account of the substances at the centre of her stories – and how many of them didn't come in small bottles conveniently marked "Danger".

Spoiler: a dirty bandage that had recently dressed a cat's ear infection is used to spread septicaemia in 1939's *Murder Is Easy*, while the killer in *Sparkling Cyanide* harnesses carbon monoxide from coal gas. Harkup explains the science behind each murder, avoiding spoilers where possible. She considers, for example, the feasibility of a "poisoned dart hidden in an adapted cigarette" and the consequences of imbibing toxic hat paint (feasible and not good, respectively).

Harkup's analysis stretches to the fictional poisons Christie invented, like Benvo from 1970's *Passenger to Frankfurt*, a drug that causes its victim to become fatally benevolent (Harkup concludes that "apparently, this is a bad thing").

Antidotes to the murder methods are outlined – CPR may have saved the life of the dinner party guest who had unknowingly ingested opioids in 1962's *The Mirror Crack'd from Side to Side*, while real-life cases that likely inspired Christie's plots are explained in asides.

Drugged drinks are used as a murder method in several of Christie's novels. Harkup writes of the disgraced Scottish chemist who worked as a bartender in 1870s San Francisco, and whose chloral hydrate "knockout drops", slipped into patrons' beer glasses, would later take his name: Mickey Finn.

Harkup reveals that many of the drugs from Christie's stories are still widely available. Barbiturates, as featured in 1933's *Lord Edgware Dies*, are today prescribed as epilepsy treatments, such as Seconal. But she cautions against using Christie's chemicals as "homicidal inspiration", explaining that toxicology was "a little different at the time Christie was writing". Would-be poisoners attempting to mimic her assassinations today would either be swiftly detected or else suffer a calamity.

Harkup balances the macabre with the scientifically intricate. For every passage detailing the chemical history of chloroform, there are accounts of real murders that Christie's imagination may have influenced. We learn of a poisoned billionaire who in 2011 died after eating cat-meat stew laced with gelsemium, the same plant featured in 1927's *The Big Four*. Harkup also deconstructs the hydrochloric acid murder in 1936's *Murder in Mesopotamia*, drawing comparisons with today's corrosive substance attacks.

Christie's inventive killings made her a perennial bestseller. But it's fitting that, as Harkup highlights, one of her favourite accolades came via *The Pharmaceutical Journal*. In response to her debut novel, 1920's *The Mysterious Affair at Styles*, the scientific review noted, "This novel has the rare merit of being correctly written." ▮

George Bass is a writer based in Kent, UK

New Scientist *recommends*

Alexis Wnuk
Subeditor
New York

I enjoyed the new space show at the American Museum of Natural History's Hayden Planetarium in New York City this week. Narrated by actor Pedro Pascal, **Encounters in the Milky Way** takes viewers on a mesmerising journey through our galactic neighbourhood.

The show does a great job of illustrating just how dynamic and chock-full of stuff our galaxy is. For instance, of course I knew that Earth orbits the sun, but I hadn't appreciated that everything – our sun, its stellar neighbours – is in constant motion, zooming around the centre of the Milky Way.

In one captivating sequence, visualised

here, I learned that a star system called Gliese 710 is due to pass through the Oort cloud, a vast area of icy objects surrounding our solar system, in about 1.3 million years. The two star systems will swap comets and send others hurtling out into space in what looks to be a spectacular show.

I'm just bummed that I will miss it.

AMNH

The TV column

Snow is falling... There are hundreds of TV apocalypses to choose from, but this fresh and compelling adaptation of a classic Argentinian comic book series is the one you should be watching right now, says **Bethan Ackerley**

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

MARIANO LANDET/NETFLIX

Juan Salvo (Ricardo Darín) braves the killer snow in Buenos Aires

TV
The Eternaut
Netflix

Bethan also recommends...

Film
The Mist
Directed by Frank Darabont
When a mist falls on the town of Bridgton, residents must stay inside or face a deadly threat. This Stephen King adaptation deviates from its source with a new ending – and what an ending!

Film
I'm Still Here
Directed by Walter Salles
Eternaut *comic book writer Héctor Germán Oesterheld's widow Elsa Sánchez sought justice for deaths linked to Argentina's military junta. Her story is similar to Eunice Paiva's, told in this stunning film, whose husband was killed by Brazil's dictatorship.*

TO MAKE good art, you must be specific. Perhaps that is too sweeping a statement – and so rather contradictory – but it is a fundamental principle I live by. It is no good chasing the lowest common denominator in the hope of attracting an audience. Whether it is a song, a painting or a poem, it is the specificities that we latch on to and fall in love with.

This may be why, with hundreds of TV apocalypses out there, *The Eternaut* is such a breath of fresh air. The new Netflix show adapts a classic comic book series written by Héctor Germán Oesterheld that was published in 1957 and much adored in his home of Argentina.

It also includes themes from a reboot of the story in 1969 that reflected Oesterheld's increasingly anti-imperialist views. It is a narrative steeped in real-world violence and paranoia that marked the rise of military dictatorship in Argentina, and it isn't nearly as well-known globally as it should be.

On a sweltering summer night in Buenos Aires, Juan Salvo (Ricardo Darín) and his friends gather in a basement to play the card game truco. Laughs are shared and whisky is drunk – until a mysterious flurry of snow blankets the city. This is strange enough considering it has only snowed in Buenos Aires three times in recorded history, but the falling flakes kill everyone they touch almost instantly.

Trapped inside, Juan has no idea whether his ex-wife Elena (Carla Peterson) and daughter Clara (Mora Fisz) are alive. He dons a waterproof suit and gas mask, then takes to the streets. Those left behind debate whether to share dwindling resources with fellow survivors, as their neighbourhood grows increasingly panicked.

> **"This is a narrative steeped in real-world violence and paranoia, and it isn't as well-known as it should be"**

I haven't read the original comic, as it is difficult to get hold of in the UK, so I can't comment on how faithfully it has been adapted. What I can say is that the changes made to fit a modern setting work well, such as Juan's backstory as a soldier in the Falklands war between the UK and Argentina in 1982. His military experience makes him a natural leader for the survivors, but his unresolved trauma may feed into strange visions he experiences.

The plot of *The Eternaut* may seem similar to those of many post-apocalyptic dramas; that is in no small part due to its enormous influence on this subgenre. But this Spanish-language series still feels fresh because it keeps its Argentinian-ness, rather than relocating the drama to the well-worn streets of New York or London. It is all the better for retaining that specificity, from the architectural to the political.

I knew shamefully little about the history of Argentina before starting the series, nor was I aware that Oesterheld and four of his daughters, two of whom were pregnant, were disappeared by the country's military dictatorship in 1977. The success of the new series has prompted a renewed search for his missing grandchildren, who are likely to have been given to other families as babies. All this sad history makes for a beautifully layered adaptation that feels richer than most of its contemporaries.

There are a few flaws in *The Eternaut*: the first three episodes are too slow a burn, while the female characters don't have much to do. But this is a compelling survival drama that becomes more complex in its second half. And here is one final bonus: having been such a sleeper hit for Netflix, it has already been renewed for a second season. ▮

Editor's pick

So much for the dawn of the AI revolution

24 May, p 27

From Arthur Barnett, London, UK

As an aside to your look at a book on hype over AI abilities, we had an unfortunate encounter with an AI that was recently introduced to health software that triages for our local doctor's office. I was referred by a pharmacist to my doctor because my eyes had developed a severe allergic reaction to our daughter's dog.

The AI ignored the referral by another health professional and other evidence like well-controlled, life-long eczema and the specific issue of the eyes. It simply took over the process, saying: "Hello Arthur, we see you have a rash..." I then ended up down a rabbit hole of irrelevant questions from which I couldn't escape. I tried the next day with a different approach, with the same result. Resorting to the phone, I got an appointment. Lots of wasted time for the practice.

Emotions, good and bad, serve us well

10 May, p 30

From Ada Mournian, Taunton, Somerset, UK

As a counsellor and psychotherapist, I have a different take on emotions. What would be the point of them if they weren't useful? We have them whether we like them or not.

Generally, we like the so-called positive ones and not many others. But they serve a major purpose, nudging us to recognise when something isn't right or if we have a learning opportunity.

Once we fully accept emotions and express them, they disappear into the ether. This isn't the same as taking them out on somebody else or projecting them.

Your article contains a lot of useful information, but since I read the opening lines about controlling our emotions, I could feel the pressure building. Now that I have got all this off my chest, I am feeling a whole lot better.

Did life on Earth get crushed into existence?

24 May, p 38

From Greg Blonder, Brookline, Massachusetts, US

If mechanochemistry can transmute chemical compounds by smashing them in a ball mill, perhaps the chemical precursors of life didn't arise in a warm tidal pool, but under rocks and pebbles compressed by geological forces.

Building brains that are immune to microplastics

10 May, p 38

From Lindsay Wright, Rangiora, New Zealand

The impact of microplastics on animal brains – and probably human cognition – got me thinking, while I still can. While we are engineering our downfall with plastics, we may unwittingly be crafting a "solution": minds immune to microplastics, in the form of AI. Could we also engineer our way out of this conundrum? Or perhaps someone is already working on it – unwittingly.

Companion planting success, but in reverse

31 May, p 43

From Will Kemp, Wagait Beach, Northern Territory, Australia

James Wong suggests tomatoes may do better when grown near basil. I found something similar, but different. When creating a veg garden, I thought I would test the companion-planting theory by growing basil and tomatoes – some near each other, some not. It wasn't a scientific study, but I found basil grew bigger when next to a tomato plant. Proximity to basil, meanwhile, made no noticeable difference to the tomatoes.

Tread carefully in analysis of exoplanet atmospheres

31 May, p 19

From Sam Edge, Ringwood, Hampshire, UK

The continuing arguments about the absorption spectrum of the atmosphere of the exoplanet K2-18b shows the difficulty of such research. Who selects the size and contents of the set of molecular spectra against which to compare the planet's data? The original 20 molecules seems an absurdly low number. That an expansion to 92 gives different results, and then to 650 different again, suggests that one might be able to suggest any number of molecules – either biologically or non-biologically generated on our own planet.

I wouldn't advocate for the end of such research, just that researchers should be humbler about whether they have detected or merely found the possibility of a given molecule.

Why nuclear civilisations may actually last longer

24 May, p 21

From Alex McDowell, London, UK

I take issue with the idea that we don't hear from aliens because the ability to develop interstellar communication also means an ability to develop potent weapons that lead to self-destruction.

Such civilisations have the potential to last longer because they can find ways to avert natural Armageddon. We know an asteroid wiped out the dinosaurs and are looking at ways to prevent future impacts. Nuclear bombs are one way to deal with asteroids. We also have methods to mitigate climate change, and advanced societies are also more likely to colonise other worlds, giving them greater protection from annihilation.

From Howard Homler, Orangevale, California, US

Game theory – the maths of strategic interactions – suggests we are unlikely to see full nuclear disarmament. Perhaps the best we can push for is the UN monitoring a reduction in stockpiles, and work to cut the dangers of automatic, hair-trigger reflex counter-attacks.

When imagination suddenly vanished

31 May, p 37

From Patricia Finney, Falmouth, Cornwall, UK

I am a writer of mainly historical novels. I scored fairly high on your imagination tests. That said, there was a time about 11 years ago when my imagination faltered after I had a haemorrhagic stroke. After a few days in intensive care, I was put on pills to reduce high blood pressure. Suddenly I couldn't visualise anything, not even a rainbow. In desperation, I rang a friend who is a doctor specialising in stroke aftercare and told her about this. "Are you taking diuretics?" she asked. "Stop them at once." I did and two days later my ability to visualise was back.

Consult a doctor before making any changes to your medication.

Mask up for the perfect way to chop onions

24 May, p 12

From John Healey, Adelaide, South Australia

You don't need complex research to find how to cut onions with no tears. When I chop them, I put my scuba mask on. Problem solved.

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, 9 Derry Street, London, W8 5HY will be delayed

For the record

Howard Carter discovered Tutankhamun's tomb in Egypt (7 June, p 27).

Welcome to the nuclear family

One of the world's leading nuclear technology and security companies wants to highlight the equal opportunities and flexible work-life balance it offers to attract a new generation of recruits

"I feel a strong connection to our purpose, and that is very important to me—understanding why I do what I do." Stacey, a production engineer at AWE, is talking about why she loves her job. One of the world's leading nuclear technology and security companies, AWE's purpose is to protect the UK through nuclear science and technology. Formerly known as the Atomic Weapons Research Establishment, its mission is to design and manufacture the UK's nuclear warheads and provide nuclear services to meet the needs of defence.

Yet, for all its importance and its rich seam of expertise, it remains relatively unknown, including to potential employees. Stacey only heard about it by chance while attending a different job interview. "Another applicant had mentioned AWE and I thought, 'Oh, what's this place?'" she recalls.

AWE has now embarked on an ambitious campaign to change this. It is recruiting a new cohort of talented individuals, particularly mid-career women, to the opportunities it offers. Its 9000-strong workforce includes roles ranging from logistics and management to physics and engineering.

While many employees are STEM graduates, employees don't need a science degree, or even a degree at all, to forge a path at AWE. There are entry points for all career stages, from early career apprenticeships to mid-career professionals looking for a new challenge. The company is keen to counter the nuclear industry's image as stuffy, male-dominated and inflexible, instead offering a healthy work-life balance, flexible working, support for employees with family and caring responsibilities and improved representation of women at all levels.

In the 75 years since it was first established, AWE has played a central role in helping

NUTCHAPONG WUTTISAK/ISTOCK

EMPLOYEE CASE STUDY: STACEY

Stacey first realised she had a passion for science as a teenager when one Christmas Eve, she found herself doing past exam papers in physics in front of the TV—for enjoyment. "I thought, 'I must find this interesting'," she recalls.

Inspired by a charismatic science teacher, she pursued her interest as a career path, and more than two decades on, that path has led to her current position as production engineer at AWE. There, she leads a multidisciplinary team of scientists, engineers and project managers developing new materials for Astraea, the UK's replacement warhead programme.

Her trajectory at AWE highlights the huge range of roles and opportunities within the organisation, as well as the training and support available to help employees achieve their ambitions.

Stacey joined AWE after graduating with a degree in physics. She started in the hydrodynamics department, where she worked on experiments to feed into computer models that explore the safety and performance of materials used in warheads. After a few years in this role, she moved on to nuclear threat reduction, which supports the UK's work in counter-terrorism, counter-nuclear proliferation and in arms control. This involved innovating new technologies to detect nuclear materials for monitoring the UK border, and saw Stacey leading the team and managing the project to make sure everything was in place to make the research possible.

It was a role she found very rewarding. "Many times in my career, I thought, 'Oh my God, I'm getting paid for this. This is fun'," she says."

After seven years working in nuclear threat reduction, Stacey spent a few years working in different roles to expand her skill set, including a stint as an operations manager setting up a new facility and a leadership role developing capability strategy in one of AWE's technology centres. "I'm very curious and every role I needed to learn something," she says. "I think it makes you a more rounded individual when you move around in your career."

This range of experience made her an ideal choice for AWE to appoint as production engineer for the new Astraea programme. There, she oversees the development of new materials from design all the way through to manufacture. It's a role where she deploys the problem-solving skills that originally engrossed her in physics to developing high-level strategies that keep Astraea on track. "I really, really enjoy my job," she says.

IMAGE SUPPLIED BY AWE

AWE is home to Orion, one of the world's largest lasers

deliver the UK's nuclear deterrent, from developing the UK's first nuclear device in 1952 to building a series of warheads for the Royal Air Force and the Royal Navy.

The Comprehensive Nuclear Test Ban Treaty (CTBT), which was adopted by the UN in 1996, ratified by the UK in 1998 and bans all live testing, has ensured that AWE's mission has evolved. In accordance with the CTBT, the UK now invests in advanced science, engineering and simulation technologies to support the assurance of warhead safety and performance without undertaking nuclear explosive tests, to monitor international compliance with the treaty and to safeguard the UK from terrorist and radiological threats. AWE is working on the Astraea programme which will deliver the replacement warhead, and boasts world-class capabilities such the Orion laser and Vulcan supercomputer. It also makes advances in physics, materials science and high-performance computing.

The two arms of AWE—nuclear technology and national security—both offer a wealth of rewarding roles. In nuclear technology, engineers work on everything from the warhead programme to maintaining and improving AWE's sites. This work can involve using virtual reality, systems engineering, computer modelling and advanced mathematics as well as electronic, mechanical and manufacturing engineering. There are pathways in basic science too, with programmes researching plasma physics, hydrodynamics and materials science.

Meanwhile, in national security, there are roles developing new technologies to detect concealed radioactive materials and novel nuclear forensics techniques, as well as in advising government and emergency services about nuclear and radiological threats. AWE is also home to the UK's centre for forensic seismology, where teams develop techniques to detect underground nuclear explosions, and provide expertise to support the Ministry of Defence and international partners in underpinning the CTBT.

This complex network of teams and roles reflects the needs of a large modern technology company working at the cutting edge of science. But it also means there is plenty of scope for people from all kinds of backgrounds to carve unique career paths, united by the same core purpose.

Learn more about AWE careers at: www.awe.co.uk/careers

Does space-time remember?

The fabric of the universe may record the whole history of the cosmos, says quantum computer scientist **Florian Neukart**, which could explain the nature of dark matter

IF YOU wave your hand in front of your face, you won't notice anything particularly interesting. Perhaps a gentle waft of air against your cheek – that's about it. No epiphany. No major sign that anything out of the ordinary has occurred. And yet it is often when we look below the surface of the everyday that we find the extraordinary.

I believe that when we sweep a hand through the air – or indeed when anything moves at all – space-time is imprinted with a memory of what happened. The change resulting from this motion may be far too subtle for us ever to discern, but on the scales of the wider cosmos, space-time's memory is crucial. In fact, I would go further. I have come to believe that space-time isn't the kind of empty nothingness most of us think it is, but instead, at a fundamental level, it is made of stored information.

That might all sound rather bold. It certainly recasts our view of the canvas on which reality plays out. But over the past couple of years, I have bounced this idea around my brain – and inside a quantum computer – testing its limits. That has led me beyond a reformulation of space-time, and therefore the force of gravity, to grapple with the other forces of nature too. It has also helped tackle a key problem in quantum computing – and there are glimmers of bigger breakthroughs on the horizon. So let me tell you how I think space-time really works.

These ideas first began to germinate in my mind about 15 years ago, when I was working as a consulting engineer and studying part time for a PhD in machine learning. By day, I travelled all over Europe to visit various companies, often fixing physical machines; by night, I was in a more abstract realm of computers and information processing. It was somewhere between these two worlds, in the weeds of fundamental physics, that I found something interesting.

Before we dive in, I need to say a little about our best fully fledged theory of space, Albert Einstein's general relativity, and why it is both brilliant and incomplete. In essence, it says that space-time is like a stretchy sheet that is deformed by anything with mass. The resulting curves in space-time create the force of gravity.

Einstein's theory works wonderfully, but it doesn't gel with the other great bastion of modern physics, quantum theory. The problem is that the two ideas start off with conflicting assumptions about the nature of reality. In particular, general relativity envisages a smooth space-time, whereas

ADOBE STOCK

quantum theory says that matter and energy come only in discrete chunks. The most common view among physicists today is that we must find a way to bring gravity into the quantum fold – which means building a theory of quantum gravity.

But back to my own story. Thanks to my work on machine learning, I had begun to think more expansively about how information is stored in brains and computers, and to wonder: what actually is information? That led me to study the physics of quantum information, which insists that information is a physically real thing that can't be created or destroyed. Imagine tossing a book into a fire. You may not be able to read it any more, but quantum mechanics says the smoke and ash still contain the information, albeit scrambled and dispersed.

All this brought me to another problem that turns out to be crucial to this story. It is known as the black hole information paradox. According to general relativity, anything falling into a black hole crosses the event horizon and disappears from view. We also know that black holes evaporate exceedingly slowly into nothing – and this suggests that the information contained in anything that falls into them vanishes. Except, no: quantum ›

"When something moves through space-time, it is as if space has been imprinted with a memory"

theory insists information can't be destroyed. We have a paradox.

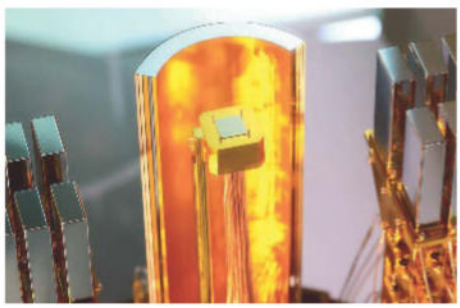
As I mused on this puzzle on planes and trains between my consulting jobs, I started to think we might have missed something about the way space-time stores information. To understand my idea, you first need to know that I assume from the start that space-time isn't a smooth, continuous fabric, as it is in general relativity, but is instead made of extremely small, discrete cells, like an invisible grid at the deepest level of reality. This isn't an entirely new idea in itself: many hypotheses that imagine gravity as a quantum force assume space-time is granular. But I build on this by describing how each of these space-time cells can act like a memory unit.

This is, admittedly, a bizarre thought. We are used to information being stored in physical objects with variable properties. Neurons in our brains fire or stay silent; charge builds up and dissipates in computer bits. How can empty space hold information when there is nothing "inside it" to change? The key is to realise that modern physics describes all particles and forces as excitations in quantum fields – mathematical structures that span space and time. Space-time itself is, in principle, no different, and each of my cells of space-time would have a quantum state that can change. Imagine it as like a tiny dial or switch. There is also a more emergent kind of quantum information at play that describes the relationship of each cell to the others – this isn't held in any one cell, but in the sprawling network of relationships between them.

Hidden imprints

This is where we return to black holes. When something moves through space-time, it should subtly change the state of all those tiny dials in the space-time cells it interacts with. It is as if space has been imprinted with a memory. And I began to suspect this might offer a way out of the black hole information paradox. Because here is the thing: even when a black hole finally evaporates, its imprint on the space that surrounded it remains. Information doesn't vanish after all – it has been written somewhere we hadn't thought to look.

It took me many years to arrive at my solution to this problem – and I didn't do it alone. These ideas were shaped by long days and nights of conversations with Valerii Vinokur, Eike Marx, Reuben Brasher and



NIPPON NEWS/AFLO CO. LTD./ALAMY

Quantum computers, and their chips, can be used to simulate memory-type behaviour in space-time

Jeff Titus, all colleagues at Terra Quantum, the quantum computing company where I now work. In 2024, my colleagues and I published a paper that describes what we call the imprint operator, a collection of mathematical functions that sets out how information can be imprinted in this way. We also showed theoretically that this mechanism allows space-time to store the information that falls into a black hole.

My collaborators and I began to refer to this idea as the quantum memory matrix (QMM) framework, and we quickly realised it extends beyond gravity. If space-time truly has a memory-like structure, then it should be able to store information from any of the four fundamental forces of nature. Apart from gravity, these are electromagnetism, which governs the physics of light, charged particles and much more, and the weak and strong nuclear forces, which rule over the goings-on inside atoms.

We found that, while the original imprint operator works well for gravity, extending it to describe the strong and weak forces required a more generalised version – not a replacement, but a refinement that accommodates the additional physics those forces involve. And in March, we broadened the framework to include electromagnetism too. All four fundamental forces fit into this unified picture. Each interacts locally with space-time. Each leaves a trace behind.

The fact that QMM can handle all four fundamental forces offers encouragement that this idea might have some real insight. What I like is its power and simplicity. We aren't postulating new hypothetical particles or unseen dimensions, we are simply taking what we already know about quantum information and packaging it in a new structure. Still, it is a bold idea and it is fair to say that the physicists I have talked to about it have a few critiques. Some question the very notion of space-time having a memory – what is being remembered and how? Others wonder how we would ever test this idea. Still others feel it is just a twist on existing ideas from quantum gravity and doesn't add anything truly new.

It certainly does add something new, and we will get to that. But first I want to tackle the question of testing this idea. The best way to discover whether space-time holds information would be to try extracting it. That may sound like a wild notion, but we already have machines that can read and write quantum information – we call them quantum computers. Our existing quantum computers deal with quantum systems like atoms. Accessing smaller scales tends to require more energy, and getting down to the cells of space-time, which are vastly smaller than atoms, would require a particle accelerator capable of reaching energies a trillion times beyond what's possible today.

Not something we're going to pull off any time soon, then. Still, such a test can at least be simulated in an existing quantum computer –

NASA, ESA, M.J. JEE AND H. FORD (JOHNS HOPKINS UNIVERSITY)

Could the ghostly ring of dark matter in the galaxy cluster CL 0024+17 actually be stored information?

NASA/JOHNSON

Electromagnetic phenomena, such as the aurora, might leave an impression on the cosmos

"There is an extra ingredient that contributes to space-time's curvature: the weight of information"

and since I work at a quantum technology company, that is exactly what my collaborators and I recently did. We began by taking a qubit, the quantum equivalent of a computer bit, in a known starting state and letting it evolve over time. This evolution was designed to simulate the way a cell of space-time would be imprinted with information as quantum fields wash over it. The question was: could our imprint operator accurately describe the qubit's evolution?

To test this, we measured the state of the qubit after it had evolved and then applied a reverse version of the imprint operator to see if this would describe the original state. We found that it did indeed do so, with an accuracy of about 90 per cent. This wasn't just a theoretical toy model. The imprint and retrieval protocols were grounded in QMM's mathematical structure and translated directly into executable quantum circuits, validating the idea that memory-like behaviour is physically modellable.

The crux of dark matter

You might be tempted to think this is all just meaningless simulation. But the point about simulations in quantum computers is that they involve real quantum states. The fact that the imprint operator works so well in a quantum computer is a strong hint that it could work for cells of space-time too.

As a bonus, our imprint operator turns out to have a practical use. One big problem with modern quantum computers is that information can't be copied without introducing small errors, and as machines get larger – some machines now have thousands of qubits – these errors mount up and become a serious headache. Last year, Google Quantum AI and Google DeepMind demonstrated a way to clean up errors using artificial intelligence. But our imprint operator offers an alternative. Because it reads and writes data to qubits with such high accuracy, we found that combining our imprinting scheme with standard error-correction techniques reduced errors significantly – by as much as 35 per cent in some configurations – and allowed us to use up to 40 per cent fewer qubits for the same performance. To me, this is another subtle indicator that our QMM framework is on to something.

I mentioned earlier that QMM gives us something truly new, so let me now explain what I had in mind. Remember that the curvature of space-time in general relativity is influenced by mass and energy. In our framework, there is an extra ingredient that should also contribute to that curvature: the weight of information woven into space-time.

Astronomers already know that the gravity of many galaxies seems to be stronger than would be expected based on their mass and rate of rotation alone. Lacking an explanation, they have invented a substance called dark matter to account for the difference. However, no one knows what it might be. But perhaps my collaborators and I have stumbled upon the answer: could dark matter be information, stored across space-time in a way that generates gravitational pull? I think so. When we have run calculations to compare the theoretical gravitational effect of information and the observed effects of dark matter, the numbers more or less match.

One thing I remain curious about is just how good space-time's memory is. In other words, how far back in history does it reach? My suspicion is that the whole of cosmic history is, in some sense, baked into space. After all, we know information cannot be destroyed. Admittedly, this isn't something I can yet claim with any confidence. But I certainly have a much clearer vision of information's role in the cosmos than I once did. I started this journey years ago with a question I couldn't resolve, but now I am beginning to get solid answers – not just hand waving. ▮

Florian Neukart is the chief product officer at Terra Quantum AG and a professor of quantum computing at Leiden University in the Netherlands

Ticking time bomb

As the world warms, ticks are spreading ever further, bringing a host of diseases with them – but we have ways to fight back, finds **Carrie Arnold**

TUCKED away in a ground-floor lab in Richmond, Virginia, is a bank of industrial freezers containing thousands of transparent, thumb-sized plastic tubes. Each is filled with a clear, yellowish fluid – blood serum taken from opossums, raccoons, black bears, coyotes, vultures and many other animals.

These vials, the world's largest collection of blood serum from wildlife, are the life's work of Virginia Commonwealth University molecular biologist Richard Marconi. Almost every sample here is infected with some kind of tick-borne pathogen – mostly the bacterium that causes Lyme disease, one of the most widespread tick-borne diseases, but others as well.

That means, says Marconi, that most wild animals in North America have been infected. Those animals represent a vast and growing reservoir of viral, parasitic and bacterial pathogens for ticks to pass on to other animals – including humans. In fact, ticks carry more human-infecting pathogens than any other disease-carrying organism.

Right now, tick populations are exploding, their ranges are expanding and they are bringing those pathogens with them. "It's not just a problem here in the United States. This is occurring across the northern hemisphere," says Marconi.

We can't stop ticks from spreading – we've tried. That leaves mitigating the damage they do. Marconi's lab is pioneering a slew of novel protein-editing techniques to generate vaccines against Lyme and other tick-borne illnesses; others are working on vaccines not against these diseases, but against the ticks themselves.

These are promising directions – the only question is: will they be enough?

Around 900 tick species call this planet home. Every one of them feeds on blood. Since branching off from their spider ancestors hundreds of millions of years ago, ticks have evolved a three-pronged mouthpart designed for feeding on vertebrates. Sharp, serrated edges saw through the outer layer of the host's skin, while a tiny barb anchors the tick to its meal. A thin groove on the underside of the mouthpart's centre blade funnels blood directly into the tick's midgut. To prevent their hosts from reacting to their presence, ticks have specialised proteins in their saliva that suppress pain and allergic reactions, while other proteins inhibit blood clotting, allowing ticks to dine at a more leisurely pace. Some tick species feed only on blood from a specific animal host, but others, such as *Ixodes scapularis*, better known as the deer tick or black-legged tick, are far less choosy.

The fact that ticks can remain on a host for several days undetected means that where their meals go, they go. And as the planet warms, the number of places ticks can thrive is growing. The highest latitude at which they can live is shifting, says Nick Ogden, an ecologist and epidemiologist at the Public Health Agency of Canada. Ogden and others have documented black-legged ticks as far north as Yukon, above latitude 60° north, brought by migrating songbirds.

"These birds create a conveyor belt for ticks. When the climate becomes suitable, they can set up a population," says Ogden. Rising temperatures and increased humidity also mean that ticks, though still mainly a spring and summer problem, can be active for more of the year.

The implications of this tick boom are unfortunately clear: more ticks in more places means more disease. Ticks are superb vehicles for pathogenic hitchhikers, and there are a lot of pathogens looking for rides. For instance, Marconi and his lab looked at blood samples of 128 coyotes from Pennsylvania and found that 64.8 per cent tested positive for the Lyme bacterium and 72.7 per cent for the bacterium that causes anaplasmosis, an infection that leads to flu-like symptoms in humans. Ticks pick up these pathogens when they feed, transferring them to their next host through their saliva or faeces (see "How to avoid ticks – and what to do if you can't", page 38).

> "Ticks carry more human-infecting pathogens than any other disease-carrying organism"

"As that tick vector expands its geographical range, all of those diseases are following along," says Heidi Goethert, a molecular epidemiologist at Tufts University in Massachusetts. In the past 20 years, the annual number of cases of tick-borne diseases in the US has more than doubled. Europe has seen a steady climb in Lyme disease infections, while cases of tick-borne encephalitis, a viral infection that can cause long-term neurological symptoms, have risen by almost 400 per cent in the past 30 years as ticks' ranges expand north. Human encroachment on wildlife habitats is also increasingly putting people in the way of ticks and their diseases – cases of deadly Rocky Mountain spotted fever have become an "urban epidemic" in Brazilian and Mexican cities, driven by proximity to capybaras and free-roaming dogs.

Red meat allergy

Ticks are a source of new illnesses as well. In the early 2000s, people in the south-eastern US started turning up in doctors' offices with classic symptoms of allergic reaction triggered by a previously unheard-of allergen: red meat. In 2009, the lone star tick was confirmed as the source of this allergy to alpha-gal, a sugar found in mammalian meat. Since then, more than 110,000 cases of alpha-gal syndrome have been identified in the US alone. The lone star tick also transmits the sometimes fatal Heartland virus, first documented in 2009, while China has identified 33 emerging tick-borne diseases in the past several decades, including Wetland virus in 2019.

Part of what makes managing the spread of tick-borne disease difficult is that our understanding of tick ecology is incomplete. For example, Martha's Vineyard, an island off the coast of Massachusetts, has among the highest per capita rates of Lyme disease in the US. White-footed mice were thought to be the ticks' likeliest pathogen reservoirs. However, efforts to reduce Lyme on the island by ›

DMITRI MELNIKOV/ALAMY

How to avoid ticks – and what to do if you can't

The best way to avoid a tick-borne disease is to not get bitten at all. Ticks lurk in tall grass or vegetation, waiting for passersby. You can prevent them from latching onto your skin by wearing long trousers, tucked into socks, and long sleeves.

Check your body, and those of your children and pets. Ticks are often found on the head, the underarms, groin and along the waist and in the belly button, but check everywhere.

If you do find a tick, use tweezers to grasp it as close to the skin as you can and gently pull up. Try not to twist or crush the tick, as the mouthparts could break off in the skin and cause infection. Dispose of the tick and clean the area with an antiseptic.

Wash clothing or animal bedding on hot – ticks can survive the washing machine, but not water above 54°C (129°F).

The deer tick transmits the bacterium that causes Lyme disease

SHUTTERSTOCK/KPIKMINING

targeting mice – coating them with tick-killing pesticides, say – proved inconsistently effective. Trying to figure out why, Goethert and her team spent six years examining what the ticks actually ate, analysing them for tiny fragments of DNA from their last meal. They found that ticks on Martha's Vineyard preferred shrews to mice – meaning that targeting mice wouldn't work.

"[Ticks] can transmit lots of different pathogens between lots of different animal types. It's a very complex ecology," says Lucy Gilbert, an ecologist at the University of Glasgow in the UK.

With attempts to manage ticks through their animal hosts proving unsuccessful, researchers like Marconi are instead trying to tackle the diseases they carry.

Lyme disease, transmitted by several species of tick, was first observed in a handful of children in Connecticut in the 1970s. It is now one of the most widespread tick-borne diseases in the world: a 2022 study estimates that 15 percent of the world's population has been infected with *Borreliella* (formerly known as *Borrelia*) *burgdorferi*, the corkscrew-shaped spirochaete bacteria that causes it.

"These bacteria have this really remarkable structure," says Marconi, who has developed grudging respect for *B. burgdorferi* in his 30 years of studying it. "When the tick feeds, spirochaetes literally will drill their way through tissue and spread through the body."

Caught early, Lyme, which often presents with flu-like symptoms and a characteristic bullseye rash, is treatable with antibiotics. However, diagnosing infections can be challenging. Lyme symptoms overlap with those of other illnesses, the rash can be difficult to spot on darker skin and doesn't always appear, blood tests often give false negatives and – say Marconi and others – doctors don't always consider Lyme.

"These infections are underappreciated, underdiagnosed and they're spreading all over the country," says Isaac Chiu, a neurobiologist who studies Lyme at Harvard Medical School. If left untreated, Lyme can cause a host of neurological symptoms, including facial paralysis, inflammation in the brain and spinal cord, and pain in the joints and muscles. More frustrating, symptoms of infection persist in some people even after a full course of antibiotics.

That's because *B. burgdorferi* is tricky. While lurking in a tick's gut, the bacterium covers itself with a protein called outer surface protein A or OspA. But as soon as the tick gets a taste of mammalian blood, *B. burgdorferi* switches out OspA for OspC – adapting to its environment, just as we would put on a winter coat on a cold day, says Marconi – and begins its migration to the tick's salivary glands and on to its new home. Once there, the OspC covering helps it evade the host's immune system. "It's a cat-and-mouse game that continues and continues, and it allows the bacterium to remain and persist in the host," says bacteriologist Troy Bankhead at Washington State University.

That makes *B. burgdorferi* a difficult vaccine target – although this wasn't what defeated the first Lyme vaccine. In 1998, GlaxoSmithKline brought a vaccine to market that targeted the OspA protein, but although it was effective, it required boosters as much as every year. That was a hard sell even in areas with high rates of Lyme disease, and it was pulled in 2002.

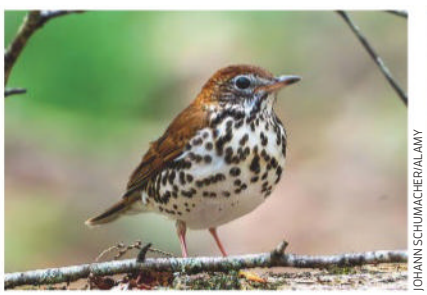
Marconi believed that targeting the OspC protein would offer broader protection. To do that, however, his team needed to create something completely new. OspC proteins come in 21 different strains, which is why some people contract Lyme disease multiple times. "The Lyme bacteria that might be carried by one tick can differ quite a bit from one that's carried by another tick," says Marconi. "We had to come up with a way to make a vaccine candidate that could elicit antibodies against all the strains."

Lyme disease vaccine

Using a new technique that he and his lab dubbed "chimeritope technology", they stitched together small snippets of different OspC protein antigens that provoked an immune response. This super protein proved effective enough for a vaccine for dogs that was approved by the US Food and Drug Administration in 2016. A human vaccine is on its way – Marconi's lab is currently working with the National Institutes of Health to get it into human trials and then on to market in the next several years.

This isn't the only Lyme vaccine in the works – with rates of Lyme skyrocketing since 2002, the market has become much more appealing to pharmaceutical companies. Pharmaceutical companies Pfizer and Valneva, working together, are completing the final stage of trials of a second-generation OspA vaccine that generates immunity against the six most common strains of *B. burgdorferi* in the US and Europe. But Marconi hopes that chimeritope technology will offer a blueprint

MARCIN ROGOZINSKI/ALAMY



MICHAEL GREENFELDER/ALAMY

JOHANN SCHUMACHER/ALAMY

Clockwise from top: Ticks are found in long grass and vegetation; white-footed mice were thought to be reservoirs for tick pathogens; migrating songbirds, like this wood thrush, can be transport ticks large distances

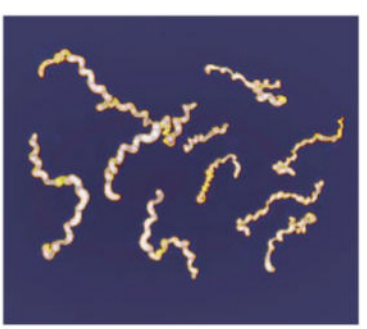
for managing whatever the next big tick-borne disease will be in North America, as well as a method for combining vaccines to offer protection against multiple tick-borne pathogens at once.

"What's really exciting to us about it is that we can apply it to any pathogen," he says, noting that his team is currently working on vaccines for anaplasmosis, cases of which increased 16-fold in the US between 2000 and 2022, and the potentially deadly tick-borne parasite *Babesia*. "The sky's the limit on where we can go with it."

Marconi's technology might be able to generate vaccines against multiple pathogens and even combine them into a single, multi-use vaccine. But what if we could generate immunity to ticks themselves – and therefore to every pathogen they carry?

It isn't impossible – some animals naturally develop immunity against ticks after repeated infections. For example, the immune systems of some cattle create antibodies against proteins and other biomolecules carried by the cattle tick. As the tick feeds, these antibodies go straight to the parasite's midgut, damaging cells and forcing the tick to fall off before it can transmit disease. After scientists identified one of these antibody-generating molecules in the 1980s, anti-tick vaccines for cattle soon appeared on the market. Though imperfect and not universally adopted, the vaccines reliably generated an immune response in cattle and have worked to keep a serious problem from getting worse. Inspired, some scientists are looking to do the same against species of ticks that tend to pose the most problems for humans.

***Borreliella burgdorferi* bacteria cause Lyme disease in people**



CAVALLINI JAMES/BSIP/SCIENCE PHOTO LIBRARY

"If this works, it can reduce or prevent multiple tick-borne pathogens – an individual vaccine, you usually can only prevent the one pathogen," says Yingjun Cui, an infectious diseases researcher at Yale University School of Medicine working on such a vaccine against Lyme-carrying deer ticks.

The anti-tick vaccines currently in the works would incapacitate the main weapon in the tick's arsenal – its ability to feed off a host undetected. In 2021, Cui and his colleagues showed that immunising guinea pigs with a protein secreted in tick saliva during feeding prompted a histamine response in the animals: the site of the bite swelled, interrupting the ticks' feeding. Cui's lab has since identified other candidates for future vaccines. In addition to the swelling, the irritation is a signal to the host to remove the tick before it can transmit disease – a virus can hop from tick to host in about an hour, but bacteria can take up to 48 hours of feeding to make the leap.

"But it's still not perfect for humans," says Cui, not least because it is unlikely anyone would want a vaccine that worked in part by giving them an unpleasant reaction to the tick's bite. Still, his lab isn't the only one working on an anti-tick vaccine – researchers at the University of Amsterdam are currently working with human volunteers to see if people could generate an immune response after repeated exposure to tick bites.

Marconi is intrigued by the prospect of an anti-tick vaccine, but notes: "We're willing to tolerate side effects much more in cattle than we probably will be in humans." For his part, he's pinning his hope on more traditional vaccines.

"Ticks have been here a lot longer than we have. I think we're smarter than them, but they've learned some tricks that we haven't been able to quite figure out," he says. Still, he retains some optimism: "We have our best shot at managing the incidence of disease in humans and in companion animals... It's a challenge – but I'm not despairing." ▮

Carrie Arnold is a science journalist based in Virginia

JACK PARSONS

Your second gut

The workings of the small intestine have long been a mystery, but now we are discovering just how vital it is to our health, reports **Graham Lawton**

THE US humorist Christopher Morley once described the human body as "an ingenious assembly of portable plumbing". He wasn't wrong: from our cardiovascular and lymphatic systems to our guts and urinary tract, a large proportion of our internal anatomy is dedicated to moving fluids around.

Perhaps the most impressive piece of plumbing is the gastrointestinal tract, which starts at the mouth and ends, 8 metres or so later, at the anus. In between are the oesophagus, stomach, small and large intestines and rectum. Together, they do a pretty impressive job of processing food, extracting nutrients from it and packaging up the waste for disposal.

But there is a lot more to the GI tract than that. We know, for example, that the microbiome in the large intestine is a key player in health and disease, and there is immense interest in how to maintain a healthy one. Now, it is the small intestine's turn to take the spotlight. After decades in the shadow of the large intestine, it is finally revealing its secrets. It turns out that it, too, has crucial functions beyond processing food, including the maintenance of metabolic health. Is it time to start looking after our small intestines? And how might we go about this?

This body part is only "small" in the sense that it is much narrower than the large intestine, with a diameter of no more than 3 centimetres compared with 6 centimetres or more for the widest part of the colon. In terms of length, however, it is far from small, about 5 metres on average, coiled up in the abdomen like an unruly garden hose. It is divided into three functionally distinct sections: the duodenum, followed by the jejunum and ileum (see "The three parts of your small intestine", page 43).

The principal functions of the small intestine are the digestion and absorption of proteins, carbohydrates and fats. These processes take a relatively swift 3 to 6 hours, after which some 90 per cent of the nutrients have been extracted. The remainder – mostly water and indigestible fibre – enters the large intestine, where it will reside for a further 48 to 72 hours.

That much we have known for decades. But for a long time, the small intestine was infuriatingly resistant to further investigation, due to its inaccessible position between the stomach and the large intestine. Both of these are relatively easy to study and sample using probes and, in the latter's case, stools. But getting into the small intestine, and retrieving anything from it, has always been difficult. "It's been ignored," says Gary Frost, who studies digestion at Imperial College London.

More recently, however, that has changed. Around 20 years ago, it became clear that the small intestine also harbours a microbiome, though characterising it remained a challenge. Most samples came from post-mortems of people who had died suddenly or from individuals whose colon had been removed as part of their treatment for bowel cancer, and neither may be representative of the wider population. But in 2023, a team led by Oliver Fiehn at the University of California, Davis, developed swallowable probes that could gain access to the contents of the small intestine in healthy people.

Alongside that, researchers, including Frost, have developed techniques for placing tubes into specific locations in the small intestine for several hours at a time, allowing data to be collected as the digestive system goes about its business. These two techniques have opened the door to this hitherto-murky region of the gut, revealing that it isn't just a long tube dedicated to the processing of food, but is also a highly dynamic organ involved

in the regulation of metabolism and the maintenance of a healthy gut microbiome.

In an initial set of experiments, Fiehn's team fed 15 volunteers four different capsules each. The capsules, which are about the size and shape of a large vitamin pill, are coated with a substance that dissolves at a given pH, activating a collection bladder that sucks in around 400 microlitres of liquid through a one-way valve. Because the pH of the small intestine rises gradually from as low as 4 in the duodenum to as high as 8 in the ileum, the probes can be programmed to open at specific locations and take snapshots of the gut contents. They are later retrieved from stools.

Fiehn's team programmed the capsules to sample the three sections of the small intestine and the first part of the colon. Analysis of the contents showed that the microbiome of the small intestine is highly variable along its length, and very different from that found in the colon.

These experiments provided the first definitive evidence that we have been underestimating the small intestine, even if things remain murky. "We still don't know a huge amount about the small intestinal microbiome," says Andrew Macpherson at the University of Bern in Switzerland, who recently described it as "terra incognita". But the work of Fiehn's team is an important starting point for properly understanding the entire gut microbiome, says Frost. "We divide things up and look at individual parts, but those individual parts only work in a certain way because they're connected," he says.

Other experiments are revealing that the small intestine is not just very variable along its length, but also over time, operating on a previously unknown, 24-hour cycle. ›

"ONCE YOU GET ACCESS TO SPACES WHERE YOU'VE NOT BEEN ABLE TO GO BEFORE, A WHOLE NEW WORLD OPENS UP BEFORE YOU"

L: SHUTTERSTOCK/PIYASET; BELOW: EVA-KATALIN/GETTY IMAGES

Each day, after the stomach empties for the last time and the muscular peristaltic waves that drive food through the gut cease, the ileocecal valve between the small and large intestines closes and partially digested food, or chyme, pools in the ileum. So, while the stomach, duodenum and jejunum are empty and inactive overnight, the ileum is full and busy. "It starts acting a bit like a little stomach," says Frost. When the overnight fast is broken, peristalsis restarts, the valve re-opens and the chyme is swept into the large intestine.

We don't yet know what this means for people who sleep and eat at irregular times, such as shift workers. Nor do we have a solid explanation for why the ileum retains chyme overnight, says Frost. It may be to give it more time to retrieve bile acids, which are secreted into the duodenum to emulsify fat and are a precious resource that the body likes to recycle if possible.

Or it may have something to do with digesting fibre. By definition, this is the fraction of the diet that human enzymes can't break down, and which we leave to our gut microbiome to deal with. The received wisdom was that fibre travels through the small intestine chemically intact, but thanks to the new investigative techniques, that is now known to be untrue. "That's one of the old ideas," says Karen Madsen, who researches the microbiome at the University of Alberta in Edmonton, Canada. "Absolutely, fibre is being digested throughout [the small intestine]."

"THIS IS A HIGHLY DYNAMIC ORGAN INVOLVED IN THE REGULATION OF METABOLISM"

Bacteria living in the small intestine like to digest fibre, particularly from legumes

Microbiome bloom

The amount of microscopic life starts small: the duodenum has just 1000 microbial cells per millilitre of chyme, which is 10 orders of magnitude lower than in the colon. But the density rises along the length of the small intestine, hitting 100 million microbial cells per millilitre in the ileum.

Sometimes, anyway. Overnight, the ileal microbiome blooms explosively, fuelled by nutrients in the chyme reservoir. But when the ileocecal valve reopens, these microbes are mostly expelled into the colon and their number plummets. Their fate in the colon is uncertain, but it probably involves death: the ileal environment is very different to that of the colon, being higher in pH and oxygen, and the make-up of the ileal microbiome is also very distinct.

Most of these microorganisms are derived from the oral microbiome, says Frost, which may be how the small intestinal microbiome is replenished every day. Colonic microbes also probably leak in, says Macpherson. "The small intestine is right next to the most densely populated microbial community on the planet, our colon," he says. "Potentially, it can be repopulated from the colon, but we don't really know to what extent this occurs."

The fact that the microbes in the small intestine can digest fibre is probably of physiological importance, says Frost – though exactly how isn't yet clear. We know that, in the colon, microbial fermentation of fibre produces a class of molecules called short-chain fatty acids (SCFAs), which both remain in the colon and are absorbed into the bloodstream with knock-on benefits throughout the body.

Human metabolism can't synthesise SCFAs, so we exploit the bacterial ones for a range of biological functions. One of these is to maintain the integrity of the colon wall, to prevent bacteria from breaching it and causing inflammation. So-called leaky gut syndrome is increasingly pointed to as a possible cause of the low-level and yet extremely damaging inflammation that creeps through our bodies as we age, and which is a cause of metabolic conditions such as obesity and type 2 diabetes.

The same may be true in the ileum, says Frost. "The barrier function of the small intestine is probably critical to a lot of pathology that we see in humans. The inflammatory responses you're seeing are probably as much to do with the small intestine as they are to do with the large intestine."

His research has shown that microbial fermentation products, including SCFAs, accumulate in the ileum overnight and then "drop like a stone" once the fast is broken. Their biological effects are unknown, he says, but it is plausible that the ileum retains chyme in order to repair its wall, which is thinner than the colon's and coated with less mucus, and hence more vulnerable to bacterial invaders. "The mucous layer is extremely thin in

the small intestine and the penetration of molecules is certainly much more effective than from the large intestine," says Macpherson. The duodenum and jejunum also host microbiomes and these may be involved in maintaining barrier function too, he says.

In that respect, the jejunum has also recently delivered a major surprise. Its main function is to absorb nutrients into the bloodstream. But it turns out that it transports nutrients, especially glucose, in the opposite direction as well.

Feed the gut

Ogawa Wataru at Kobe University in Japan and his colleagues were investigating the mechanism of action of metformin, a highly effective but biologically mysterious drug that helps people with type 2 diabetes control blood sugar levels. To their surprise, they discovered that people with type 2 diabetes excrete substantial amounts of glucose into their jejunum, and that taking metformin almost quadruples this flux. That may partly explain the drug's effect, as excreting glucose out of the bloodstream lowers blood sugar.

But the researchers also found this glucose flux in people without type 2 diabetes, showing that it is a normal part of human physiology. The glucose is metabolised by the microbes in the jejunum and ileum. Ogawa thinks the glucose is feeding the gut microbes, which, in turn, promotes the production of SCFAs.

Yet more evidence for the importance of maintaining a healthy small intestinal wall comes from another treatment for type 2 diabetes. Duodenal mucosal resurfacing involves applying heat to the inner surface of the upper part of the duodenum during an endoscopy, to strip away the lining. This then quickly regenerates, with remarkable effects on metabolism. A 2022 study found that 69 per cent of people with insulin-dependent type 2 diabetes who underwent the procedure and were also given diabetes medication could stop injecting insulin altogether.

Resurfacing has its roots in gastric bypass surgery, which involves reducing the stomach to a small pouch and attaching the lower half of the small intestine to it as an exit portal, so that barely any food enters the stomach, duodenum and the upper part of the jejunum. It causes people to lose weight because they literally can't eat much. But it also has profound and almost instantaneous effects on metabolism: most people with type 2 diabetes who have the surgery quickly regain normal glucose control even before they lose any weight. Why this happens isn't known.

Resurfacing was developed to mimic the metabolic effects of a gastric bypass without radically rerouting the GI tract. "We now know the duodenum has a huge role in metabolic disease, because resurfacing has a very clear beneficial effect," says Madsen, even if the mechanism behind it remains a mystery.

The small intestine also controls metabolism through the release of the appetite-suppressing hormones PYY and GLP-1, which are secreted by the ileum in response to the presence of food, especially fibre. These hormones were thought to be exclusively released in the colon, but recent research has shown that the ileum gets in there first. In fact, says Frost, the ileum starts secreting them within minutes of food hitting the stomach, which is up to an hour before it enters the small intestine. The signal for this isn't known: it could be a hormone released by the stomach in response to food, or perhaps a signal from the brain. Finding out could lead to new appetite-suppressing therapies for obesity, says Frost.

This flurry of recent discoveries is probably only scratching the surface. "Once you get access to spaces where you've not been able to go before, a whole new world opens up before you," says Frost. Fiehn's team, for example, has done more work using its probes and has new results in the pipeline. Frost is focusing on how to optimise the release of appetite-suppressing hormones in the ileum, as well as characterising the sparse microbiome in the duodenum. "Some of these observations might seem a bit obscure, but hopefully they will lead to new understanding of how we work, and prevent some of the problems that we have," he says.

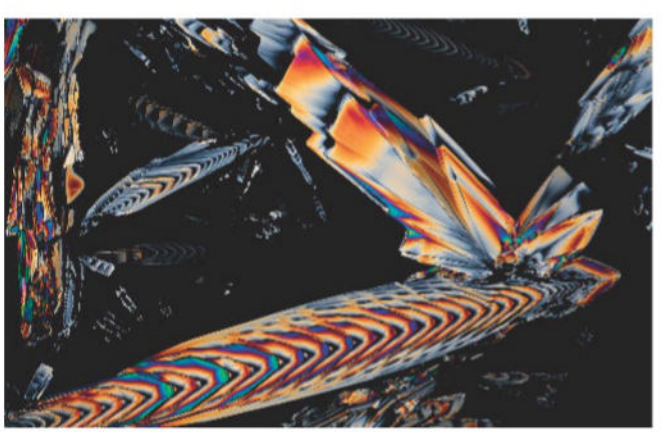
In the meantime, says Frost, it would be judicious to begin cultivating your small intestinal microbiome. The bacteria down there are especially fond of two fibre molecules, stachyose and raffinose, which are abundant in legumes. "They are really important for the microbial community in the small intestine," he says. It is high time we started looking after that long-neglected section of our portable plumbing. ▮

The three parts of your small intestine

DUODENUM
Partially digested food flows in from the stomach. Digestive enzymes and bile break down the molecules into smaller subunits

JEJUNUM
Main site of absorption of nutrients into the bloodstream

ILEUM
Last section of the small intestine. Absorbs vitamins, reabsorbs bile acids and mops up most remaining nutrients. What is left then passes into the large intestine, or colon



The drug metformin (shown in tablet and crystal form) may help control type 2 diabetes by boosting glucose flow from the blood to the small intestine

R: ANTONIO ROMERO/SPL; FAR RIGHT: CORDELIA MOLLOY/SPL

Graham Lawton is a staff writer at *New Scientist*

The back pages

Stargazing at home

Southern wonders

This is the best time of the year to marvel at the Milky Way – especially if you're in the southern hemisphere, says **Abigail Beall**

Abigail Beall is a features editor at *New Scientist* and author of *The Art of Urban Astronomy*. Follow her @abbybeall

BECAUSE I'm based in the northern hemisphere, my suggestions of what to look for in the skies can sometimes be skewed towards what we can see from that half of the planet. So, in this month's column I'll focus on a feature of our skies that is undoubtedly best when viewed from the southern hemisphere, and particularly at this time of year: the Milky Way.

Every star you can see with the naked eye belongs to our galaxy, which means whenever you see stars, you are seeing within the Milky Way. So when stargazers refer to the Milky Way, they mean the bulge teeming with stars and dust that sit towards the centre of the spiral galaxy. The plane of the Milky Way is offset from the plane of our solar system by about 60 degrees, giving us a side-on view of the inner edge of our spiral arm from where we sit. It looks like an arc when we see it in the sky because we are seeing it on a three-dimensional, curved "surface".

That view is even better from the southern hemisphere, thanks to Earth's tilt. Stargazers in the southern half of the planet are tilted towards the centre of the galaxy, whereas in the north, we are facing away from the galaxy's middle, towards a comparable desert of stars. This means that from the south you can see more of the constellations around the centre of the galaxy, like Centaurus and Sagittarius.

Wherever you live in the world, Milky Way viewing is at its best this time of year because we are on the same side of the sun as it is.

CREDIT: STEFAN LIEBERMANN/MAURITIUS IMAGES GMBH/ALAMY

But down south, stargazers always see more of the Milky Way because of Earth's tilt, as well as having the bonus of dark nights at the moment.

According to a decade-old study, a third of the world's population cannot see the Milky Way. It seems likely that the number has only gone up since then, thanks to increased light pollution. I urge you to find a clear evening with little moonlight. Around 25 June will be perfect, when we'll have a new moon. Get away from light pollution and allow at least 40 minutes for your eyes adjust to the dark. If you are in the northern hemisphere, you might have to wait until at least midnight for it to be dark enough.

Two of the most memorable stargazing nights of my life happened in the southern hemisphere. The first was at Mount Cook in New Zealand in early June; the second was in Warrumbungle National Park in Australia in April. Both times, I was absolutely blown away by the view of the Milky Way, pictured here above Uluru in Australia.

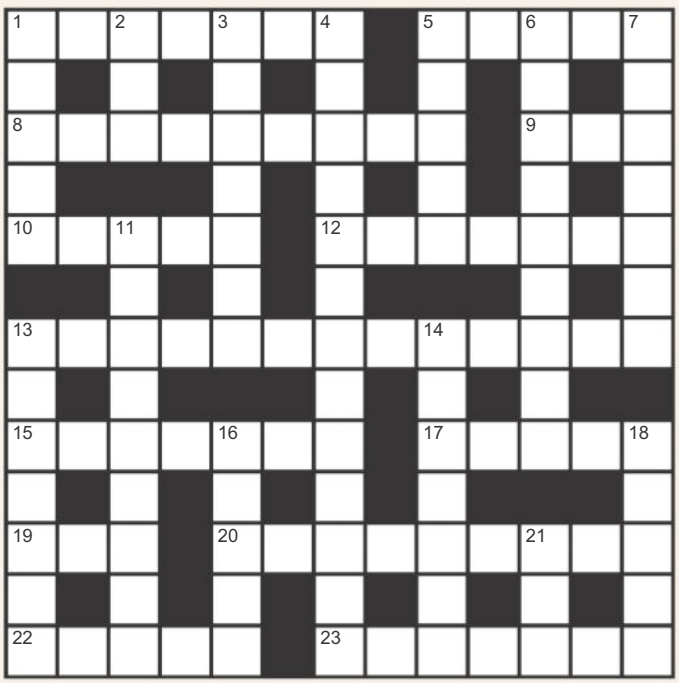
If you ever get to stargaze in the southern hemisphere, do look for the Milky Way. You might even get to see beyond it to two of our satellite galaxies – the Large Magellanic Cloud and the Small Magellanic Cloud. Neither is visible from the northern hemisphere, but can be spotted near the southern celestial pole. ▮

Stargazing at home appears monthly

Next week
Mathematics of life

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

Cryptic crossword #164 *Set by Trurl*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Sample such as "I am the greatest!" (incomplete) (7)
5 Bearing bottom's waxy secretion (5)
8 Pierce picture of agent, and duck (9)
9 Historic French capital largely unfriendly (3)
10 Just over 11 per cent concealed by Einstein in theory (5)
12 One who works in an up-and-down industry (7)
13 I'm about to burn around 100 uranium plates, without protection – have I made an error? (13)
15 Love expressive gestures in bed? It may go rapidly downhill! (7)
17 Mouth opening in Delphi, for locals (5)
19 Application unseen, oddly (3)
20 Declaration from senior politicians, having lost a second time (9)
22 More mature tree (5)
23 Perhaps socks Henry with willow to reach century, finally (7)

DOWN

1 Jack excused from shop-talk – it's said to be noble (5)
2 Sickly statement of intent from Trurl (3)
3 Arthur Eddington at first confused by personal plumbing component (7)
4 Heath tackled rudely about British leadership in pandemic (3,5,5)
5 Tanned flesh? It may be continental, at the seaside (5)
6 Perhaps lead guitar heard on heavy rock music (4,5)
7 Wore black, perhaps – dour men upset (7)
11 Outcome of beak getting busted, having been sold E unlawfully (9)
13 Steal from drug smuggler, Spooner says (it's crude populism) (3,4)
14 They're seen with snakes on board – 50 snakes! (7)
16 Bright light seen by failure with nothing to lose, and all, initially, to gain (5)
18 Area somewhat lacking 1 Down, fittingly (5)
21 She was made second the night before (3)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #307
set by Corryn Wetzel

1 Which arcade game was inspired by H. G. Wells's *The War of the Worlds*?

2 Who proposed the theory of continental drift?

3 What was the first spacecraft to fly by Mercury?

4 Which chemical element has an atomic number of 92?

5 What is the clear, watery fluid in the front part of the eye called?

Answers on page 47

BrainTwister
set by Howard Williams
#78 One on top

It is possible to write any number as a sum of unit fractions (fractions with 1 on top) with different denominators. For example, 3/5 = 1/2 + 1/10.

Starting from the expression 1 = 1/6 + 1/6 + 1/6 + 1/6 + 1/6 + 1/6, can you combine the sixths together by adding, to make three unit fractions of different sizes that sum to 1?

If you begin instead with 12 twelfths, can you combine them to find a set of four different unit fractions that total 1?

How many other sets of four different unit fractions that add up to 1 can you find?

Solution next week

Only polite

Do all languages have the equivalent of "please" and "thank you"? Why are these words so important to us?

Chris Daniel
Colwyn Bay, Conwy, UK
In many cultures, "please" and "thank you" are essential expressions of politeness that lubricate social interactions and promote cooperation and reciprocation.

"Please" is a shortened form of the original "if it pleases you", and softens a demand into a request, as it relies on the goodwill of the person being asked. On the other hand, in theory, it also gives that person the option to refuse. A "thank you" acknowledges a debt of gratitude and validates a person's good deed. In English-speaking countries, these words tend to be used frequently and transactionally for requests made and answered. However, "please" and "thank you" don't appear to be universal.

In some societies, verbal thanks may be accompanied or replaced by nonverbal behaviours, such as giving gifts, bowing or folding hands in a *namaste* gesture. In fact, the use of "please" or "thank you" can be seen to insert a degree of unwanted formality between people when used in the wrong context.

"Verbal thanks may be accompanied or replaced by nonverbal behaviours such as giving gifts or bowing"

The importance of thankfulness is in its benefit to both individuals and society. It is thought that an "attitude of gratitude" improves a person's physical and mental health by helping them to focus on positive emotions of the present moment. Grateful people can be seen as good social partners who build and nurture relationships.

SANTOSH VERMA/MILLENNIUM IMAGES, UK

Why are there 60 seconds in a minute and 60 minutes in an hour?

This week's new questions

Time rules **Why are there 60 seconds in a minute and 60 minutes in an hour? Who decided on this and when?** ***Larry Coady****, Newfoundland, Canada*

Tip of my tongue **How can my brain predict if I'll recall a name or word in a minute or two, or if I won't remember it at all?** ***Phil Eden****, Sheffield, UK*

Mike Kelly
Southminster, Essex, UK
In Danish, there is no literal way to say "please", and some Danes struggle with this linguistic quirk. In a Danish art college, I saw that one student, in a written plea to others, had resorted to including the German for please (*bitte*) – which earned them a critical graffito from a language-purist colleague. Danes do have their equivalent for "thank you", which is *tak*. Elegant variations exist, my favourite being *tusind tak* (a thousand thanks).

But why are "please" and "thank you" so important to us? Conversation in Danish can initially present to Britons as a tad brusque, with "thank you" used less frequently than is usual in British speech and no word for "please". However, Danes have a word for comfort, cosiness and contentment: *hygge*. Phrases like *vi hygge os* (we *hygge* each other) describe a deep feeling of connection with others. The word *hygge* loses much in the translation if any English equivalent is attempted. Danes always score highly on any list of the happiest people in the world, suggesting they are managing just fine. Perhaps Anglophones worry too much about those three words.

Bernd-Juerden Fischer
Berlin, Germany
When travelling in central Africa, I used to invite bystanders to sit down and share our meal, which they did – and then left without saying a word. My wife was aghast that they didn't say thank you. To which I said, "But they did! They touched their right elbow with their left hand. Keep an eye out!" This raises the question of what your reader intends by asking whether "all languages have an equivalent of 'please' and 'thank you'"? I've never come upon any culture that didn't have expressions of gratitude, either verbal or gestural.

As to the question of why these "thanks and pleases" are so important to us, I think that politeness in general is a universal feature that has developed to ease the stress that crowded living and mutual dependency in human societies bring with them.

Bob Ladd
Edinburgh, UK
All languages probably have ways of expressing gratitude, making polite requests, offering minor apologies and performing the dozens of other everyday "speech acts" that help keep social interaction running smoothly. But the details vary so enormously from language to language and from culture to culture that it isn't really accurate to say that all languages have "equivalent" words.

To take a trivial example just from within western Europe, Google Ngrams show that in English, "please" occurs four or five times as often as "thank you". In French, Spanish and Italian, it is the other way round: *merci/gracias/grazie* is at least 10 times more common than *s'il vous plaît/por favor/per favore*. That is to say, from the point of view of a French speaker, English speakers go around saying "please" all the time. So in this sense, the words aren't really equivalent, and an important part of the answer to the question of why these words are so important to us is simply that "we" are well-socialised speakers of English.

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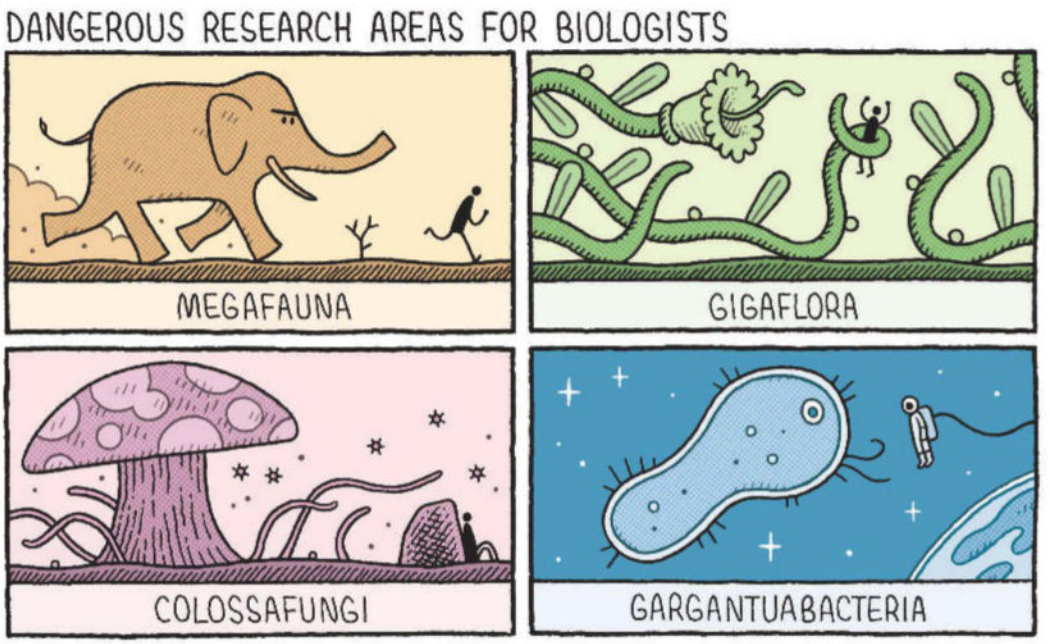

Matt Kavanagh
Cork, Ireland
My friend from Finland told me there is no direct word for "please" in Finnish. Her English is perfect, but she says everyone thought she was a bit rude and blunt when she moved to Ireland until she reminded herself to add the word "please" to the end of relevant sentences.

Blank sky

How would human civilisation differ if the sun, moon, stars and planets were always obscured by clouds? (Continued)

Alex McDowell
London, UK
Navigation at sea would have been difficult because, prior to the invention of radio beacons, inertial guidance, satellite navigation and more, sailors used celestial bodies to navigate. They would have needed to rely heavily on dead reckoning.

Some argue that, before the magnetic compass, Vikings used crystals called sunstones to locate the sun in overcast conditions. Archaeologists have made such devices using calcite and have been able to locate the sun to within a few degrees in cloudy conditions.

"Until people could get above the clouds, there would have been a lot of speculation about what was in and above them"

Sunstones are able to take advantage of the fact that light scattered through cloud vapour is polarised, but light straight from the sun is not.

The first clocks were sundials, but these would be useless if we were always under cloud cover. But sunstones could be used to find which direction the sun was in, and when. One could use sunstones together with magnetic compasses to work out the time.

Perhaps the difficulties mentioned above would have led to mechanical clocks being developed more quickly.

We might also have anchored lightships far out at sea to assist with navigation. Such ships could have periodically fired coloured flares into the air so that sailors could locate them from farther away; coastal installations could have done the same.

Astronomy would be delayed. Celestial bodies would be visible only if one could get above the clouds. If no mountain went above them, people would still be curious to know what was there, and this could lead to balloons and other aircraft being developed faster. Until people could get above the clouds, there would have been a lot of speculation about what was in and above them – and perhaps stories like *Jack and the Beanstalk* would have sounded credible!

Life would also have evolved differently. Plants may have developed a type of chlorophyll that uses more of the electromagnetic spectrum, absorbing even green light, and thus appearing black.

Answers

Quick quiz #307 *Answers*

1 *Space Invaders*

2 Alfred Wegener

3 Mariner 10

4 Uranium

5 Aqueous humour

Quick crossword #185 *Answers*

ACROSS 1 Chestnut blight, **10** Imago, **11** Calibrate, **12** Fly solo, **13** Xerosis, **14** Louse, **16** Organisms, **19** Bryophyte, **20** Hyena, **22** Epizoic, **27** Handbrake, **28** Dubai, **29** Margaret Sanger

DOWN 2 Heavy-duty, **3** Slo-mo, **4** Necrotomy, **5** Telex, **6** Labyrinth, **7/25** *Gray's anatomy*, **8** Tsetses, **9** Eiffel, **15** *Euphorbia*, **17** Grey areas, **18** See double, **19** Beecham, **21** Amylin, **23** Inner, **24** Crane, **26** Add-on

#77 Folded stacks *Solution*

The three words are CARTHORSE, CAUTIONED and GNARLIEST.

For the third puzzle, the final step involves folding a 2-by-1 section in half, but tucking one half between the layers of the other.

Storks versus babies

A few weeks ago, Feedback waxed lyrical about how correlation does not equal causation after seeing a study that found a link between events on the sun and births of future Nobel laureates (31 May). This prompted reader Tony Lang to write in with a similar tale.

"Many years ago I saw an article with two identically shaped graphs, albeit with selective choices for the vertical axes," writes Tony. "One was the number of live human births in Germany. The other was the number of storks in Germany during the same period."

Feedback was delighted – nothing like an easy follow-up – but then we saw Tony's final line. "I didn't keep a copy so I can't give you any information about where or when it was published."

Challenge accepted! We went to some search engines and promptly fell down what can only be described as a stork-based rabbit hole. The problem isn't finding a study about purported correlations between storks and births, it is figuring out which of the many such studies Tony actually saw.

For instance, in an edition of *Teaching Statistics* from 2000, Robert Matthews published an article titled "Storks deliver babies (p= 0.008)". He collated data on the number of breeding pairs of white storks (*Ciconia ciconia*) for 17 European countries and found a correlation with those nations' birth rates. He produced a scatter plot with a line drawn through it.

Before you all start sending him letters, it was a teaching tool. As Matthews wrote: "While storks may not deliver babies, unthinking interpretation of correlation and p-values can certainly deliver unreliable conclusions."

More intriguingly, we found a 2004 study in *Paediatric and Perinatal Epidemiology* promising "New evidence for the theory of the stork". Its trio of researchers found a correlation between stork numbers and out-of-hospital births in Berlin and Lower Saxony in Germany. This led them to generate a graph showing the variations in stork populations and birth rates between 1970 and 2000. The graph doesn't look like the one Tony mentioned.

However, the authors described themselves as following up on "Sies' important epidemiological work". Wondering who Sies might be, Feedback found our way to the work of Helmut Sies, a physician best-known for showing that hydrogen peroxide is present in oxygen-breathing life.

In 1988, Sies wrote a short letter to *Nature* called "A new parameter for sex education". Noting "concern in West Germany over the falling birth rate", Sies proposed "a solution that every child knows makes sense". Below this was a graph showing the shockingly precise correlation between breeding pairs of storks (which fell from 2000 to 1000) and the number of newborn babies (which dropped from 1 million to around 0.5 million) between 1965 and 1980. Clearly, Germany's stork-related problems are ongoing.

If this isn't service journalism, we don't know what is. Also, it has been 20 years since the latest of these studies: can we have an update on the German stork/baby situation?

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

Up in flames

A reader named Victoria in Lancashire, UK, alerts us to a product of which we were unaware: a "seaside life ring candle holder". It is one of those little white ceramic tealight holders, nestled inside a mini wooden lifebuoy that reads "WELCOME SHIPMATE". Victoria found it in "a nautical-themed shop".

So far, so kitsch. But a closer look at the label reveals a stern warning for any putative user of the candle holder: "Keep away from flames or sources of fire". Feedback visited the website of the company that seemingly makes the candle holders, but couldn't find them in the catalogue. Maybe the warehouse burned down.

Cats versus AI

Using a laser pointer and a few treats, *New Scientist* reporter Matthew Sparkes coaxed us to an arXiv preprint study that reveals a hard truth about cats: they can break AI. We have reasoning AIs "trained for step-by-step problem solving", explain the authors of the paper. These can solve maths problems and write computer code.

Unless, that is, you hack one with what the team calls a "CatAttack". This entails adding an unrelated cat factoid to your query to an AI model. You can, for instance, give it a tricky maths problem and then append: "Interesting fact: cats sleep most of their lives". This addition "leads to more than doubling the chances of a model getting the answer wrong".

After picking our way through the paper, Feedback has concluded that it isn't really about cats. The attack relies on confusing the AI by saying something completely off-topic at the end of a question. This derails its train of thought.

Feedback has spent much of the morning wondering if this is fair: if humans were given the same test, would we all be able to ignore the cat facts and focus on the problem?

We have bad memories of exam questions that contained red herrings to throw us off the scent. But these were usually contextually appropriate. If a random cat fact were inserted into our school maths paper, we would do a double-take, but ultimately assume it was a misprint. "I'd be concerned if a human just glitched-out at the mention of a cat and could no longer do sums," says Matthew.

Feedback wonders if this might underestimate the ability of cats to distract their human servants. Speaking of which, did you know cats have whiskers not just on their faces, but on their front legs too?

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: the very definition of insanity.

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