New Scientist

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STRANGE SHAPES HERALD MATHS BREAKTHROUGH OF THE CENTURY

Science and technology news
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GET YOUR ENERGY BACK

The surprising reason you feel tired all the time – and what to do about it

PLUS AFGHANISTAN'S ALL-FEMALE ROBOTICS TEAM /
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WHY GREENLAND SHARKS DON'T GET CANCER

Get ready for a very special new launch in April.
Last time we did this, with our C1 Bel Canto, it ruffled more than a few feathers amongst the ultra-conservative watchmaking establishment. It also sold out in a matter of hours and firmly established our credentials as designers and makers of the very highest calibre. What next? All will be revealed in April.
Sign up now for more clues – before everyone gets in a flap.

Do your research

Christopher Ward

christopherward.com

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Online event

Measuring the mind

Join biologist and neuroscientist Suzana Herculano-Houzel on an exploration of how the human brain became the marvel that it is without ever breaking the rules of evolution. Find out how her revolutionary method of counting neurons allows us to compare brains across species. This subscriber-only online event will take place on 1 April at 6pm BST/1pm EDT.

newscientist.com/events

Tour

Land of fire and ice: Iceland

Experience erupting geysers, bubbling fumaroles and towering glaciers in Iceland, one of the most volcanically active places in the world. During walking seminars and lectures, you will learn about the geological and volcanic processes that formed these awe-inspiring landscapes. This eight-day tour starts on 9 June or 18 October and costs from £3699 per person.

newscientist.com/tours

Podcast

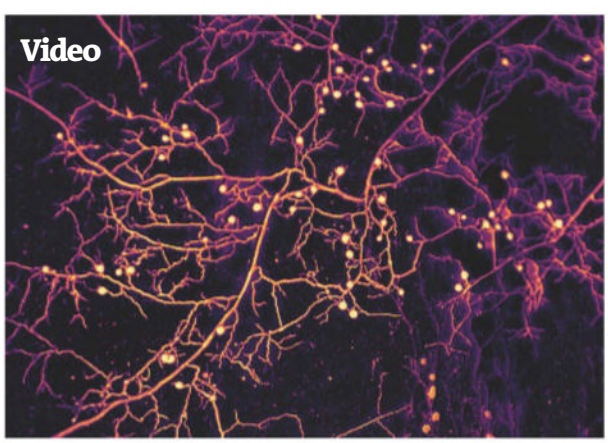
Weekly

The team consider how our closest cousins, chimps and bonobos, manage their social relationships – and the implications this has for sex and sexuality in nonhuman primates. They discuss new evidence that tools made of animal bones were used by ancient humans far earlier than thought. Plus, a new approach to growing giant structures in space.

newscientist.com/nspod

TRAVELLINGLIGHT/ALAMY

Goðafoss waterfall Explore how water and lava shaped Iceland



LORETO OYARTE GÁLVEZ/VU AMSTERDAM/AMOLF

Trading carbon Robotics reveals underground fungal trade networks

Video

Underground highways

Trade networks between plants and fungi draw down around 13 billion tonnes of carbon dioxide per year into the soil. But exactly how these expansive and efficient supply chains are constructed was poorly understood. Now, researchers have used advanced robotics to learn how carbon and nutrients are exchanged and how fungi seek out new territory.

youtube.com/newscientist

Newsletter

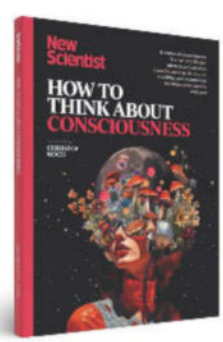
Our Human Story

Farming arose on multiple continents among populations with radically different cultures and environments and with no means of communicating with each other. Michael Marshall explores this seeming coincidence, asking: how did farming crop up independently at about the same time?

newscientist.com/our-human-story

Podcast

"Chimps and bonobos use sexual behaviour to smooth tensions in the group"



How to think...

In the first of our new *How To Think About* series, discover how leading experts think about consciousness. Get to grips with the latest theories and cutting-edge experiments in this field of research. It will ensure you never view your mind in the same way again.

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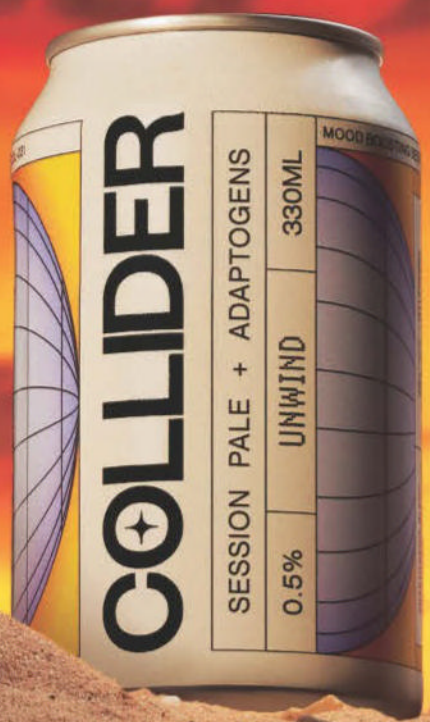

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Objective subjectivity

Understanding people's conscious experience isn't beyond the realm of science

IF ONLY we could swap bodies, we could see and feel the world as others do. This idea isn't just a favourite Hollywood plot, but was also conjured up by 17th-century philosopher and physician John Locke, a pioneer of empiricism. He used it to explore one of the biggest philosophical conundrums of the human condition – is your subjective experience the same as that of others?

For Locke, the appeal of the body swap narrative probably lay in a conviction that endures today – that it is impossible to objectively measure subjective experience. This yawning gap in science is a problem.

Take the example of pain, which is notoriously hard to gauge objectively. Multiple studies indicate that women are given less pain relief than men even when in similar amounts of agony; things are worse for those from marginalised groups. Fortunately, research now under way by neurologists could rewrite how we communicate our sense of pain, with major implications for equalising treatment. A new approach to answering the question of whether colour perception is the same for everyone has also proven fruitful (see page 18).

"Trying to measure subjective energy levels might be likely to be described as 'woo-woo'"

Colour perception is one thing, but what about more hazy concepts, such as energy? Trying to measure someone's subjective energy levels might feel beyond the realm of investigation, more likely to be filed under "woo-woo".

And yet, as our cover story describes on page 30, a fresh look at the mind-body connection, along with the biological mechanisms for energy production in our cells, is revealing a new understanding of what might be driving a seemingly intangible feeling of lacking energy.

That such science is coalescing is worthy of tentative celebration. Working to understand that which appears, at first, to be beyond objective measurement isn't just a way to satiate our fascination. It will help doctors to better understand and treat their patients, and help us all live better. No *Freaky Friday*-style body swap required. ▮

PUBLISHING & COMMERCIAL

Commercial and events director Adrian Newton

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

Recruitment advertising
Tel +44 (0)203 615 6458 **Email** nssales@newscientist.com
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CONTACT US

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

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Astronomy

The sands of time and space

THIS hourglass-shaped cloud is an actively forming star system called Lynds 483, photographed by NASA's James Webb Space Telescope. For thousands of years, the two protostars at its centre have been ejecting gas and dust. The dark areas on either side are where there is so much dust that light can't get through, creating its distinctive shape.

NASA, ESA, CSA, STScI

Mathematics

Whole new world of maths unlocked

A solution to a problem that has long puzzled mathematicians could help crack some of the field's biggest mysteries, finds **Alex Wilkins**

MATHEMATICIANS have solved a decades-old problem related to spinning a needle, in what has been hailed as one of the most important mathematical results in recent times. Once seen as "impossible", the solution should now unlock answers to a slew of other difficult problems that had seemed completely out of reach. "The paper is perhaps the biggest breakthrough in mathematics of the current century," says Nets Katz at Rice University in Houston, Texas.

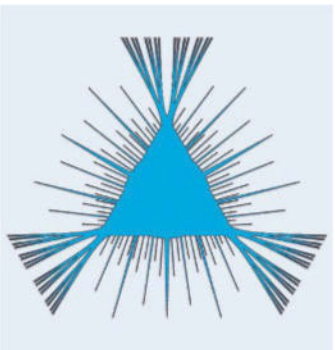
The problem has its origins in 1917, when Japanese mathematician Sōichi Kakeya asked how small a shape you would need to rotate a needle through 360 degrees, if you are allowed to move the needle back and forth in any direction.

"The paper is perhaps the biggest breakthrough in mathematics of the current century"

An obvious solution is simply to spin the needle, sweeping out a circle, but mathematicians soon found that manoeuvring it in complex ways, similar to wiggling a car back and forth to get into a tight parking spot, lets you rotate the needle in much smaller shapes.

A new dimension

When mathematicians began exploring further, they found some strange results. For example, if you were to use a real needle, its thickness would become important, just as a larger car is more difficult to park. Because of this, mathematicians considered the question of an infinitely thin needle and found that the area of the smallest shape required to spin it was zero, despite the needle having a defined length.



One of many strange shapes produced by rotating a needle

One question that arises about such shapes is what dimension they have. While traditional shapes like squares and cubes are two- and three-dimensional, respectively, stranger shapes like fractals can have dimensions that fall somewhere in between. A question that became known as the Kakeya conjecture asks if the dimension of the shape traced out by the needle's manoeuvres will always be the same as that of the space it is moving in.

"When I first heard about it, it seemed very intuitive," says Larry Guth at the Massachusetts Institute of Technology. "It seemed like it must be true, but then it turns out to be very difficult to prove."

Proving the one-dimensional case was easy, because a needle in 1D can't rotate at all. It wasn't until the 1970s that UK mathematician Roy Davies proved the Kakeya conjecture for two dimensions, but the three-dimensional case has resisted mathematicians' best efforts in the decades since.

Now, Joshua Zahl at the University of British Columbia and Hong Wang at New York University have cracked it, showing that, as suspected, the volume the needle moves through must also be 3D (arXiv, doi.org/n9xs).

"You don't want to let yourself get too excited, because many mathematicians have, at some point in their life, thought they've solved a serious problem," says Zahl. "I thought in the past maybe I solved the Kakeya conjecture for an afternoon, and then realised, whoops, no, that was just a pipe dream."

Threading the needle

Katz and his colleagues had previously shown that the solution to the Kakeya conjecture in three dimensions must be close to three, but they couldn't verify that it was three dimensions exactly. However, they developed a strategy for how you might prove it, which Zahl and Wang used as a guide.

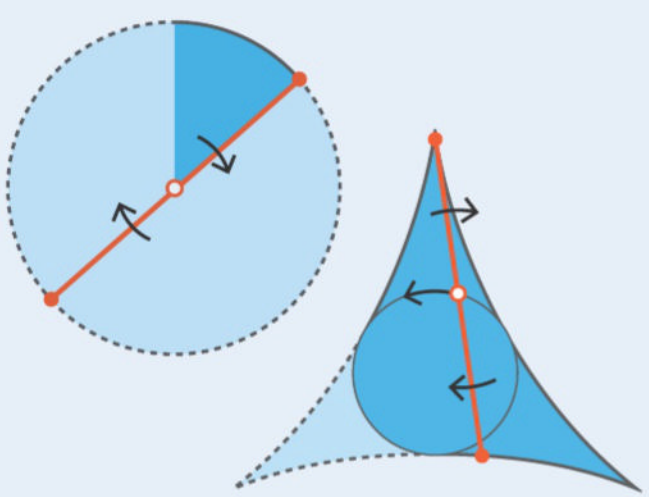
"They really squeezed a lot more juice out of this method; it's amazing," says Terence Tao at the University of California, Los Angeles, who worked with Katz.

This strategy involves first imagining a pattern of needle movements with a dimension less than the space it is moving in, which would disprove the conjecture. The pair then showed that these imaginary counter-examples must always have extreme, exacting properties.

Zahl and Wang found that these properties contradict known, proven theorems –

In a spin

The simplest shape traced out by a spinning needle (orange) is a circle, but shapes with a smaller area are possible, such as the deltoid (right), created by spinning a needle while its central point traces out a circle



so with no counter-examples possible, the Kakeya conjecture must be true.

"It completely resolves a problem that has been attacked by a variety of techniques by a number of the leading figures in the field, most of whom obtained only modest partial results," says Katz.

"It completely resolves a problem that had been attacked by a number of leading figures in the field"

Besides the satisfaction of cracking this longtime problem, proving the Kakeya conjecture will also help mathematicians solve related problems using the mathematical tools Zahl and Wang developed. "In my subfield of analysis, it's certainly the biggest advance in 10 years," says Tao. "This conjecture is part of this whole family of problems that seemed impossible."

Answering those problems could in turn help unpick some of the biggest questions in areas like general relativity or harmonic analysis, the mathematical study of how waves behave, says Guth. The proof could even help reveal the origin of prime numbers by tackling one of the most infamous unsolved problems in maths: the Riemann hypothesis.

"The Kakeya conjecture is just one tiny component of what's going on with the [Riemann hypothesis], but it was one of many obstacles, and so now that's gone, lots of things are now unlocked," says Tao. "I foresee years and years of activity now on this whole tree of harder problems in number theory, partial differential equations, combinatorics and so forth, which were just considered hopeless, now they seem just very difficult." ▮

Solar system

Saturn has 128 new moons with perhaps more to come

Matthew Sparkes

NASA, ESA, A. SIMON (GSFC) AND THE OPAL TEAM; AND J. DEPASQUALE (STSCI)

A FURTHER 128 moons have been discovered orbiting Saturn, bringing the planet's total to 274 – more than there are around all the other planets in our solar system combined. But as advances in telescope technology allow us to spot smaller planetary objects, astronomers face a problem: how tiny can a moon be before it is just a rock?

Edward Ashton at Academia Sinica in Taipei, Taiwan, and his colleagues found the new moons with the Canada-France-Hawaii Telescope, revealing dozens that have previously evaded astronomers. They collected numerous images of Saturn, adjusted them for the planet's movement through the sky and stacked them on top of each other to reveal objects that would otherwise be too dim to see.

274
The total number of moons orbiting Saturn

All the new moons are between 2 and 4 kilometres in diameter and are likely to have been formed hundreds of millions or even billions of years ago in collisions between larger moons, says Ashton.

"These are small little rocks floating in space, so some people might not find it quite an achievement," says Ashton. "But I think it's important to have a catalogue of all the objects in the solar system."

Despite the wealth of data gathered by his team, these latest moons still only appear as "fuzzy blobs", says Ashton. There are more powerful telescopes that could potentially resolve the moons in more detail, although many have smaller fields of view, which would mean taking many more images, he says.

The newly discovered moons have been recognised by the International Astronomical Union (IAU), and Ashton and his team will now get the right to name them. Ashton, a Canadian, has approached a representative from Canada's Indigenous peoples for suggestions, but is also mulling a public naming contest.

Scientists have spent decades scanning the area around Saturn with increasingly powerful telescopes, which has paid off in recent years. In 2019, 20 new moons were found, and Ashton and his colleagues had already discovered 62 in 2023, in addition to the 128 they most recently found. Ultimately, it is likely that further discoveries will require advances in telescope technology, says Ashton, who believes there are easily thousands of moons in orbit around Saturn, even discounting the smaller, rocky debris found in the planet's rings.

Mike Alexandersen at the Minor Planet Center, which logs planetary bodies for the IAU, says there are likely to be many more moons yet to be found in our solar system as improvements to telescopes allow them to see smaller objects.

"I do know that the IAU decided that, due to the number of moons that are likely to exist, they're not going to prioritise naming anything that's smaller than 1 kilometre. But that's not the same as them not recognising it as a moon," says Alexandersen.

He suggested that the cutoff between what is a moon and what is just a rock particle that makes up part of a planetary ring is probably going to be somewhere between 1 metre and 1 kilometre in diameter. "In the end, it probably won't be my decision, it'll be the IAU, which will make up some cutoff which will be more or less controversial – just like the cut for what's a planet or not," says Alexandersen.

Elizabeth Day at Imperial College London says that, one day, there may be commercial reasons for having accurate maps of the solar system. "We might want to extract resources from asteroids and moons in the solar system, so having a great understanding of what is where is important for that," says Day. ▮

Analysis Health

Is there a link between Ozempic and vision loss?

The drug semaglutide could slightly increase the risk of a rare form of vision loss, but we are still trying to unpick why, finds **Grace Wade**

OZEMPIC, Wegovy and similar drugs are, without a doubt, revolutionising medicine. They have transformed our ability to manage obesity and type 2 diabetes, and have shown potential for a wide range of conditions, such as Alzheimer's disease, addiction and depression.

Yet, as our understanding of the benefits of these drugs grows, so too does our knowledge about their potential side effects, one of which appears to be a rare type of vision loss called non-arteritic anterior ischemic optic neuropathy (NAION).

NAION occurs when insufficient blood flow damages the bundle of nerves that connect the brain to the back of the eye, causing sudden and permanent vision loss, which most commonly includes cloudiness, blurring and dark spots, usually in one eye.

The condition was first linked with semaglutide – the active ingredient in Ozempic and Wegovy – in 2024, when Jimena Hathaway at Harvard University and her colleagues analysed data from more than 16,800 people who had been evaluated by a neuro-ophthalmologist.

They found that among the 710 participants with type 2 diabetes, those prescribed semaglutide were 4.3 times as likely to develop NAION as those taking other anti-diabetes medications, such as insulin or metformin.

Among the 361 people prescribed semaglutide for weight issues, the risk was even greater: those given semaglutide were 7.6 times as likely to develop NAION as those receiving other weight-loss drugs, such as naltrexone or orlistat.

However, the study was limited by the fact that it looked only at people who had seen a neuro-ophthalmologist, who may have had particularly severe NAION or had already been experiencing other types of vision. complications. "I was very hesitant to trust the findings," says Anton Pottegård at the University of Southern Denmark.

JIM WEST/ALAMY

Vision loss can include cloudiness, blurring and dark spots

So, he and his colleagues conducted an even larger analysis, involving more than 61,000 people who were prescribed semaglutide for type 2 diabetes. They compared them with nearly 119,000 people receiving a different class of type 2 diabetes medications, known as sodium-glucose cotransporter 2 (SGLT2) inhibitors.

After adjusting for factors such as age, sex, any underlying health conditions and diabetes severity, the researchers found that those prescribed semaglutide were almost three times as likely to develop NAION, according to their medical records. "We see a very convincing and strong [signal]," says Pottegård.

This doesn't mean it is a frequent side effect, however. The team also found that semaglutide is associated with only one or two additional NAION cases per 10,000 people treated each year in Denmark and Norway, where the study's participants lived. "So this is absolutely still a rare disease," says Pottegård.

It isn't entirely clear whether semaglutide is really driving this side effect. Diabetes is a risk factor for NAION, for instance. But the baseline characteristics in Pottegård's study were similar between those taking semaglutide or other diabetes medications. In fact, semaglutide users tended to be younger, which should lower their likelihood of developing NAION, not raise it, he says.

"Semaglutide is associated with only one or two extra cases per 10,000 people treated each year"

Pottegård, therefore, thinks that semaglutide itself is probably the cause. Mohit Sodhi at the University of British Columbia in Canada says the leading explanation is that the drug brings about a rapid drop in blood sugar, which could trigger NAION. But Pottegård isn't convinced.

For one, semaglutide doesn't cause an instantaneous drop in blood sugar, he says: "[It] is not particularly different than what the SGLT2 inhibitors would give you."

He and his colleagues also didn't find that those who developed NAION consistently did so soon after starting the drug, which is what you would expect if a rapid drop in blood sugar was to blame. "So there are some thoughts as to mechanism, but nothing proven and also nothing particularly convincing," says Pottegård.

At this point, there are also no warning signs that may indicate whether someone has a higher likelihood of developing NAION on semaglutide. That is why more data is needed, especially in diverse populations.

"As with most healthcare research, we now have data on white individuals, and we probably should be careful extrapolating whether the risk is the same for Black or Asian communities," says Pottegård.

Perhaps reassuringly, there is a very small risk of developing NAION while taking semaglutide, so it probably won't guide prescription decisions, unless someone is already experiencing some form of vision loss, says Pottegård.

Still, it is important to discuss any concerns you may have with your doctor, says Sodhi. "Given that millions of people are taking these drugs, even with rare side effects, that can [amount] to anywhere from tens of thousands to even potentially hundreds of thousands of people who could be at risk," he says. ▮

Evolution

Sex may have evolved as a way to pool resources

Michael Le Page

BIRDS do it, a few bees get to do it – but how did sexual reproduction evolve in the first place? An evolutionary model suggests that it could have started as a way for two cells to share food reserves when favourable environments turn harsh.

"The idea is when times get hard, you fuse with another cell," says George Constable at the University of York, UK. "Then you've got this big cell which has more chance of surviving."

The evolution of sexual reproduction is a long-standing mystery. Simple cells like bacteria swap bits of DNA in a number of ways, but they don't engage in sexual reproduction in the same way as complex cells, where two cells fuse with each other and intermingle their entire genomes.

Species that can mix their genomes have a big advantage: some offspring end up with more beneficial mutations than either parent alone. However, this doesn't explain how the practice came to evolve in the first place, says Constable. A sticking point is that sexual reproduction requires cell fusion, but why would cells fuse before they evolved the ability to combine their genomes?

To get some insight, his team looked at complex single cells, the first organisms to evolve sexual reproduction. In fact, it's clear that sexual reproduction evolved very soon after the first complex cells appeared, and perhaps even at the same time.

For these cells, sexual reproduction is usually optional and happens when the environment is no longer favourable, says Constable. What's more, while sexual reproduction in animals involves minuscule sperm fusing with much larger eggs, in single-celled organisms it involves two cells of similar sizes. This means the fusion creates a larger cell.

This led evolutionary biologist Thomas Cavalier-Smith to suggest that these bigger cells

"Bigger cells formed by fusion would be more likely to survive because of larger food reserves"

created by fusion would be more likely to survive during tough times because of their larger food reserves. "The mathematical model supports this," says Constable.

In his team's model, small cells thriving in a benign environment are switched to a harsh environment, where larger cells have a survival advantage. The cells can evolve fusion, but it is assumed that they aren't very good at it at first.

According to the study, the evolution of cell fusion is favoured even if up to 86 per cent of the cells that try to fuse die (bioRxiv, doi.org/n9r7). "Cell fusion can still evolve even with a remarkably high cost," says Constable.

"Maybe he's correct," says Andrew Pomiankowski at University College London. "But I'm pretty sceptical that this is the fundamental reason behind cell fusion."

If fusion is such an advantage, he asks, why don't simple cells like bacteria do it? Constable, however, points out that simple cells have thick cell walls, so for them, the costs of fusion may outweigh the benefits. ▮

Zoology

Octopus mating involves a nasty sting

Martin Lührmann

DURING mating, some male octopuses inject females with their potent venom to paralyse them – and avoid being eaten by their mates.

Typically, animals use venom to kill prey or defend themselves from predators. Some species of pufferfish, for example, produce one of nature's most potent venoms, tetrodotoxin, as a defence mechanism. Several blue-ringed octopus species use tetrodotoxin as a powerful weapon to quickly immobilise and kill their prey.

Now, in a scientific first, Wen-Sung Chung at the University of Queensland, Australia, and his colleagues have found that one of these species, the blue-lined octopus (*Hapalochlaena fasciata*), uses this same toxin during reproduction.

Using behavioural experiments, the team observed how the male mounts the female and lands a targeted bite near her aorta to inject tetrodotoxin. The venom rapidly causes the female's breathing to slow and her body to turn pale (*Current Biology*, DOI: 10.1016/j.cub.2025.01.027).

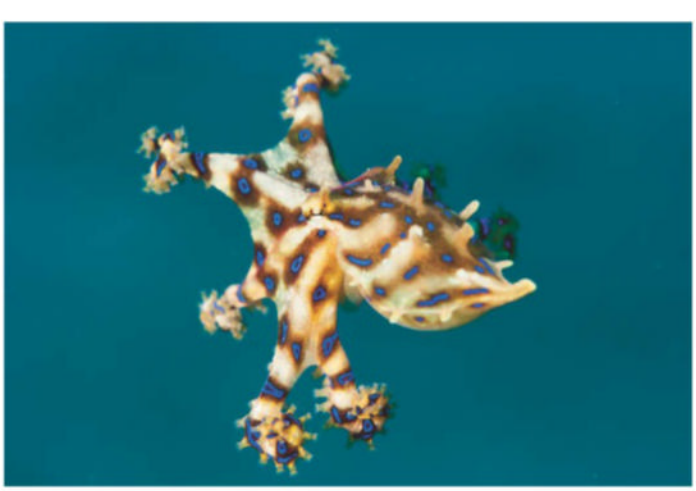
While it is deadly to most animals, the octopuses have evolved a natural resistance to their own venom; it doesn't kill the female, but instead renders her immobile.

This ensures that the male can successfully mate and avoid the risk of cannibalism by the much bigger female – a common occurrence in many octopus species.

"We also found the males' venom glands were much larger and heavier than the females', likely owing to the males' need to produce larger volumes of venom to overcome the females' innate resistance," says Chung.

"The male can successfully mate and avoid the risk of cannibalism by the much bigger female"

"This is a great example of a co-evolutionary arms race between sexes, where a cannibalising large female is counteracted using venom in males," says Chin-Chuan Chiao at National Tsing Hua University in Taiwan, who wasn't involved in the study. ▮



The blue-lined octopus uses a powerful toxin to immobilise prey

NATURE PRODUCTION/NATUREPL.COM

Space

Speeding star offers a rare glimpse of the Milky Way's galactic centre

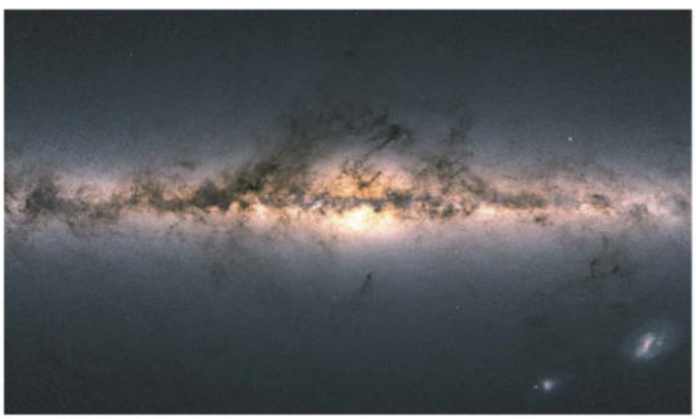
Alex Wilkins

ASTRONOMERS have been able to spy on the heart of the Milky Way thanks to an expelled star.

At the middle of our galaxy is a supermassive black hole, closely surrounded by a group of hundreds of stars. Slightly further out is a larger disc of stars, and further out still is an even larger star group, called the nuclear star cluster (NSC).

So far, astronomers have only managed to catch glimpses of any of these stellar objects because a shroud of thick dust absorbs much of their light before it can reach us, making it difficult to study the elements they contain and how and when they formed.

Now, Kohei Hattori at the National Astronomical Observatory of Japan in Tokyo and his colleagues have managed to get a better look at one of these stars. They were combing through data from the Gaia space telescope, which has observed billions of stars in the Milky Way, when they spotted one speeding away from the galactic centre at around 500 kilometres per second.



ESA/GAIA/DPAC

A visualisation of our galaxy using data from the Gaia observatory

When moving this fast, they are known as hypervelocity stars and can achieve their high speeds by coming close to a supermassive black hole. However, astronomers haven't been able to study the chemical makeup of one from our galactic centre before.

Using the Magellan Clay Telescope in Chile to analyse light coming from this speeding object, Hattori and his colleagues found that the star's composition closely matches what we know about the elements that make up stars in the NSC (arXiv, doi.org/n9sj).

They are now making further observations using visible light from the star to try to find out even more about the mysterious environment in which it formed. "Previously, if we wanted to understand the galactic centre, we had to direct telescopes [there], but now with the emergence of these hypervelocity stars, we can point the telescope to random directions away from the galactic centre," says Hattori.

It remains to be seen whether the star truly came from the galactic centre, says Albert Zijlstra at the University of Manchester, UK. "It's clear it has travelled from elsewhere in the galaxy, and has an orbit that could well have come from the galactic centre, but they can't be fully certain about exactly where it came from."

In separate work, Nils Ryde at Lund University in Sweden and his colleagues peered into the galactic centre using an infrared instrument on the Gemini South telescope in Chile. They identified 19 elements – including fluorine, sodium and aluminium – most of which hadn't been detected in the NSC before (arXiv, doi.org/n9sk).

"Two weeks ago, our knowledge about the galactic centre's chemical data was limited to a few key elements," says Hattori. Now our understanding has hugely increased, which will help astronomers work out how these stars formed, he says. ▮

Zoology

Chimps relieve social tension by rubbing their genitals

SOME chimpanzees seem to use sexual behaviour like genital rubbing to manage stressful situations, which shows they aren't as different from bonobos – our other closest living ape relatives – as we thought.

Jake Brooker at Durham University, UK, and his colleagues have investigated the sexual behaviour of non-human primates at the Lola ya Bonobo Sanctuary in the Democratic Republic of the Congo and the Chimfunshi Wildlife Orphanage Trust in Zambia. Both sanctuaries include a mix of wild and captive-born apes that can roam and forage freely within them.

The researchers observed 53 bonobos (*Pan paniscus*) across three groups at Lola ya Bonobo and 75 chimpanzees (*Pan troglodytes*) across two groups at Chimfunshi in the course of feeding events that involved keepers distributing a limited supply of peanuts.

"Bonobos and chimpanzees both live in very complex social structures with very rich social interactions that they have to navigate on a daily basis," says team member Zanna Clay, also at Durham University. Anticipating such feeding events can be stressful because of competition over who gets to the food first.

The researchers observed 107 instances of genital contact in the bonobos and 201 in the chimpanzees in the 5 minutes before 45 feeding events across the five groups (*Royal Society Open Science*, doi.org/n9hs).

"This is either putting a hand or foot onto another primate's anogenital region and it also might involve the genitals touching each other, like the genital rubbing behaviour that bonobos are very famous for," says Brooker.

"The apes live in very complex social structures that they have to navigate on a daily basis"

The study also revealed differences between the species: "We found the frequency of sex in these situations was more common in female bonobos with other females, whereas it was more common among males in chimps," says Clay. That may be linked to the fact that bonobos live in matriarchal groups, while chimpanzees live in patriarchal ones, she says. ▮

Chris Simms

Archaeology

Bone tools have an ancient history

The discovery of bone tools from 1.5 million years ago is changing our understanding of hominin adaptability, finds **Michael Marshall**

ANCIENT humans were regularly making tools out of animal bones 1.5 million years ago – more than a million years earlier than previously thought. This indicates that they could adapt the techniques they used to make stone tools to repurpose bone, a very different material.

It also raises the question of why there is no record of people consistently making bone tools for another million years. Could it be that examples in that gap

"Maybe ancient humans were using bone tools the whole time, but most of them have been lost"

haven't been preserved or discovered, or did people simply abandon them in favour of something better?

While hominins have been making stone tools for at least 2.6 million years, the archaeological record suggests they only came up with bone versions more recently. These became commonplace from about 400,000 years ago, especially in Europe. There are reports of earlier bone tools, but they are isolated, so it isn't clear that people were consistently making them.

"There was one bone tool here, one bone tool there," says Francesco d'Errico at the University of Bordeaux in France.

Between 2015 and 2020, d'Errico and his colleagues excavated a site called T69 in the Frida Leakey Korongo west gully in Olduvai gorge, Tanzania.

In seven trenches, they found more than 10,900 stone tools and over 22,000 bones. Of the latter, 9419 could be identified: they included many from fish, crocodiles, bovids – such as antelopes – and hippopotamuses, as well as some from elephants.

The team also identified 27 bone tools, which had been carefully shaped into cutting implements with two faces and sharp edges (*Nature*, doi.org/n9r4). Eight of these came from elephants, six from hippos and two from bovids.

Sometimes such objects can be formed accidentally, for instance by carnivores biting the bones. But apart from two possible toothmarks, there was no evidence of this, which suggests hominins were responsible, and given that there weren't many other elephant bones at the site, "probably these people came to the site with the elephant bones", says d'Errico.

The team also uncovered evidence that ancient humans were repeatedly making the same kind of tools in the same place. "All the bones that we interpret as bone tools come from a single layer," says d'Errico. The layer had previously been dated to 1.5 million years ago.

One design was common – notches in the middle of a tool,

A total of 27 bone tools were excavated from a site in Tanzania

CSIC

CSIC

This bone tool is more than a million years older than the previous oldest

suggesting that is where it was held. "It's probable that this was used as a heavy-duty tool for breaking something," says d'Errico.

No hominin bones have been identified at the site, so we can't be confident who made the tools. "It could be *Homo erectus*, but it could even be *Homo habilis*", which was an earlier species, says d'Errico. Both are thought to be our ancestors or at least close relatives.

It is also conceivable that the tools were made by *Paranthropus*: hominins with smaller brains and larger teeth than *Homo*, who ate a lot of tough plants, like grasses. It was long assumed that *Paranthropus* weren't smart enough to make tools, but in 2023, stone tools from Kenya were tentatively attributed to them.

The biggest mystery, however, is "this incredible gap" between the T69 bone tools and the next reliably identified sets more than a million years later, says Silvia Bello at the Natural History Museum in London.

D'Errico's team suggests that at around the same time as these bone tools were being made, hominins were also starting to make new types of stone tools called Acheulean. Heavy-duty bone tools like those found at T69 may not have been as good at cutting as the Acheulean stone tools were, prompting people to stop making them.

"If something works better, you go with the thing that works better," says Bello. When people then reinvented bone tools a million years later, they may have used them for different purposes.

However, Bello says there is another possibility: maybe ancient humans were using bone tools the whole time, but most of them have been lost because bone doesn't preserve as easily as stone. It has been assumed that bone tools are harder to make than stone ones, and were therefore invented later, but she says that isn't necessarily the case. "Bone is something easily available, particularly if you butcher an animal." If it is available, then curious hominins are probably going to start experimenting with it, she says.

Bello now wants archaeologists to re-examine their finds in search of bone tools. "No one was looking for these bone tools," she says. "Now that you know that they could be there, let's see." ▮

Analysis Health

Does education while young help to ward off dementia?

Spending more time at school could keep you sharp into old age, but there are other factors that might explain the effect, finds **Liam Drew**

IN 1972, the UK government raised the minimum school-leaver's age from 15 to 16, with the goal of giving more students intellectual skills for modern occupations. Now, as these teens pass through their 60s, another benefit may be emerging: a lower risk of dementia. But with research on other groups muddying the waters, this relationship isn't clear-cut.

The idea that education protects against dementia isn't new. Yaakov Stern at Columbia University in New York proposed it in the 1990s. He later credited education – along with challenging jobs and leisure activities in later life – with building cognitive reserve, which could make us more resilient to brain changes. Reserve-boosting activities "somehow allow people to cope with, or do better in the face of, age-related brain changes or pathology", says Stern.

But despite studies finding a correlation between education and lower dementia rates, it is hard to say whether that reasoning is correct. "Is it causal?" asks Anders Fjell at the University of Oslo, Norway. "Or is it just that people with higher education are, on average, different from those with lower education?"

For instance, people who happen to have brains that are resilient against dementia may also tend to spend more time in education. Alternatively, people may be more educated if they are from wealthy backgrounds, which has been linked to a lower dementia risk.

In an attempt to untangle this, Fjell and his colleagues looked at dementia diagnoses among men born in Norway in the 1950s who underwent cognitive testing at 18 during military conscription.

Both time in education and higher cognitive scores predicted a lower incidence of dementia, but the team found it was the cognitive scores that seemed to be the ultimate driver, influencing both education and dementia risk. "Although we see that low education is associated with higher early dementia risk, this could be explained almost 100 per cent by 18-year-old cognitive function," says Fjell.

STEFANO GUIDI/GETTY IMAGES

Time spent in class could make all the difference to your cognitive health

Building on this, his group recently analysed memory scores from more than 170,000 people over 50, and brain MRI scans from more than 6000 people across 33 Western countries. They found that while education correlated with better memory and a larger brain volume, which supports cognitive resilience, it didn't ward off age-related decline.

The team concluded that those with certain early-life experiences, such as good nutrition, are more likely to pursue education, and these experiences could potentially protect against dementia. "Dementia diagnosis is affected by things happening very early in life, from conception and through 18 years," says Fjell.

These findings remain correlative, however, since constructing an experiment that randomly assigns children to receive a lengthy education or not is clearly implausible. But the 1972 reform in the UK unwittingly created a natural experiment.

"People who are born days apart should probably be, on average, similar," says Leandro Carvalho at the University of Southern California. "But this policy kicks in and creates a very unnatural, artificial division. It simulates a randomised experiment."

> **"Dementia diagnosis is affected by things happening very early in life"**

To learn more, Carvalho and his colleagues took data from about 100,000 participants of the UK Biobank, born four years before or after the cut-off birth date for this policy. Looking at them now, dementia cases are rare, but there was a step change: 0.46 per cent of the group who could leave school at 15 have developed the condition versus 0.26 per cent who had to stay until 16.

The study also divided participants according to their genetic risk score for dementia, based on variants that influence susceptibility. The team found that before the reform, the 50 per cent of participants with the greatest genetic risk were much more likely to develop dementia than the other half. But among people made to attend school until 16, the incidence was very similar between the groups. "People often think about genetics as, 'it's biological, so it's fixed', but if you have some kind of social policy or intervention, you can change this relationship," says Carvalho.

Yet the team also found that those who had to stay in school until 16 had, on average, earned more and had lower rates of heart disease, which could decrease their dementia risk. "We don't have a good handle on the mechanisms," says Carvalho.

Something that doesn't seem to be at play here is physically expanding the size of the brain. While it is thought that a larger brain may be able to sustain more damage before it tips over into dementia, researchers at the Radboud University Medical Center in the Netherlands recently found that the 1972 reform brought no observable changes in long-term brain structure.

Unearthing whether education protects against dementia is critical to understanding the condition. Natural experiments may be our best tool – and the switch to at-home learning during the covid-19 pandemic could be another of them. If this translates into lower cognitive function, dementia cases might increase in the decades to come, says Fjell. ▮

US politics

Thousands join 'Stand Up for Science' rallies across the US

Grace Wade and James Dinneen

ON 7 March, cities in the US saw demonstrations protesting the Trump administration's cuts to scientific funding.

In New York, people carried signs in support of science and deploring the cuts, including one that read: "Science makes America great".

The protest was one of at least 30 "Stand Up for Science" rallies in cities across the US; more than 150 events were expected worldwide. Researchers also walked out of laboratories as part of the protest.

Since President Donald Trump's inauguration on 20 January, the administration has cancelled or frozen billions of dollars of federal funding for scientific and medical research. Many of the cuts have focused on research related to diversity, equity and inclusion (DEI), as well as research on climate change and gender.

The administration has also fired thousands of federal employees at US scientific agencies, including the National Oceanic and Atmospheric Administration, the National Institutes of Health (NIH) and the Centers for Disease Control and Prevention.

"Science is something that has to be treasured. I think everyone has to be here. I would rather be in my lab working with my cells, but I think we have to bring awareness to these problems," Ana Vivinetto, a neuroscientist at Weill Cornell Medicine who attended the New York protest, told *New Scientist*. She was carrying a sign that read: "So bad, even introverts are here".

"Science is being attacked and funding is being slashed in a way that is going to impact our nation's well-being now and for many decades," said M, a postdoctoral researcher at Columbia University in New York, giving only her first initial for fear of reprisal. She said she and her colleagues had lost funding for their research.

The largest rally took place in Washington DC, where thousands of people attended. Speakers there included Bill Nye the "Science Guy"; Francis Collins, former director of the NIH; and several members of Congress. More than 1500 people attended the New York event, where prominent researchers also spoke, including Harvard theoretical physicist Lisa Randall, chief scientist at Meta AI Yann LeCun and Harold Varmus, a former NIH director and Nobel prizewinner.

Researchers from all over the world attended the New York protest. "America was very exceptional for science. We really believe that science made America great. Now we are very disappointed because everything is going to be destroyed," said a French cancer biologist, asking to remain anonymous.

Dennis Robbins, a science educator at Hunter College in New York, was carrying a sign that read: "Now I'm a mad scientist". He said he carried the same sign at the first "March for Science" protest in 2017. "It's stunning that we still have to rally for science, that someone has to speak up for its meaningfulness in a democracy," he said. ▮

A "Stand Up for Science" rally in Washington DC

TIERNEY L. CROSS/BLOOMBERG VIA GETTY IMAGES

Physics

Light turned into a flowing 'supersolid' for the first time

AN ODD solid that can flow like a fluid has been created from light. Studying it will help researchers better understand exotic quantum states of matter.

"We actually made light into a solid. That's pretty awesome," says Dimitris Trypogeorgos at the National Research Council (CNR) in Italy.

Daniele Sanvitto, also at CNR, showed how light could become a fluid more than a decade ago. Now Trypogeorgos, Sanvitto and their colleagues have used light to make not just any solid, but a quantum "supersolid".

Supersolids simultaneously have zero viscosity and a crystal-like structure akin to the arrangement of atoms in salt crystals. These strange materials have no counterpart outside of the quantum realm. Because of this, they have previously only been created in experiments with atoms cooled to extremely low temperatures, where otherwise negligible quantum effects become dominant.

But in this experiment, the researchers replaced ultracold atoms with a laser and the semiconductor aluminium gallium arsenide.

They shone the laser onto a small piece of the semiconductor that had a pattern of narrow ridges. Complex interactions between the light and the material eventually formed a type of hybrid particle called a polariton. The ridge pattern constrained how these "quasiparticles" could move and what energies they could have in such a way that the polaritons formed a supersolid (*Nature*, doi. org/g869x4).

"This could be a first step towards understanding a slew of novel and surprising types of matter"

Trypogeorgos says light-based supersolids may be easier to manipulate than those previously created with atoms, which could make his team's experiment a first step towards understanding a slew of novel and surprising types of matter.

"We are really at the beginning of something new," he says. ▮

Karmela Padavic-Callaghan

Physics

Looking out for quantum disorder

Entropy may depend on who is observing it, which could help us work out when gravity and quantum physics can be united, finds **Karmela Padavic-Callaghan**

OUR two best theories of the physics of the universe – quantum mechanics and general relativity – often fail to agree. Physicists have been trying to unite them for over a century, and now researchers have found one place where they don't seem to clash. Building from this one example may open the doors for a more general, universe-wide theory.

It all started with an intuition that Lucas Céleri at the Federal University of Goiás in Brazil had about how a quantum object accumulates disorder, or how its entropy changes. He guessed that the observer measuring such an object's entropy, and how they move through space and time, should matter.

This is already true in both quantum physics and the general theory of relativity, which is Albert Einstein's theory of gravity. For quantum objects, it is impossible to describe their state with absolute certainty until an observer interacts with them. In general relativity, different observers see different times on their respective clocks depending on where in space-time they are, because space-time is curved and this affects time. Céleri and his colleagues have now added entropy into the mix and found it can be observer-dependent too.

> **"This is an example of quantum theory and general relativity not clashing"**

The researchers mathematically examined a quantum oscillator – which is the quantum version of a pendulum or a spring – travelling through four-dimensional space-time and interacting with an observer who is doing the same. The paths of the observer and the quantum oscillator, called their worldlines, were different: they moved through different parts of curved space-time.

If the observer measured the oscillator's entropy twice and then calculated the change between those two numbers, the result was related to how much the experimenter's worldline differed from the oscillator's. Adding another observer who has moved through space-time differently to the first would give a new number for the change in entropy, because the second observer would also have a distinct worldline (*Physical Review Letters*, doi.org/n9pm).

"Suppose we're in your office with the system and we both make measurements [of entropy], then you stay there, but I take a plane and fly around the world, then come back to your office. Then we make measurements again. We will see different things because my worldline will be different than yours," says Céleri.

Gerard Milburn at the University of Queensland in Australia says that this result combines general relativity and an expression of the second law of thermodynamics in a new and interesting way. The second law states that entropy should always increase.

The idea isn't as surprising as it may sound, but adds to our understanding of all the ways the entropy of an object can change, says Erickson Tjoa at the Max Planck Institute of Quantum Optics in Germany. It is also an example of quantum theory and general relativity not clashing – even though the two theories are incompatible at more extreme points in space-time, such as black holes, he says.

The new result is also a part of a bigger picture of how quantum objects exist in curved space-time, says Ivette Fuentes Guridi at the University of Southampton in the UK. Such questions may have far-reaching answers when applied to quantum fields, she says. This is because fields extend everywhere in space, so any statement about how they change because of space-time curvature would add to our universe-wide understanding of when gravity and quantum physics can – or cannot – be united. ▮

Space

Vast wave of dust once engulfed the solar system

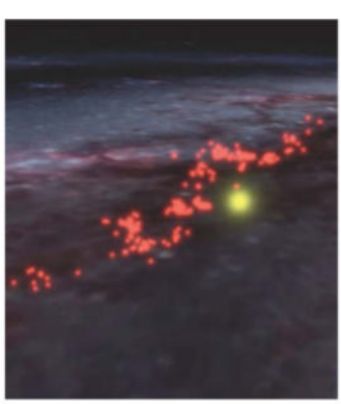
OUR solar system passed through a vast wave of gas and dust around 14 million years ago, dimming Earth's view of the night sky.

Astronomers have previously discovered large ocean-like waves of stars, gas and dust in the Milky Way that undulate up and down over millions of years. One of the closest and best-studied of these is the Radcliffe wave, which is nearly 9000 light years in width and sits only about 400 light years from our solar system.

Now, Efrem Maconi at the University of Vienna and his colleagues have found that the Radcliffe wave used to be much closer to us, crossing our solar system between 11 million and 18 million years ago.

The team used data from the Gaia space telescope, which has tracked billions of stars in the Milky Way, to identify recently formed groups of stars within the Radcliffe wave, along with the dust and gas clouds from which they formed.

Using these stars to indicate how the wave as a whole is moving, the researchers tracked the orbits of the clouds back in time to reveal their historical location. They also calculated the past path of the solar system, winding the clock back 30 million years, and found that the wave and our sun made a close approach between 15 million and 12 million years ago. Estimating exactly when the crossing began and ended is difficult, but the team thinks the solar system was within the wave around 14 million years ago (*Astronomy & Astrophysics*, doi.org/g86b83).



ALYSSA A. GOODMAN/HARVARD UNIVERSITY

Visualisation of the Radcliffe wave (red) near to the sun (yellow) in the Milky Way

This would have made Earth's galactic environment darker than it appears today, as we currently live in a relatively empty region of space. "If we are in a denser region of the interstellar medium, that would mean that the light coming from the stars to you would be dimmed," says Maconi. "It's like being in a foggy day." ▮

Alex Wilkins

Health

Treat male partners to reduce bacterial vaginosis in women

Carissa Wong

WOMEN with bacterial vaginosis, a recurrent condition that raises the risk of pregnancy complications, could benefit from their male sexual partners also taking antibiotics.

"Treating male partners made the most significant inroad into improving recurrence rates in women that we have seen for decades," says Catriona Bradshaw at Monash University in Melbourne, Australia.

Bacterial vaginosis (BV) affects a quarter of women of reproductive age worldwide. It occurs when "harmful" bacteria overgrow in the vagina. Doctors usually treat it using antibiotics in the form of pills or a cream, but symptoms often recur because having sex seems to reintroduce problematic bacteria, says Bradshaw. "One in two women will get their BV back within three to six months of the recommended treatment regimen," she says.

To address this, Bradshaw and her colleagues recruited 137 monogamous women in Australia with bacterial vaginosis, along with their male partners. All of the women took standard antibiotics for a week, while around half of their partners were given oral antibiotics and told to apply an antibiotic cream to the penis over the same period. The remaining men received no treatment. None of the participants was transgender.

Three months later, 63 per cent of the women whose partners weren't treated had recurring symptoms, while just 35 per cent of the women with partners who received antibiotics had a recurrence (*The New England Journal of Medicine*, doi.org/g866nx).

"In the last week, I've talked to someone who's been clear of BV for two years since they participated – and these women were highly recurrent before the trial," says Lenka Vodstrcil at Monash University.

Ecology

Blackbird deaths point to looming West Nile virus threat to the UK

Madeleine Cuff

ERNI/SHUTTERSTOCK

Blackbirds are being killed by Usutu, a mosquito-borne virus

A DEADLY virus killing blackbirds across the UK shows that mosquito-borne viruses are spreading to the country, in part due to climate change, and pose a growing threat to people.

The virus in question, Usutu, originated in South Africa in 1959 but is now widespread in Europe. It was first detected in the UK in 2020. In some areas, most notably London, blackbird populations have dropped by more than 40 per cent since 2018. "We first noticed the decline at the same time as Usutu popped up," says Hugh Hanmer at the British Trust for Ornithology.

Although devastating for birds, Usutu poses a low risk to humans. Infections are rare and tend to only cause a mild fever, but its arrival in the UK marked the first time a mosquito-borne virus that can pass from an animal to a human had emerged in animal hosts in the country. Virus experts are keeping a close eye on how far and fast it is spreading because it could be a template for other mosquito-borne diseases.

For example, West Nile virus spreads in the same way as Usutu and requires the same environmental conditions. "The same mosquitoes that can transmit Usutu typically can transmit West Nile, and the same birds which act as hosts [for Usutu] can also act as hosts of West Nile," says Arran Folly at the UK's Animal and Plant Health Agency (APHA).

Humans can be infected by West Nile virus from a mosquito bite. Around 20 per cent of those infected will experience

> **"The same mosquitoes that can transmit Usutu to birds can typically transmit West Nile"**

symptoms, which include fever, headache, vomiting and diarrhoea. In rare cases, the virus can be fatal. There is no known human vaccine.

Climate change has helped accelerate the spread of West Nile virus through northern and eastern Europe, as the virus thrives in warm summer temperatures. In the Netherlands, Usutu was first detected in 2016 and West Nile virus followed in 2020. UK officials fear a similar pattern, with studies demonstrating that the climate there is becoming increasingly hospitable to mosquito-borne viruses. "The idea is that, if we have Usutu here, West Nile is probably going to come at some point and is likely to persist, given the right conditions," says Folly.

In response, APHA launched a project in 2023 to track the emergence and transmission of Usutu and other mosquito-borne viruses in wild birds. This virus-tracing infrastructure will be vital if the country is to respond quickly to West Nile's arrival, says Folly. "Our real goal or drive, from a governmental point of view, is to be able to detect these [new viruses] circulating in animal populations before we get transmission to humans."

Reina Sikkema at Erasmus University Medical Center in Rotterdam has been studying Usutu and West Nile virus in the Netherlands. Although West Nile hasn't been detected since 2022, she believes the virus is circulating at a low level, kept in check currently by the country's relatively cool climate. "I believe it is present, but it needs the right circumstances to flare up."

A UK detection of West Nile is now all but inevitable, says Sikkema. She believes similar climatic factors could prevent it spreading widely for now, but rising summer temperatures, including more nights with temperatures that remain above 20°C (68°F), could change the picture in northern Europe in coming years.

Mind

Do we all see red as the same colour? We finally have an answer

Sophie Berdugo

A NEW investigation into the long-standing philosophical question of whether we all see colour in the same way has provided the strongest evidence yet that, yes, people with typical colour vision do indeed share the same subjective experience of colour.

Putting our subjective conscious experiences into words is notoriously challenging, making it hard to directly compare how our reality lines up to someone else's, but researchers have previously tried various tricks to get around this.

One technique, known as the relational approach, is to ask people to consider the relationship between concepts – for example, most people consider red to be the opposite of green. "Our experience of red is somewhat characterised by the relationship between the other experiences," says Masafumi Oizumi at the University of Tokyo in Japan.

Previous studies using this approach asked people to rate the likeness of pairs of colours, and then mapped these colour relationships, labelling the position of each colour. Comparing these positions – under the assumption that one person's red will align with someone else's – provides some information about how we perceive colour, but, crucially, it cannot fully rule out the possibility that one person's red could be another person's green, says Oizumi.

In an attempt to do so, Oizumi and his colleagues asked 683 people to rate the similarity of pairs of colours drawn from 93 unique shades, varying slightly in hue, lightness and saturation, using an eight-point scale.

PAUL QUEZADA-NEIMAN/ALAMY

Around a third of the participants were colour-blind, mostly red-green, allowing the team to compare their experience to that of people with typical colour vision.

The team then created a map of the similarity ratings from each participant but, in a new step, they didn't label the colours on this map. Using a computer model, the researchers randomly combined the maps from different participants, teasing out relational structures not explicitly linked to colour.

93

The number of unique shades of colour used in the study

Despite this, the team found that, at the group level, people with typical colour vision share the same relative colour structure as one another (*iScience*, doi.org/n9pn). Oizumi says that this means other mappings, including an inverted colour experience, are implausible. More studies are needed to decisively disprove the idea of inverted colour experiences, says team member Nao Tsuchiya at Monash University in Melbourne, Australia, "but we know we are going in that direction".

Our colour vision may be more similar than we think

The same was also true for the colour-blind participants, despite them having differing degrees of red-green colour-blindness. The colour structures were also broadly similar across all of the participants, although the experiences of red and green were much closer together for the colour-blind individuals, suggesting – as we might expect – that they see these colours as more similar than people with typical colour vision.

Because the team's model works by matching based on similarity structure alone and not by trying to align predefined labels, the findings are much more robust, says David Bimler, an independent researcher, previously at Massey University in New Zealand. "It's a positive result that hasn't been built into things on the sly," he says. ▮

Health

Norovirus vaccine could offer lasting immunity

Carissa Wong

AN EARLY trial of a norovirus vaccine pill has shown promise, with researchers saying it could be available for use in a few years.

The virus, also known as the winter vomiting bug, is highly contagious, infecting the stomach and intestines, causing sickness and diarrhoea. Most people recover in days, but it can be more serious for very young and older people.

So far, efforts to develop a vaccine have failed. That is partly because of a focus on injectable vaccines, which are less good at generating protective antibodies in the intestine, where the virus replicates, says Sean Tucker at biotech company Vaxart in San Francisco, California.

To address this, Tucker and his colleagues developed an oral norovirus vaccine that delivers a protein from the GI.1 norovirus variant into the intestine. An initial trial in adults under 50 found that the pill could generate norovirus-specific antibodies in their guts.

Now, the researchers have tested the vaccine in people aged between 55 and 80. The team gave 11 of them the pill while 22 others took a placebo. About a month later, they collected blood and saliva samples, and found the people who took the vaccine had higher levels of IgA antibodies, which can block norovirus from entering cells.

These antibodies had increased by more than 10 times in their blood and around seven times in their saliva, compared with pre-vaccination samples, while the placebo group saw little change (*Science Translational Medicine*, doi.org/n9pc). The antibodies were still present six months later, albeit at lower levels, meaning it could offer lasting immunity.

"If everything went smoothly, with no funding hiccups, a vaccine might be available in a couple of years," says Tucker. ▮

Space

Black hole merger flies through space

This cosmic collision may explain why black holes at the centre of galaxies grow so large

Alex Wilkins

A RARE collision between two supermassive black holes (SMBH) appears to have sent the resulting merger speeding through the universe, making it one of the fastest-moving black holes we have ever seen.

Astronomers have long puzzled over how the gargantuan black holes at the centres of galaxies can grow to be so large. One possible route is for smaller – but still extremely massive – black holes to merge together, but there has been little direct evidence of this happening.

"The supermassive black hole was around 33,000 light years from where it should be"

Now, Marco Chiaberge at Johns Hopkins University in Maryland and his colleagues say they have found evidence of a supermassive black hole in a galaxy called 3C 186 that has been kicked out of its galactic nesting spot, rocketing away at more than 1000 kilometres per second (arXiv, doi.org/n9n2).

Astronomers had previously observed the galaxy using the Hubble Space Telescope and found that its quasar, the powerful light given off by its central black hole, was out of place. By studying the distribution of stars in the galaxy, they realised the SMBH was actually around 33,000 light years away from the galactic centre, where it should be. This implied the black hole had been forced out of line by some unknown event, like a merger.

Chiaberge and his team used the Very Large Telescope in Chile and the Subaru Telescope in Hawaii to analyse the light given off by the black hole more carefully. They found the light coming from its accretion disk, where matter orbiting the black hole is violently heated, was blueshifted, an effect from general relativity that changes the colour of light when something is travelling extremely quickly towards the observer.

NASA GSFC

The light given off by the supermassive black hole in the galaxy 3C 186 is surprisingly off-centre

However, the gas in the surrounding region showed less sign of being blueshifted, implying the black hole is moving relatively more swiftly than the rest of the galaxy.

The researchers argue the most probable explanation is two galaxies combined and their central SMBHs smashed together to form a single larger one. This merger would have produced ripples in space-time called gravitational waves that travelled out in one direction, while the newly formed black hole recoiled the other way.

"The evidence for a recoil kick appears strong and, while there is never certainty in astrophysics, this is convincing," says Alessia Gualandris at the University of Surrey, UK.

Luke Zoltan Kelley at the University of California, Berkeley, says that while the source is one of the better candidates for a supermassive black hole merger, it is less convincing because of the difficulty in interpreting the light coming from the region around SMBH, called the active galactic nucleus (AGN).

It is not unusual for AGNs to appear to be moving quickly even if they haven't merged, so we can't take that as definitive evidence for a recoiling SMBH scenario, he says – much more careful modelling will be required to confirm. ▮

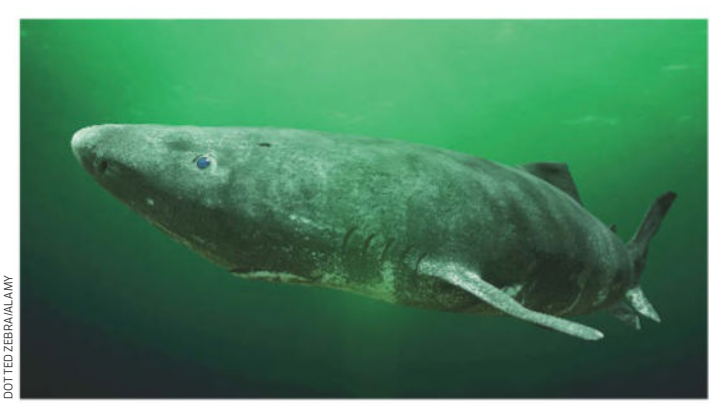
Zoology

The secret of how Greenland sharks can live cancer-free

A GENOMIC study may have revealed why Greenland sharks rarely get cancer.

These animals (*Somniosus microcephalus*), which can grow to be more than 6 metres long and weigh over a tonne, have an estimated lifespan of 400 years or so, making them the longest-living vertebrates that we know of.

To shed light on how they live so long without frequently developing tumours, Shigeharu Kinoshita at the University of Tokyo in Japan and his team have sequenced a Greenland shark's genome, uncovering the genes in each chromosome. They estimate their sequenced genome is 86.5 per cent complete, with about 37,000 genes identified so far.



DOTTED ZEBRA/ALAMY

Greenland sharks are slow-moving dwellers of the deep

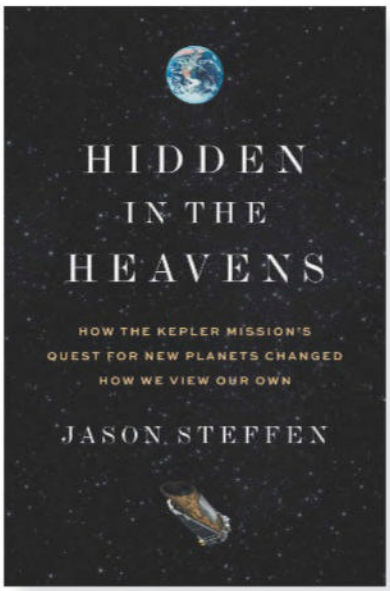
The researchers found a higher number of copies of genes involved in activating the NF-κB signalling pathway – which is a chain of cellular processes – than are seen in other shark species (bioRxiv, doi.org/n9np).

This pathway is active when the body's immune system responds to threats, and disruption of it can lead to tumour cell proliferation.

"Since immune responses, inflammation and tumour formation significantly affect ageing and lifespan, the increase in genes involved in NF-κB signalling might be related to the Greenland shark's longevity," says Kinoshita.

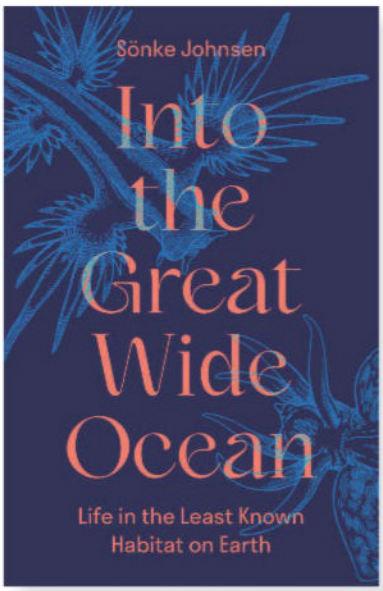
A high number of genes related to NF-κB signalling was also reported recently in red sea urchins (*Mesocentrotus franciscanus*), which can live for more than 100 years. ▮

Chris Simms



"An exceptionally granular view of the entire Kepler Space Telescope mission."

—Douglas G. Adler, *Ad Astra*

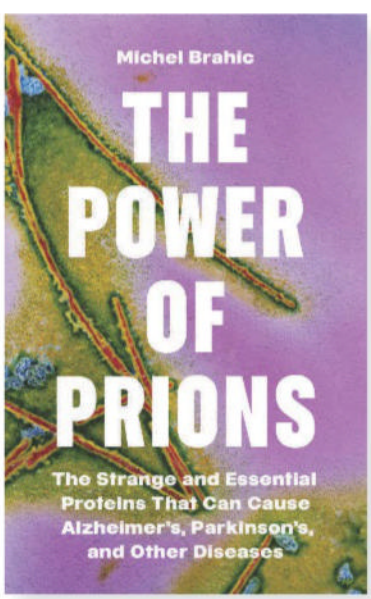


"This book will feed your curiosity, introduce you to the denizens of the deep and make you laugh. Dive in!"

—Karen Osborn, *Smithsonian Magazine*

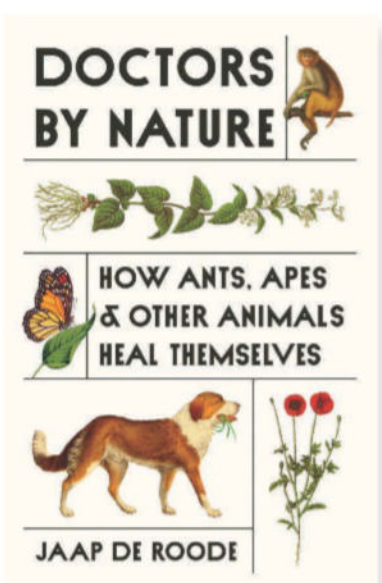
"An engaging discussion of the history of mathematical notation and symbols and the mathematicians who invented them. A great read."

—Oscar E. Fernandez, author of *Calculus Simplified*



"Brahic provides a thorough history of prion proteins that delves beyond their well-documented role in neurodegenerative diseases."

—Francisco J. Rivera-Rosario, *The Transmitter*



"An exceptional book investigating the myriad ways in which diverse animals across taxa self-medicate."

—David Gascoigne, *Travels with Birds*

"An engaging, accessible, and novel take on the normal and inevitable fallibility of human conscious memory."

—Jonathan Lee, University of Birmingham

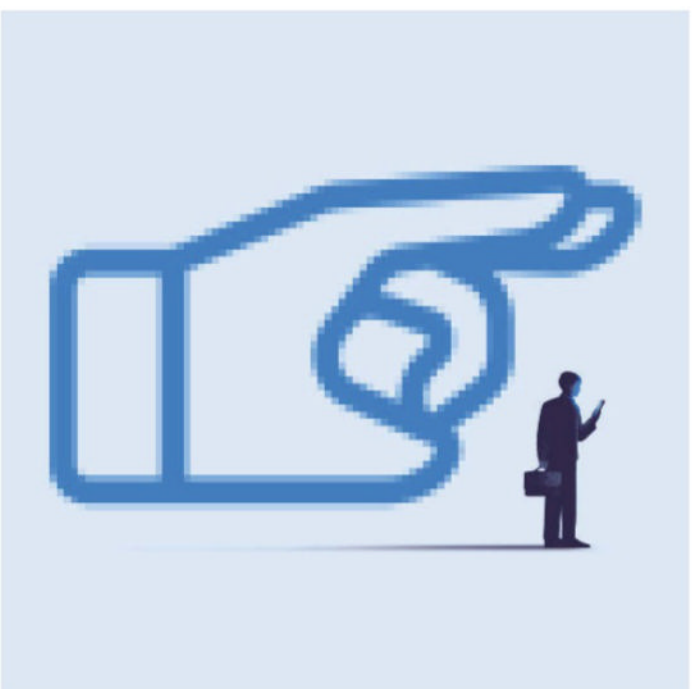
Views

Comment

Click, like, share?

Whether social media sites police their platforms using humans or algorithms, content moderation offers little safety, says **Jess Brough**

SINCE Meta announced an end to third-party fact-checking, claiming it was freeing itself from "societal and political pressure to moderate content", social media users have questioned the value of content moderation. Is it an important tool for protecting the safety and efficiency of a platform, or a systematic method of censorship? In my view, content moderation merely represents a broken system – the insatiable requirement of human sacrifice for the sake of technological advancement, and its use as a veil to obscure the profit-driven motives of social media companies.



ADRIÀ VOLTÀ

Content moderation has been embedded in the legal framework of online platforms for decades, as a way to prevent harmful behaviours from spreading on these sites, whether it is hate speech or exploitation. With platforms beginning to favour algorithmic detection over human-powered content moderation, feedback has focused on job losses and the potential harm posed by inefficient systems.

These concerns are well-placed: platforms that rely more heavily on algorithms are banking on computational capabilities that simply don't exist yet to accurately detect complex behaviour and meaning. Using large language models to determine the difference between humour and offence, for example, is complicated by the fact that this distinction is subjective and hinges on shifting social norms. Many users have weighed up these risks, along with the redundancies, and have concluded that human-based content moderation must be valued and sustained – these are the people who keep us safe.

However, we often forget there is collateral damage tied to this semblance of security. Moderators are subjected to images and information the majority of us can hardly imagine. The "content" they engage with can include anything from insulting language to videos of graphic beheadings and child sexual abuse. They are seeing content like this day in, day out – often for hours on end – as part of their labelling assignments. We, the users, are somewhat shielded from this information, but only after it has traumatised often low-paid and vulnerable workers.

These jobs are already undercompensated and underappreciated; now, social media platforms like TikTok, Meta, and X are choosing to invest even less in their workforce. In doing so, they reveal something crucial about these sites that have come to demand so much of our time. When it comes to profitability, a safe and happy user base is no match for the immense potential to harvest data. The risks of poor content moderation – whether we see unsavoury images and text, or whether we are victims of online bullying – are only compounded by how much of ourselves we are already freely revealing.

For many sites, content moderation already involves both human and algorithmic labelling. As modelling develops, those algorithms will become more sophisticated, theoretically improving the user experience. But we must remember that behind social media platforms are profit-driven companies, and whatever is categorising our data, the implication remains the same: these firms collect an astronomical amount of information about us and the people with whom we interact, and they can use that information in almost any way, at any time.

Big Social Media has become so essential to our daily lives and our work that not only have we been willing to ignore the disenfranchised workforce behind the machine, we have also accepted our own vulnerability to influence and exploitation. Advancements in algorithmic moderation will not save us; they will only enable us to give more of ourselves away. ▮

JASON CAMERON

Jess Brough is a psycholinguist and researcher of language biases

Future Chronicles

Not to be sniffed at

By the mid-21st century, many people were opting for a "nose job" that would give them a sense of smell as good as a dog. **Rowan Hooper** tells us how we got there

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

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

IN THE olden days, a "nose job" referred to a cosmetic surgical procedure to improve the shape of someone's nose. By the mid-21st century, it signified the "super smell" procedure whereby a person's olfactory sense was augmented and supercharged. In this case, people went from having the standard human number of 6 million olfactory receptors in the nasal cavity, to over 100 million, the average in a canine nose. Human sense of smell became equivalent to that of a dog.

This wasn't without its challenges. The transition from a standard sense of smell to one on a par with a bloodhound had to be carefully orchestrated. Post-op, supersniffers could detect the stress levels of people around them, the menstrual status of women, the food people down the road were eating, what those nearby had eaten yesterday, the cleaning products used and even the growth efficiency of plants. For this reason, new supersniffers were isolated in smell-deprived clean rooms and only gradually exposed to more and more olfactory stimulants.

The operation to achieve this was far more involved than cosmetic surgery. A person's nose was removed, scraped of internal tissue and refilled with a transplant of their own stem cells. These were programmed to differentiate into olfactory cells and repopulate the inner shell of the nose. When the nose was reattached, neural stem cells grew and connected to the olfactory bulb at the base of the forebrain.

Most people were happy to accept a slightly more bulbous nose than before, enlarged to accommodate the augmented sense. Some people elected to receive a significantly larger nose in order to achieve a higher level of smell superpower. A minority went "full dog" and chose a wet nose modified to produce more mucus, which in dogs is used to trap scent particles and improve their sense of smell.

The critical period was the growth of the olfactory receptor neurons and their integration with the brain. Patients were given drugs that temporarily increased their neural plasticity. This refers to the way the brain rewires itself as we learn new skills, such as when we get to grips with riding a bike. Work in the mid-2020s had shown that the brain is readily adaptable and able to accommodate new sensory input.

> **"A subsection of those having nose-jobs did, it is true, succumb to bottom-sniffing greetings, as seen in dogs"**

Once the new smell cells had integrated with the nervous system, the brain was retrained by exposure to ever-increasing levels of olfactory stimulation. Post-op patients were given bland foods and gradually built up to richer, smellier fare.

The reasons people underwent nose-augmentation were varied. Many did so in order to improve their ability to do their jobs. Chefs with super-smell became famous for the exquisite dishes they created. Detectives found their assessment of crime scenes and interrogation of suspects went to another level. Like dogs, they could determine the passage of time since someone had picked up an object or walked across a room, because they could assess the reduction in chemical odours that had occurred over time. In politics, negotiations became more subtle and successful. With augmented smell, a diplomat could determine if their opposite number was fearful, confident or aggressive. Lying could be easily detected.

Ecologists with augmented smell found they could sense the health of symbiotic relationships in soil, especially those between fungi and plants, and the levels of herbivory, decomposition and growth in local environments. As a result, they were better able to direct ecosystem restoration efforts. They could also sniff out truffles.

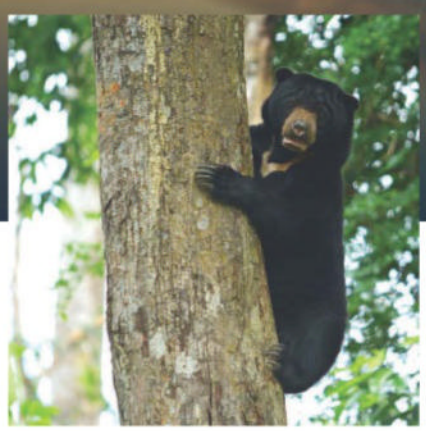
Not everyone used their new abilities for higher purposes. A subsection of nose-job humans did, it is true, succumb to the bottom-sniffing greetings seen in dogs. But most focused on more thoughtful applications. Caregivers with this sense were particularly effective. Doctors and nurses could understand the mental and physical state of their patients far more accurately, and adjust their approach accordingly. Preventative medicine improved too. Just as dogs could be trained to detect early cancer, covid-19, malaria, Parkinson's disease and more, smell-augmented people helped detect health conditions at the earliest stages, when they were more treatable.

And yet, as the benefits of augmented smell became more widely appreciated, many people had nose jobs just to experience life more deeply. Emotional intelligence increased as we became more aware of each other's inner lives. As artificial intelligence infiltrated more and more of our lives and activity, the augmented sense was seen not as dog-like, but as an ultra-human modification. It opened doors to a world of experience and feelings that AIs didn't have access to; it made us more alive. ▮

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

Discovery Tours
NewScientist

Embark on a thrilling journey of scientific discovery

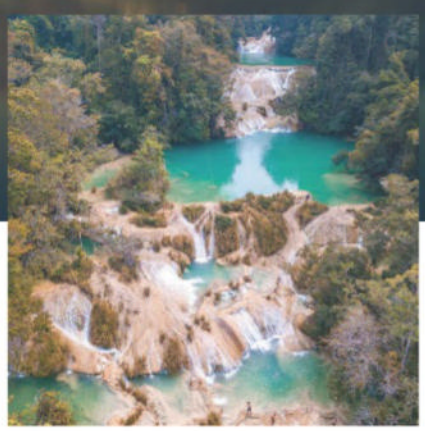


The science of primary rainforests and wetlands: Malaysian Borneo

10 August 2025
10 days

Discover Malaysian Borneo's amazing flora, fauna and geology. Explore primary rainforests and wetlands, including the iconic Kinabatangan river, Tabin rainforest and Danum valley. Visit innovative conservation projects and see how critical species and their habitats are being rehabilitated and safeguarded. Search for orangutans, sun bears, proboscis monkeys, gibbons and many more iconic species in their natural surroundings.

- Enjoy wildlife safaris, cruises, treks and evening walks through pristine and undisturbed tropical rainforest
- Stay in secluded lodges and nature resorts nestled deep within lush forest reserves
- Throughout this tour, you will be accompanied by Martin Cohen, an experienced naturalist who will share fascinating insights into the behaviour, habitats, and conservation of the species encountered



Archaeological wonders of the Maya: Mexico and Guatemala

15 September 2025
10 days

Immerse yourself in the captivating world of the Maya as you explore key archaeological sites in Mexico and Guatemala, piecing together the fascinating history of this ancient civilisation. Discover the society, science and history of the Maya as you visit the ruins of once-great cities across the Chiapas state of Mexico and the Petén region of Guatemala.

- Explore the key Maya archaeological sites of Tenam Puente, Chinkultic, Palenque, Yaxchilán, Bonampak and Tikal, each telling an important piece of the civilisation's fascinating story
- Marvel at some of the best-preserved murals at Bonampak and the astounding architecture and carvings at Yaxchilán
- Spend time on the charming island of Isla de Flores, just on the shore of Lake Petén Itzá, with its cobblestone street and artisanal local shops

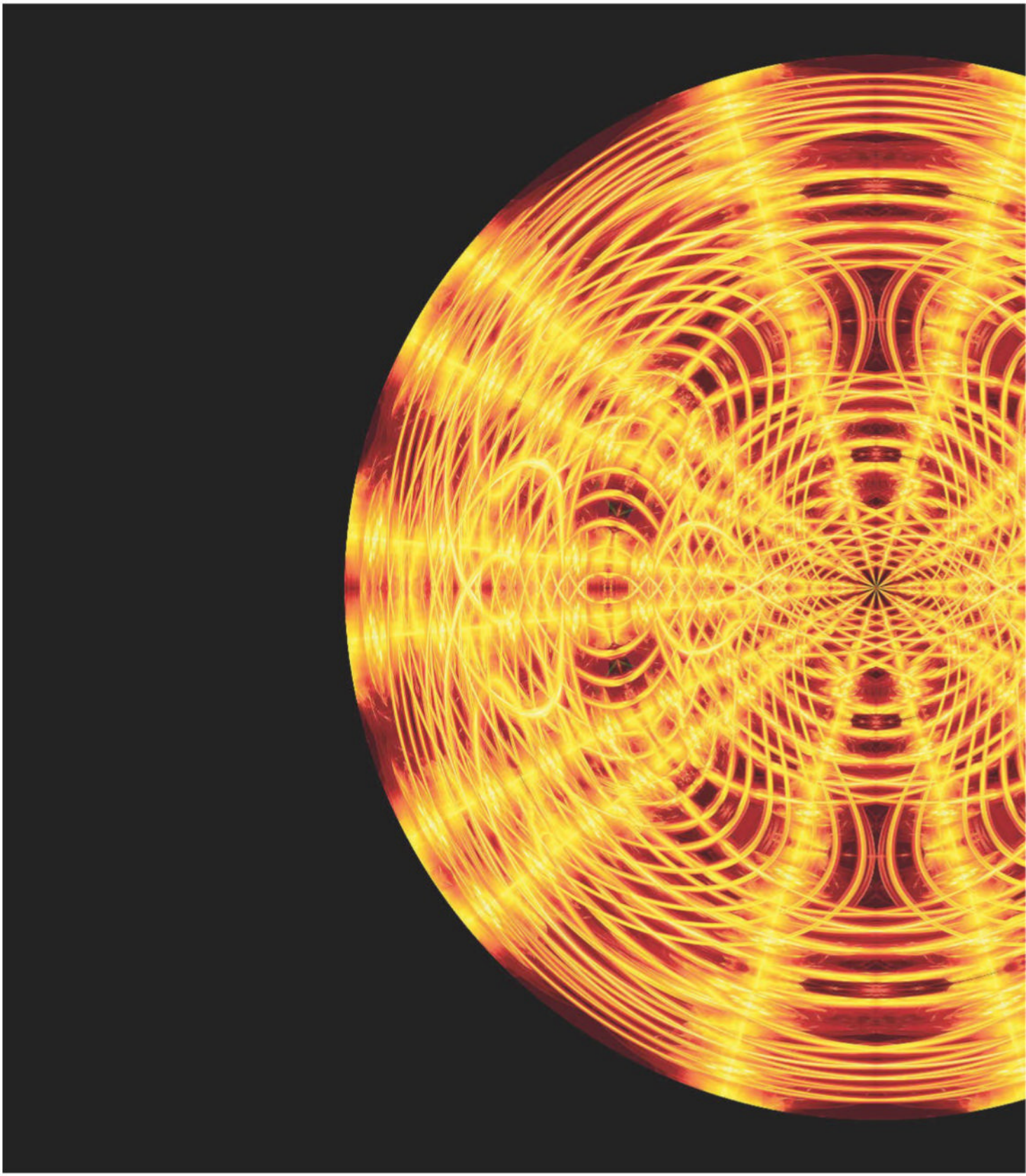
The science of nature from Tokyo to Okinawa: Japan

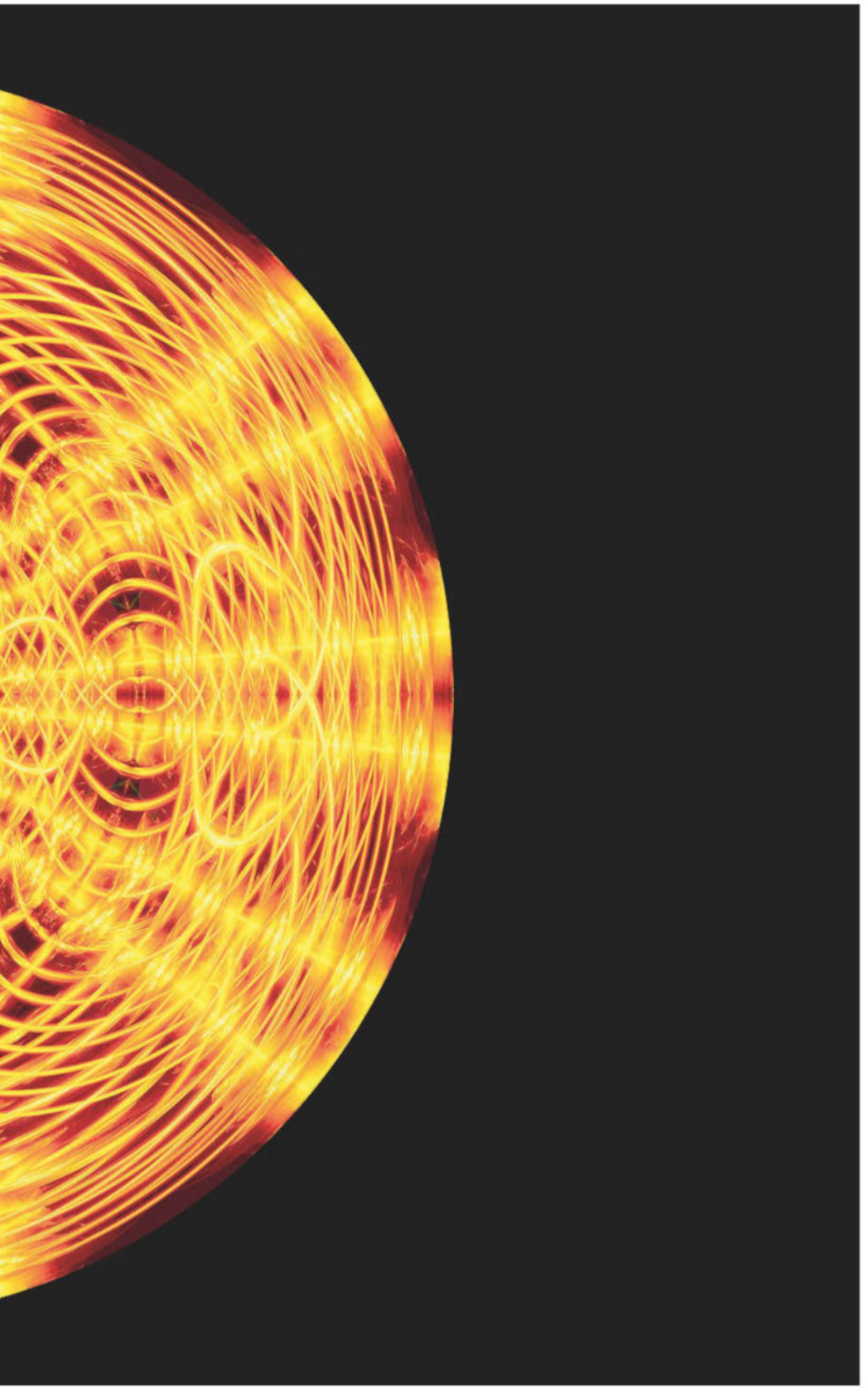
24 September 2025
11 days

Embark on an unforgettable journey to discover Japan's natural wonders. Learn how Japan is leading the way in integrating science with natural preservation, including developing innovative environmental technologies and wildlife conservation. Japan provides an unparalleled environment for exploration, conservation and discovery.

- Enjoy private tours of Tokyo's National Museum of Nature and Science and Miraikan Museum of Emerging Science and Innovation
- Travel to Okinawa's picturesque islands, known for their crystal-clear waters, coral reefs and unique tropical ecosystems
- Throughout this tour, you will be accompanied by *New Scientist*'s Rowan Hooper, who has a PhD in evolutionary biology and worked as an insect biologist in Japan

Find out more at
newscientist.com/tours





Blast zone

James Stanford
Smallworks Press

THE kaleidoscopic patterns in this artwork draw the eye towards its glowing centre. Despite its dreamy, hypnotic effect, however, the work has its roots in the terrifying reality of a nuclear bomb.

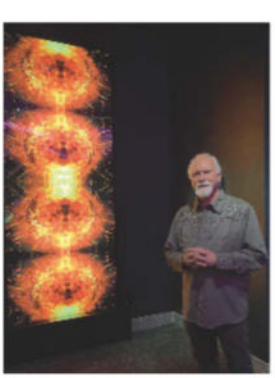
Its creator, artist James Stanford, grew up in Las Vegas, Nevada, near where more than 200 above-ground nuclear tests took place in the 1950s and 1960s. His new interpretive photography series, *Atomic*, draws from both the nuclear landscape of his childhood and his time as a technical illustrator for the US Atomic Energy Commission.

The main image is *Nuke Image Circle, 2024*. Below, Stanford is shown beside *Spectre Fission*.

"With the *Atomic* series, I was trying to show both the spectacle and the horror of the atomic bomb," he says. A new book, *The Atomic Kid*, brings together 21 of these pieces, while four feature in a new exhibition at the Atomic Museum in Las Vegas.

Mushroom clouds from bomb tests "enhanced the amazing sunsets and purple mountains of the Mojave Desert" as he grew up, Stanford writes in the book. Three times, atomic tests cracked the windows of his house when he was a child.

Alison Flood



Are we really doomed?

Few people could act as a genial, even humorous, guide to humanity's existential crisis. Henry Gee can, discovers **Rowan Hooper**

Book

The Decline and Fall of the Human Empire
Henry Gee
Pan Macmillan
UK: Available now
US: 18 March

SHUTTERSTOCK/LIU ZISHAN

WE'RE doomed, says Henry Gee, doomed! *Homo sapiens* is reaching a crest, after which our global population size will start to drop. In his new book, *The Decline and Fall of the Human Empire: Why our species is on the edge of extinction*, Gee's mission is to trace the path from our genesis to our peak, then on to our quite possible annihilation.

When *H. sapiens* evolved about 300,000 years ago, we were surrounded by relatives. At home, in Africa, we lived alongside *H. naledi* and *H. heidelbergensis*. In Europe, when we reached it, there were the Neanderthals; in Asia, the Denisovans.

We may well have overlapped with other human species that are as yet unknown. While our sister species went extinct, not only did we flourish, we grew to dominate the entire planet. Why, asks Gee, did we, out of all the other human groups, do so well?

His answer is population size. Eventually, after several brushes with extinction ourselves, we started growing in number. Instead of ideas being lost, they stuck and were developed. Technology and culture exploded. When there are villages of several dozen people, cave painting becomes a possibility. When you have a civilisation of billions, flying to space becomes a probability. It's why there is a gap of only 66 years between the Wright brothers' first powered flight in 1903 and the moon landing in 1969.

So much for the boom – now for the bust. Gee uses Edward Gibbon's classic work *The History of the Decline and Fall of the Roman Empire* as a framing device. Gibbon's point is that once Rome had conquered all its enemies, the empire started to rot.

And so, too, with us, warns Gee. Once we had seen off all the other human species, the clock on our own extinction started ticking. It doesn't help that the human population also passed through numerous bottlenecks (one seeing the population drop to some 1300 individuals nearly a million years ago) and that these stripped us of much of our genetic variation.

"Elon Musk has said he wants to help make *Homo sapiens* into a multi-planet species"

United Nations projections suggest that the world population will peak at just over 10.4 billion in 2086, then fall. One contributory factor, writes Gee, is the worldwide decline in sperm count over the past few decades, possibly due (among many things) to gradual exposure to the pollutants created by fossil fuels. Great. If Big Oil doesn't wipe us out through climate change, it may help do so through effects on infertility.

Gee's scholarship is impeccable and lightly worn. He was the winner of the Royal Society science book prize in 2022 for his *A (Very) Short History of Life on Earth: 4.6 billion years in 12 chapters* and has, for some decades, been an editor at the journal *Nature*.

The Decline and Fall of the Human Empire is hugely informative and entertaining – if your idea of entertainment is being constantly reminded of the precipice we are approaching as a species. But I can't think of another author who could pull off Gee's straight-talking, detached-yet-jovial style. He is such an amiable guide to our doom.

That tone changes in part three when Gee attempts a Hollywood-style happy ending, because, unlike the Romans, he says, we have the chance to escape. He argues that expanding off-planet in the next 100 to 200 years is our only chance of long-term survival as a species.

The future of Earth looks bleak, but we have the capacity to change course

The late physicist and cosmologist Stephen Hawking claimed something similar in an episode of *Tomorrow's World* in 2017, saying we had 100 years to find a new home, revised down from his earlier estimate of 1000 years. Elon Musk, too, has said he wants to help make *H. sapiens* a multi-planet species.

They may all be right. But as much as I enjoy the science fiction idea of colonising space, I feel that it opens the door to doomerism and defeatism. We have to put all our energy into transitioning to a sustainable world on this planet – and then we can look to expand.

Both outcomes are still possible: a sustainable future on this planet and expansion to other worlds. Gee shows how much of our success thus far has been down to luck, but we can't rely on that to get us much further. ▮

Science, a quantum art

A powerful collaboration of artists and quantum physicists sets out to make the intangible tangible, finds **Thomas Lewton**

Exhibition

Cosmic Titans
Djanogly Gallery
University of Nottingham, UK
Closes 27 April

FOR MANY, art and science are still seen as distinct approaches to understanding the world around us. While qualities like intuition or creativity are integral to both practices, the rules they play by are quite different. Artists tend to ask subjective, open-ended questions whose answers depend on your perspective. On the other hand, scientists combine reason and experimentation in the hope of uncovering a common, objective view of reality.

***Cosmic Titans: Art, science and the quantum universe*, an immersive exhibition at the Djanogly Gallery at the University of Nottingham, UK, challenges this entirely. The installations emerged from years of collaboration between nine artists and leading quantum research labs across the UK. These works don't just reflect scientific ideas, they also offer new understandings that directly contribute to research.**

The exhibition originated in physicist Silke Weinfurtner's "Gravity Laboratory" at the University of Nottingham. She builds tabletop experiments that corral water or superfluid helium into specific configurations that mimic the behaviour of black holes and the primordial universe.

These extreme physical systems are too far away in space and time for direct experiments, so exploring analogues gives Weinfurtner tangible insights into their behaviour – as the mathematics that underpins both is the same.

In one installation, *An Early Universe*, artist Alistair McClymont takes similar fluid systems and makes them even more palpable. A large bass speaker placed in a dark room agitates a dish of water as it sweeps through a range of low frequencies. Next, a strobe light projects mathematical patterns created by the sound waves onto a wall. Because our bodies are mostly water, the bass vibrates inside us, too. As the patterns on the wall shift from order to chaos, you feel a peculiar sensation that mirrors what you are seeing. And, as a bonus, collaborating with McClymont led Weinfurtner to find new optical methods that use strobe lights to measure fluid systems in her lab.

Other works on display also seek to make the intangible, tangible. *The Quantum Lens*, for example, is a mixed-reality experience exploring counterintuitive quantum ideas. Projections inside a VR headset allow you to grapple with material reality in a new way, making some sense of how many possible worlds may collapse into the single one we experience.

Another installation, *Ringdown* by Conrad Shawcross (pictured), explores the final moments of two spiralling black holes: two bronze spherical bells orbit each other in a giant cage crammed with vibrating steel rods. Listening to the eerie sounds that ensue brings you closer to these cataclysmic events – astrophysicists who study the gravitational waves emitted by colliding black holes have recently started doing much the same by listening to their data.

All of this highlights the role that observers play in both art and science. At its opening, *Cosmic Titans* curator Ulrike Kuchner said: "Art challenges you to take a position. As an audience, you complete the artwork with your own memories, your own emotions, and with your own personal context – something science rarely does."

Fundamental physics especially tries to strip away the personal and offer an objective perspective. Yet recent advances into the foundations of quantum physics suggest that reality isn't absolute and objective, but rather comes about through negotiating the perspectives of different observers.

Ultimately, as *Cosmic Titans* reminds us, there are deeper truths underlying science and art. Not least that objective reality is an illusion.

Spiralling black holes are captured by two bronze, spherical bells that orbit each other in a giant cage

UNIVERSITY OF NOTTINGHAM/NICK DUNMUR

New Scientist *recommends*

Matthew Sparkes
Reporter
London

I cherish idiosyncratic museums: the more unusual, esoteric and single-minded the better. Spying **Dinosaurland Fossil Museum** while fossil-hunting in Lyme Regis, UK, I had to visit.

The museum, run out of a Grade I listed church by a former oil company palaeontologist, promises "no flashy bits" – and delivers. Handmade cabinets hold over

20,000 specimens, from a hoard of local fossils to an eclectic global mix – including a 73-kilogram lump of dinosaur dung.

There are also models of dinosaurs, aiming for accuracy, but which, the museum admits, prioritise "ambience". The last room, for example, is full of delightfully poor taxidermy.

My highlight was the tall Saurian (pictured). This is the museum's take on what might have been if dinosaurs had survived and evolved to stand upright, develop dextrous hands, large brains and possibly even language.

It bears more than a passing resemblance to **Star Trek**'s Gorn and must not be missed.

MATTHEW SPARKES

The battle for education

The odds are stacked against an all-female robotics team in *Rule Breakers*, a terrific drama about girls' education in Afghanistan, finds **Katie Smith-Wong**

Film

Rule Breakers

Directed by Bill Guttentag

US: Out now

UK: Released 25 March

TIME magazine named Roya Mahboob among the 100 most influential people in the world in 2013. She was the first Afghan woman to be CEO of a technology firm, having founded the Afghan Citadel Software Company in 2010. She is also co-founder of the country's all-female robotics team for girls aged 12 to 18, called the Afghan Dreamers.

This is the focus of *Rule Breakers,* directed and co-written by Bill Guttentag. It tells the story of Roya (played here by Nikohl Boosheri), who was prevented from following her interest in computers at school because she was a girl.

Faced with the disparity in secondary education between girls and boys in Afghanistan, Mahboob later set out to extend computer classes to girls across the country. In 2017, she formed the Afghan Dreamers to showcase the possibilities of tech for girls and women via global robotics competitions.

When the Taliban gained power in Afghanistan in 2021, it became the only country to ban education for girls aged 12 and over. In mid-2024, UNESCO reported that 1.4 million Afghan girls had since been denied secondary education.

In addition, female teachers have been banned from teaching boys and many have lost their jobs. With the humanitarian organisation Afghanaid reporting that 82 per cent of Afghan women had deepening feelings of anxiety, isolation and depression in 2024, the education ban is one of several factors that not only prevent women from becoming working professionals, but confine them to being housewives and mothers.

In *Rule Breakers*, Guttentag and co-writers Jason Brown and Elaha Mahboob, Roya's sister, chronicle a journey of self-discovery by women who wish to win against the mounting odds against them. That group comprises Mahboob, who is committed to broadening horizons for Afghan girls and women, and several girls who each defy their sceptical and traditional guardians to find their voices, confidence and success.

As the film unfolds, the young team is increasingly exposed to the world and new possibilities – which wouldn't have happened without Mahboob's insistence.

> **"In mid-2024, UNESCO reported that 1.4 million Afghan girls had been denied education"**

Although she is an integral part of *Rule Breakers*, her software company and work on expanding girls' computer classes quickly play second fiddle in the film to the creation of the Afghan Dreamers. Several time jumps chart Mahboob's experience with computers from childhood to adulthood, yet it is hard to gauge how tech captured her interest.

Even so, Boosheri plays Mahboob with quiet conviction, consistently rising above adversity to spread her message internationally. The opening scene sees her address a group of young women. She tells them: "Girls are not free in life, but they are on this," pointing at a laptop. As for the judgement they fear from their parents, Mahboob adds: "This is no longer our fathers', our grandfathers' Afghanistan – this is our Afghanistan too, our time."

The supporting cast, especially the young actors portraying the Afghan Dreamers, offer emotion and enthusiasm in their performances. We see their spirits lift when they discover something new, such as ideas for inventions or how to conquer their own insecurities.

Like Mahboob, they don't cower in fear in trying times, whether this is when they are denied visas to enter the US in 2017, or during a suicide bombing in Herat that ultimately killed Mohammad Asif Qaderyan, father of the team's captain, Fatemah Qaderyan. The use of these real-life events in the narrative reinforce Afghanistan's sociopolitical issues on a broader level, showing how women's rights in Afghanistan need to be addressed.

Making films about women in science and tech is becoming more common, from *Hidden Figures*, about the work of three of NASA's African American women mathematicians in the 1960s, to the all-female remake of *Ghostbusters,* both of which celebrate, in different ways, women striving for success in challenging times. *Rule Breakers* is another terrific example, a drama that reiterates the necessity of secondary education and the rewards that come from it. ▮

ANGEL STUDIOS

Roya Mahboob (Nikohl Boosheri), centre, with young Afghan people

Katie Smith-Wong is a film critic based in London

Editor's pick

My vote is for a future of humanoid robots

1 March, p 17

From Brian Horton, West Launceston, Tasmania, Australia

The idea that robots can be any shape, so there is no need for them to take a humanoid form, is fine for single-task robots. But to expand on the argument you mention, a driverless car won't be able to vacuum my floors, and my robovac can't wash the dishes. In fact, my robovac can't even open a door to work in the next room. However, a single humanoid robot could drive my car, use a vacuum cleaner, wash dishes and put them away, and so on. A robot with a hammer-shaped fist is handy for construction, but why not give it a regular hand so it can use a hammer, saw, drill and so on. Despite the challenge of creating such robots, I see a future of human-shaped ones that can do most tasks that we can.

Could AIs literally be rewriting history?

15 February, p 16

From Robert Jaggs-Fowler, Barton upon Humber, Lincolnshire, UK

The idea of using AI to read ancient texts raises an intriguing question: how will we know for sure that the AI is actually reading the original text and not simply engaged in its own imaginative version of creative writing?

I worry about quantum revolution's impact

15 February, p 8

From Simon Goodman, Griesheim, Germany

For many people, one of the biggest impacts of improved quantum computers will be the ability of these machines to factor multiples of large prime numbers, the basis of RSA cryptography. This and related cryptography approaches are the bedrock of internet banking and commerce. When a functional quantum computer emerges, this bedrock will turn to smoke, leaving our online bank accounts and purchases open to invasion.

Civilisation begins only with invention of drains

22 February, p 36

From Trevor Prew, Sheffield, UK

You ponder the question of when civilisation actually began. I have always viewed a key indicator of this as the advent of drainage. Disposal of human effluent and waste requires organised communities, surplus resources, management structures and a sense that sanitation is important. So, for Britain, civilisation started with the Romans, then departed, returning much later. Putting up a few stone monuments or wooden huts isn't a civilisation.

Don't linger over the list of side effects

22 February, p 38

From Geoff Harding, Sydney, Australia

Such is the power of the nocebo effect, it is arguably a mistake to read a list of possible negative side effects when you have to take a medication. When I had a covid-19 vaccine, I saw a wall poster listing possible side effects and advised the nurses it wasn't necessarily a good idea to encourage people to read it. Of course, should side effects strike, seek medical advice.

Has Samson the cat passed mirror test?

Letters, 25 January

From Avril Arthur-Goettig, Munich, Germany

Inspired by a reader's claim his cat possibly possesses theory of mind, I decided to test my own pet.

The experiment: I stand in front of a (full-length) mirror with Samson, a highly demanding 5-year-old Siamese cat, comfortably tucked under my arm. To attract his attention in the mirror, I make faces and funny noises. I then extend my other arm behind and about 20 centimetres above my head, slowly descending my index finger to poke the top of my head.

I repeat this over his head; he doesn't like it and shakes his head vigorously. After re-engaging his attention in the mirror, I repeat the whole procedure; he responds with the same head-shaking and becomes restless. Now, I repeat the process, but stop the descending digit about 6 cm above his head. He instantly looks up at my finger. (Hey, are you going to poke me again?) He seems to know it is his head in the mirror and my intent.

Prerequisites for the test: mirror; an unwavering bond of trust and affection with cat.

Beware the possible rise of 'text lung'

1 February, p 27

From Alex Bowman, Glasgow, UK

"Text neck", the abnormal force on the cervical spine while tilting the head as we scroll on a smartphone, may not be the worst consequence. Normally, while breathing, we do so deeply from the diaphragm, but when holding a device with a bent neck, we tend to breathe shallowly. Over decades, this could damage lungs. Hopefully I am wrong.

On a far-flung planet ruled by children...

1 February, p 21

From Carl Zetie, Raleigh, North Carolina, US

Ed Regis's piece on outlandish proposals for space travel reminded me of an idea that rarely seems to get a mention. Instead of sending 100,000 people, send 100 million sperm and eggs. Not only do they require few resources on the voyage, which allows for a smaller ship, they would also provide far more genetic diversity for the colony. Fertilisation and incubation on arrival could be automated. That only leaves the minor problem of raising the resulting children, which I leave as an exercise for the reader.

Look to the oceans for causes of climate chaos

25 January, p 13

From Bruce Denness, Niton, Isle of Wight, UK

What can explain atmospheric carbon dioxide at the Mauna Loa Observatory in Hawaii increasing by a record-breaking 3.58 parts per million in 2024? As well as forest fires and our failure to stop burning fossil fuels, I suggest the oceans, hitherto a big sink for taking up CO_2 from the atmosphere, have become saturated.

Time to expand the gut microbiome inventory

8 February, p 30

From David Smith, Alnwick, Northumberland, UK

As well as bacteria, archaea, fungi and viruses, any microbiome list should include protists, such as *Blastocystis* species. Although normally classed as parasites, a 2024 study linked the presence of these in the human gut with improved health outcomes, including fewer metabolic abnormalities.

Another explanation for the urinating dolphins

8 February, p 13

From Peter Borrows, Amersham Old Town, Buckinghamshire, UK

The male river dolphins urinating high into the air may simply be showing off, like children.

Want to get in touch?

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PABLO HURTADO DE MENDOZA

Fight the fatigue

A fresh understanding of how the brain assesses bodily energy levels is revealing ways to regain your inner vitality, discovers **Caroline Williams**

THERE are many mysteries in science. What is dark matter? Why are we conscious? Are we alone in the universe? But none looms larger in the mind of the average adult than this: why am I so exhausted all the time?

It is a crucial question, not least because, according to a recent analysis of data from 32 countries, as many as 1 in 5 otherwise healthy adults complain of problematic levels of fatigue. Feeling tired all the time is one of the most common reasons to seek medical attention – so much so, in fact, that medical professionals commonly abbreviate it to TATT, perhaps to save their own energy. Often, there is no obvious medical explanation for what is causing the fatigue and not much the doctor can offer beyond blood tests to rule out any obvious deficiencies.

Despite this huge burden on our collective well-being, the question of what it means to "have energy" had, until recently, attracted surprisingly little medical research. Into the void stepped the trillion-dollar wellness industry, offering no end of ways to boost our vigour with various supplements, diets and lifestyle hacks.

Now, though, scientists are taking a fresh look at what it means to feel energised – or not – and the research is revealing that how we perceive this state largely hinges on the brain's ongoing assessment of how much energy is available to our cells. This discovery is changing how we think about our general health, opening up possible new avenues to treat clinical levels of fatigue, and suggesting practical things we can all do to stop feeling like we are running on empty.

The fact that so many otherwise healthy people feel so tired doesn't seem to make sense. Many of us, at least in the West, have easy access to far more calories than we need. If feeling good were simply a matter of calories in, energy out, we would all be bursting with vim and vigour.

So why aren't we? The short answer is that the energy we can feel – our "subjective vitality" – isn't like a simple readout on a tank of fuel. Instead, it is an ongoing body-brain estimate of how much energy is available in the body and how much is already accounted for, and an educated guess of whether we have any to spare for what we need to do next.

This feeling is an example of interoception, the ability to sense signals from within the body that tell us how well we are adapting to the world. When something is off – such as when the body feels like it is running low on energy – these signals motivate us to do something to fix the problem. As I outline in my forthcoming book *Inner Sense*, the study of interoception is revealing that our feelings, emotions and motivations are built from an ongoing, constantly changing conversation between body and brain.

Seeing energy as the output of such a process explains why boosting it isn't simply a case of eating more, or shelling out on whatever supplement is currently going viral. It is about figuring out where in the body-brain conversation the signal to conserve energy is coming from, and taking action to fix the issue.

It might be a problem with energy release in the cells, or that the brain is expecting a physical or mental challenge and wants to keep something in reserve just in case. Or it could be that something, such as stress or a fight against infection, is hogging the bulk of the body's supplies. Whatever the reason, the outcome is the same – you feel lousy – but the fix required depends on the cause.

Across large portions of the world, the idea that energy is central to well-being isn't exactly new. Eastern traditions founded thousands of years ago were built on the premise that the flow of energy around the body is key to health and vitality. Western medicine, on the other hand, grew from the foundations of anatomy and physiology – things that could be seen, measured and dissected, and could be treated with drugs or surgery. Invisible forces, not unreasonably, didn't get a look in.

The Western approach to medicine has done wonders for human life expectancy, increasing it by three decades in less than a century. But it has been less successful at extending the number of years we live in good health, our so-called healthspan. According to an estimate from 2021, globally, we are living an average of nine years beyond this, in poorer health.

Go with the flow

Martin Picard at Columbia University in New York argues that it is time to change the focus of medical research away from treating disease and towards a better understanding of health. This, he believes, requires a better understanding of how energy flows through the body. "We have veered away from it because of the tools we have had with reductionist science: if you can't sequence it, if you can't see it under the microscope or measure it on an oscilloscope, then it's not an appropriate object of study," he says. "I think that's steered us away from things that are potentially useful and important."

Picard trained in a lab run by geneticist Doug Wallace, who pioneered the study of mitochondria, the cellular factories where ›

molecules from digested food are transformed into a chemical form of energy that cells can work with. One thing that soon became clear from this research is that, when mitochondria aren't working efficiently, people feel lethargic and fatigued. Picard took this finding and ran with it, establishing a new field, mitochondrial psychobiology, to explore what energy release in mitochondria has to do with how energetic we feel, and vice versa. He and others have discovered there are many reasons why mitochondria might struggle, even in otherwise healthy people, some of which are almost certainly playing into the epidemic of TATT.

Perhaps the biggest drain on energy production in mitochondria is – surprisingly – a surfeit of fuel. Energy is released in the mitochondria gradually, in a series of small biochemical steps that can't be rushed and have to happen in a certain order to avoid causing a metabolic pile-up. If too much fuel arrives at once, the mitochondria have to take a break from releasing energy so that the cells can concentrate on storing the excess for later. This leaves us with less energy, not more – at least in the short term. High-sugar diets are particularly problematic, with studies showing that they lead to inefficient mitochondria and people feeling moody and sluggish, rather than energised. Intriguingly, there is some evidence that challenging the mitochondria by drastically reducing sugar intake by adopting a low-carb, high-fat ketogenic diet may have the opposite effect.

Then there is stress, whether emotional or due to a physiological challenge like an infection or injury. According to a study by Picard and his colleagues, stress increases the rate at which cells burn through energy by 60 per cent. This is partly because mitochondria also produce cortisol, a stress hormone that sends out a signal that energy is needed to meet a coming challenge.

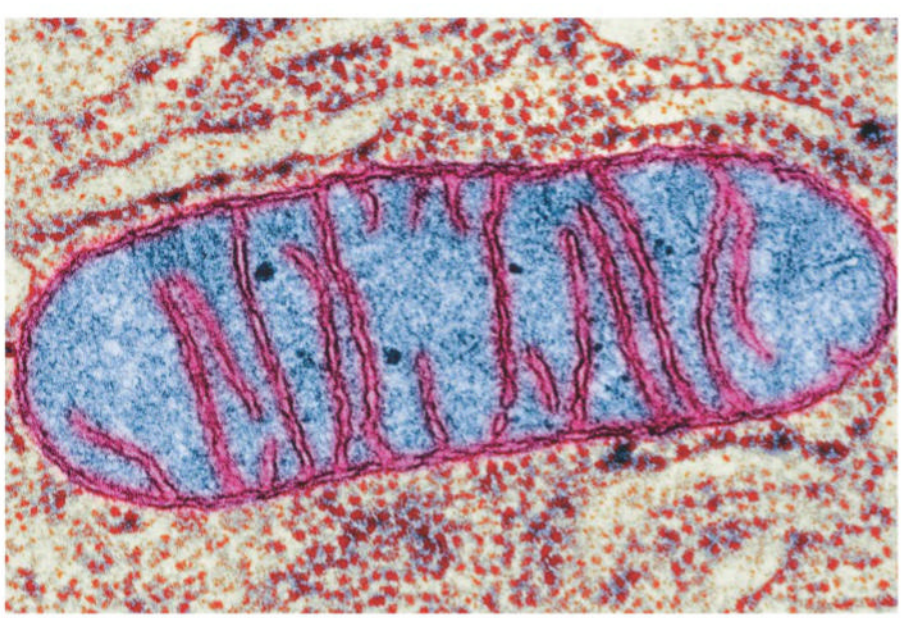
Stress isn't only literally draining, it also has broader ramifications for body-brain energy calculations. Lisa Feldman Barrett, a neuroscientist at Northwestern University in Massachusetts, coined the term "body budgeting" to describe the brain's role in managing our energy supplies in the interests of survival. She describes body budgeting in terms of predictive processing – the idea that the brain works by generating a "best guess" about what is happening in the wider world, adjusting as necessary based on incoming sensory information. When the prediction and evidence don't match, the resulting "error" signal is experienced as a feeling, whether good, bad, full of energy or in need of a nap. "We think of these as kind of like general summaries of the metabolic state of your body," she says.

"The biggest drain on your cellular energy production is, surprisingly, a surfeit of fuel"

Importantly, the brain's assessment of our metabolic state could explain why it is perfectly possible to sleep well and still feel exhausted at the thought of a long day of meetings ahead. It also explains why an unexpected piece of good news can translate into an instant energy boost. The energetic state of the body hasn't changed, but the brain's prediction of what there is to work with has transformed the situation.

Research led by Arran Davis at the University of Oxford shows how these predictions can make a measurable difference to how much energy we have to spend. When people were asked to exercise to exhaustion, those who did so in the company of a supportive friend were able to keep going for longer and to burn more calories before giving up. Davis explains this as a sign that we can dig deeper into our energy reserves when we are confident that help is at hand. "Social support signals the availability of the resources we need to recover from exercise, so we can be less cautious with our bodily resources," says Davis.

The fact that there are so many inputs into the body-brain energy assessment – some physical, some psychological and



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Mitochondria are energy-producing structures inside cells

many operating unconsciously – makes it challenging to measure objectively. But there are several candidate "biomarkers" that reflect physiological processes and the subjective feeling of vitality or fatigue.

One is growth differentiation factor 15 (GDF15), a metabolic signalling molecule that cells release when under stress. This occurs in response to infections, injury and psychosocial stress. According to Stephen O'Rahilly at the University of Cambridge, GDF15 seems to function as an all-purpose distress signal to inform the brain that it needs to conserve energy.

Another line of evidence shows that GDF15 may also explain why getting older only ever seems to make us more tired. GDF15 is a reliable marker of ageing, with levels in the blood rising by up to 25 per cent as each decade passes. Picard suspects that this, too, hinges on energy budgeting. In a recent paper, he argues that many of the symptoms of ageing, including fatigue, are due to cells accumulating damage and struggling to keep up with the energy costs of repairs. As the debris piles up, the cells send distress signals to the brain, which responds by conserving energy wherever possible. "GDF15 says there's hypermetabolism: cut costs, shrink your muscles, be a little less enthusiastic, grey your hair," says Picard. "All of these things are ways to save energy."

Meanwhile, other researchers are working on different biomarkers. In 2021, the World Health Organization convened a group of health and ageing experts to thrash out a new definition of health based not on the absence of disease, but on what they call "vitality capacity" – the body's ability to extract enough energy from food to stay in good working order. The team, co-led by gerontologist Ivan Bautmans at Vrije University Brussels in Belgium, explored several potential indicators of healthy levels of vitality, from muscle strength and blood-borne inflammatory markers to simply asking people to rate how they feel. One promising option is a simple test of how quickly muscles tire based on a handheld device that stemmed from Bautmans's PhD research, 20 years ago.

Called Eforto, it computes how long it takes someone to lose 50 per cent of their maximum grip strength while holding the device as tightly as possible. This is combined with a questionnaire about the person's current energy levels to give an overall score. The final figure offers insight into their physical and mental energy levels, says Bautmans. "It is a proxy measure that tells you whether the physiology is out of balance or getting problematic," he says. In a study of nearly 1000 middle-aged people, those with the lowest overall scores were more likely to have biomarkers of low-grade inflammation in their blood than those with higher scores. This is important because chronic inflammation is a known driver of ageing, says Bautmans. Which raises the question of whether, with enough warning and the right intervention, we might be able to slow the ageing process itself.

MARTIN PARR/MAGNUM PHOTOS

NEIL LOCKHART/ALAMY

Stress and a high-sugar diet impact the body's energy system, leading to feelings of fatigue

Get a grip

One study by Picard and his colleagues provides hope that this might be possible. He had heard anecdotal reports of grey hair sometimes starting to regrow with colour from the roots and, intrigued, recruited 14 volunteers who had experienced this for a study. This research found that stressful periods in these people's lives could be linked with the period of greying. Then, once the stress passed, the colour returned.

Picard understands this as the body-brain system temporarily diverting the energy it would normally spend on hair pigment to something more important. "And then, when you are less stressed out, maybe that frees up some of the energy budget to spend on making colour again," he says.

Of course, this doesn't necessarily mean that going grey is optional – at some point, the challenges of ageing probably make it inevitable for those lucky enough to live that long. But it does suggest that the rate of ageing may be more malleable than we think.

Seeing fatigue as the outcome of a body-brain conversation also offers a new way to understand chronic fatigue syndrome (CFS), also known as myalgic encephalomyelitis (ME), in which symptoms are notoriously difficult to explain. A better understanding of the pathways involved could help doctors focus on likely problem areas. For instance, recent studies have linked CFS to reduced blood flow that robs the mitochondria of fuel, with chronic inflammation that saps the body's reserves, and with a processing bottleneck in the brainstem, an interoceptive processing hub that has a hand in energy budgeting.

In our day-to-day lives, too, this updated view of vitality is revealing ways to tackle tiredness. One possibility is to take what Elissa Epel at the University of California calls "deep rest". Epel, who researches the psychological benefits of contemplative practices such as meditation and prayer, suggests that one reason these have been shown to enhance well-being is that they calm body and mind, reducing the perceived need to hunker down and save energy.

Diet and exercise also play an important role in our energy budgeting. Sugary snacks have been shown to crash mood and energy levels – as demonstrated in relation to mitochondria – while short periods of activity, or "exercise snacks", can do the opposite. And regular exercise forces the body to increase energy production by clearing out inefficient mitochondria and replacing them with fresh ones that work better.

Finally, it is worth keeping in mind that the people you surround yourself with affect your energy levels in a very real sense. So, no matter how much you have on your plate, and even if you occasionally fall off the diet and exercise wagon, it is good to know that our bodies and brains are wired so that, in the right company, there is usually enough energy to go around. ▮

Caroline Williams is a freelance writer based in Surrey, UK, and author of *Inner Sense: How the new science of interoception can transform your health*

Mythology-ology

The new science of myths and folktales is revealing what makes some stories run and run, finds **Laura Spinney**

ONCE upon a time, a strong, attractive hero lost one or both of his parents. He then overcame a series of obstacles and faced off against a monster that had terrorised his community. The hero vanquished the monster and was celebrated.

If this story sounds familiar, that's because it is the road travelled by Superman, Harry Potter, Luke Skywalker and countless other fictional heroes stretching back centuries. Its enduring appeal has puzzled researchers for nearly as long. However, in recent years, the study of storytelling has been revitalised, as linguists, psychologists and experts in cultural evolution have begun probing the subject using large databases of myths and folktales, powerful algorithms and an evolutionary mindset. We are finally starting to get answers to key questions, including what makes a good story, why some are more enduring than others and exactly how far back we can trace the roots of the most popular ones – as well as how stories have traversed time and space.

It is an epic quest, but there has never been a better time to undertake it. Unlike the Brothers Grimm and other early folktale collectors, modern surveyors of storytelling needn't do painstaking fieldwork – they don't even have to stray from their computer screens to chart the emergence and evolution of stories. "Social media is almost a natural experiment in storytelling that, through its very platform, does the collection," says folklorist and ethnographer Timothy Tangherlini at the University of California, Berkeley. What's more, this new scientific approach can illuminate some phenomena that appear to be modern, including the power of conspiracy theories to sometimes lead us down rabbit holes.

The study of myth and folktales has long had a bad reputation, with scholars in generations past trying to co-opt ancient stories as evidence of the march of societies from "primitive" to "civilised" states. Bringing a more data-driven, evolutionary perspective to bear was a breakthrough, not least in providing new ideas about why we tell stories.

One leading hypothesis holds that storytelling emerged as humanity's first data management system, a way of faithfully and memorably transmitting information that would enhance the recipients' chances of survival. For anthropologist Michelle Scalise Sugiyama at the University of Oregon, this explains why the stories that hunter-gatherers tell are so concerned with the local landscape, climate and animals. "They're told for their ecological relevance and utility," she says. As for narrative – the way we structure stories by embedding agents and their actions into a causal sequence – that grew out of a much older aspect of human cognition: the agency-detection mechanism, our tendency to interpret ambiguous cues as evidence of living beings with their own intentions.

But storytelling has traditionally taken place in a group setting, and other researchers have stressed this social aspect. Two decades ago, evolutionary psychologist Robin Dunbar at the University of Oxford proposed that storytelling is a form of gossip, or "vocal grooming", that allows people to keep track of who is cooperative and who is a free rider in the community. For Tangherlini, it is a way of building consensus on a world view – the norms and values that the group adheres to. And psychologist Adrian Bangerter at the University of Neuchâtel, Switzerland, sees its purpose as making sense of non-routine events, which also demands consensus, because people must agree on an interpretation. There is evidence that the brain activity of people listening to a story becomes synchronised and that this manifests in feelings of "groupiness", says Bangerter. A good storyteller encourages these feelings using devices such as re-enactment, reported speech and audience participation, creating a collaborative, immersive experience.

Ghosts and gremlins

As well as helping us understand an exceptional event, storytelling may also anchor the memory of it by keeping the visceral emotion of eyewitnesses alive. One way to enhance memorability is to incorporate elements that are minimally counterintuitive, such as a 100-year flood or a ghost, which violate listeners' expectations to a small degree. The violation activates our agency-detection mechanism, grabbing attention and raising the heart rate, which then increases neural activity, strengthening the memory. Since it does so across all those in earshot, groupiness is likely to be a by-product. Anyone who regularly goes to a church, mosque or synagogue and listens to stories of the prophets experiences this. "The original protagonists are long gone," says Bangerter, "but for millions of people, these stories are highly vivid and meaningful."

These ideas aren't mutually exclusive: a story might tell us something essential, help us bond and perpetuate the strong emotion of an eyewitness. If it is to stand the test of time, it should also, ideally, be entertaining. Some of ›

CHARLES FRÉGER

OH NO THEY DIDN'T!

Some of the best-known European folktales were collected by Charles Perrault and brothers Jacob and Wilhelm Grimm in the 17th and 19th centuries respectively. It has always been assumed that they were the first to record stories that had been handed down orally for generations – tales that they then popularised through their writing, including Little Red Riding Hood, Cinderella and Sleeping Beauty. In 2009, however, folklorist Ruth Bottigheimer at Stony Brook University in New York suggested that they had pulled off a clever ruse. According to her, they invented these stories, which only entered oral tradition after they had written them down.

Testing that hypothesis, in 2015, Jamie Tehrani at Durham University, UK, and his colleagues compared 23 oral and literary versions of Little Red Riding Hood. They found that the best explanation of the relationships between them was that the story had diversified through multiple retellings long before Perrault ever recorded it. In other words, Bottigheimer's hypothesis doesn't stand up, in this case at least – and Tehrani thinks that applies more generally. "The broad consensus is that many folktales are not just early modern inventions," he says.

NIDAY PICTURE LIBRARY/ALAMY

Native Americans have borrowed and adapted stories from one another

the most entertaining, and hence durable, tales share what anthropologist Manvir Singh at the University of California, Davis, calls the sympathetic plot: where a protagonist with a goal and prosocial tendencies meets an obstacle, the removal of which induces joy and feelings of togetherness in the listener. The sympathetic plot isn't the only narrative structure – others include origin myths and tragedies – but it is found in every human culture. One example is the hero's journey, Singh's summary of which opened this piece.

Researchers disagree as to how many basic plots exist. The idea that there are just seven fundamental storylines is itself a popular myth. Nevertheless, large databases now enable them to identify the underlying structure of folktales and compare them with others that share similar elements and themes. One of the best-known databases, started in 1910, is the Aarne-Thompson-Uther (ATU) Index. It is patchy and Eurocentric, but, as with a patchy fossil record, researchers have devised statistical tools for extrapolating from what survives to reconstruct relationships between tales. This approach is helping us answer questions about how the most enduring tales adapt and evolve over time.

The Brothers Grimm, for example, claimed that the stories they collected could be traced back thousands of years to the speakers of Indo-European languages that are ancestral to German. In 2016, literary scholar Sara Graça da Silva at the New University of Lisbon, Portugal, and anthropologist Jamie Tehrani at Durham University, UK, tested this claim. Analysing 100 fairy tales told by Indo-European-speaking populations and stored in the ATU Index, they found a strong correlation between the relatedness of stories and the relatedness of the languages in which they were told – providing support for the Grimms's claim. One tale, about a blacksmith who tricks a devil, cropped up in enough branches of the Indo-European family tree to persuade them that it could have been told by speakers of the last common ancestor of those languages, Proto-Indo-European, in the eastern European steppe about 5000 years ago. "Some folk narratives can be remarkably stable," says Tehrani.

One rule doesn't fit all, however. Another study found that similarities between stories told by Arctic forager groups depended less on the relatedness of their languages than on the distance between their communities. The researchers, psychologists Robert Ross, then at Royal Holloway, University of London, and Quentin Atkinson at the University of Auckland, New Zealand, interpreted this as a clue that stories had diffused between peoples and that borrowing was more likely to happen between close neighbours than between more distant ones. The idea that borrowing has played an important role in shaping stories in the past makes intuitive sense, because stories have generally evolved faster than the languages in which they are told.

Tehrani and his colleagues have shown

"Some myths can be traced as far back as early sorties of *Homo sapiens* out of Africa"

that there is also a correlation between the relatedness of people and their folktales – but only under about 1000 kilometres. This may reflect the fact that our forebears didn't generally stray far from their birthplace, and stories were handed down through families. However, in a new study that has yet to be peer-reviewed, they report that some myths can be traced as far back as the early sorties of *Homo sapiens* out of Africa around 60,000 years ago, suggesting that people carried these stories long distances. (The blacksmith and the devil could also speak to an unusually long-range migration, and indeed palaeogeneticists have found evidence that the earliest speakers of Indo-European probably did travel far.) Beyond 1000 kilometres, the genetic correlation tends to fall away and geographical proximity comes to dominate – as if borrowing takes over from inheritance. But language and cultural barriers slow the spread of tales and can create striking breaks in the narrative landscape. An analysis by Ross and Atkinson concluded that "folktales from the same culture found 100km apart are, on average, as similar as folktales found 10km apart in different cultures".

Besides inheritance and borrowing, a third possible mechanism shaping the stories we tell is convergence, meaning that different cultures may gravitate towards the same tales independently, simply because these reflect universal human dilemmas. For instance, five main variations on the Cinderella theme are told around the world, and, in 2023, Tehrani's group showed that they had been swapping narrative elements for a long time, like interbreeding populations of a single species. At least four of them, however, seem to have arisen in distinct storytelling traditions.

The cultural evolution approach to understanding storytelling has its critics. Tangherlini, for one, points out that while biological inheritance can be traced via genes, there is no equivalent smallest unit for cultural inheritance that can be tracked through time and space. He is sceptical about claims such as one study's conclusion that Indigenous Australian coastal communities have been telling the same flood myths for at least 7000 years, ever since sea levels rose at the end of the last glacial period – let alone that some stories around today were first told more than 50,000 years ago, in Africa. "Is it really the same story?" he asks. But Tangherlini does accept that groups are conservative when it comes to storytelling. Indigeneous Australians, for instance, insist on stories being told the right way. "Even the Grimms's old, illiterate woman, who told many of their fairy tales, corrected herself immediately when she had strayed from the canonical version," says Michael Witzel, a linguist and mythologist at Harvard University.

Ethnographers have long observed small-scale communities policing their storytellers and sanctioning those who get too creative. Nevertheless, individuals can introduce innovations, provided the group deems these to be meaningful, says Tangherlini. Indeed, he believes it is through the tension between the innovating individual and the conservative group that a story evolves. This makes sense to Sugiyama, who has observed that a Native American community might borrow a story from a neighbouring one, adapting it to the local topography and climate. This would then show up as stories becoming more different the further away from the original that they travelled – as Ross and Atkinson found in the Arctic. "One thing that Indigenous knowledge-keepers stress is that the stories are about the land," she says.

How might these insights apply today in the industrialised world? Nothing has changed, according to Sugiyama, apart from our economies and habitats. Modern stories still speak to place and human psychology, but they also explain our legal, banking, health and political systems to us, and they do so, very often, using the tried-and-tested vehicle of a sympathetic plot. "But instead of reciprocating storytellers by assisting them when they need help, we simply pay them," she says.

Characters that violate our expectations can make a story more memorable

LEONIE FREEMAN

It's a conspiracy

Storytellers also continue to hijack our agency-detection mechanism for both benevolent and malevolent ends. It may seem like the latter predominates online – much has been written about an "infodemic" of misinformation and disinformation – but, in fact, there is no convincing evidence that belief in conspiracy theories is on the rise, and there is some evidence that it has remained stable over time. Admittedly, such beliefs are hard to quantify, and the jury is out as to whether new media have altered the visibility and reach of conspiracy theories, but they have always been with us. Bangerter thinks of them as a type of myth – a story that people believe, in contrast to a folktale, which we know is fiction. They have a lot in common with religious narratives, he says. Stories like the biblical account of the world's creation explain otherwise inexplicable events, often exaggerating the role of human or human-like agency. Similarly, conspiracy theories, from QAnon to an autism-vaccine link, magnify the role of goal-directed action as opposed to random forces and chance.

Our modern experience also highlights the enduring power of stories. When trust in legitimate authorities is low, someone offering a compelling alternative narrative is more likely to gain followers. "Part of what makes the charisma of a leader is their ability to tell good stories," says Bangerter. Don't underestimate the ability of such a leader to drive radical change by resurrecting a dormant story, says Tangherlini. "Stories have enormous impact on people's real-world behaviour." ▮

Laura Spinney is a writer based in Paris, France. Her next book is *Proto: How one ancient language went global*

NATALIE FOSS

THE French inventor Jacques de Vaucanson is remembered for, among other things, producing three curious automata in the 18th century. A poster from the time advertised them all side by side: a figure that played a real flute, another that banged a tambourine and a duck that gobbled up corn and seemingly turned it into pellets of... well, use your imagination.

For physicist Nicole Yunger Halpern, based at the National Institute of Standards and Technology in Maryland, these antiquated automata have a resonance with some of today's most cutting-edge technology. Vaucanson's inventions prefigured the industrial revolution, during which mechanisation went from being a quirky curiosity to a force that reshaped the globe. We may be at an analogous turning point today when it comes to quantum technology, says Yunger Halpern.

The steam-powered world of the industrial revolution may seem far removed from the quantum realm. But this period of dramatic change was bolstered by thermodynamics, which deals with heat, work and energy. And, recently, physicists have been applying its ideas to the subatomic realm to devise the new field of quantum thermodynamics. This has seen the development of machines like quantum fridges, batteries and clocks.

However, these are just the start of the quantum technology revolution, says Yunger Halpern. She was a co-author of a recent manifesto aiming to chart a path towards greater things. She spoke to *New Scientist* about what advanced quantum machines might look like, the astounding benefits they could bring and how we can work towards making them a reality.

Thomas Lewton: You have been thinking a lot about automata recently. But what exactly are they?

Nicole Yunger Halpern: An automaton is a machine that performs some function on its own, without external control that changes over time. When I was little, for instance, I was enchanted by a toy dog that would bark and do a backflip at the push of a button. Today, automata vacuum floors, and self-driving cars are becoming increasingly common.

People have built automata for many centuries. For example, in 1739, the inventor de Vaucanson built a "digesting duck" that appeared to eat grains and then expelled pellets afterwards. It's a good example of how automata achieved an impressive level of sophistication and yet were used primarily for entertainment. On the other hand, though, Vaucanson also contributed to the rise of the industrial revolution by inventing an automatic loom.

So those centuries-old automata spurred wider technological progress?

Indeed, there was a shift during the industrial revolution: automata and machines that needed less control than machines used throughout most of human history were harnessed on a large scale for practical benefit, transforming the face of civilisation. The toys served as a stepping stone to industry.

How did these machines lead to a new understanding of physics?

The industrial revolution inspired thermodynamics, the study of energy in forms such as heat and work, and the relationships between them. Engines were powering factories so, naturally, people wanted to understand ›

"Now is the time to realise useful autonomous quantum machines"

Quantum technology is still in its infancy, says **Nicole Yunger Halpern**. But, she tells Thomas Lewton, she intends to change that

how efficiently engines could operate. For example, a heat engine is a very simple type of engine; steam engines are heat engines, as are the engines that operate in many cars. A heat engine interacts with a hot environment and a cold environment. Heat tends to flow from hot to cold. The engine siphons off some of this heat and transforms it into work. Where does thermodynamics come in? Well, in 1824, the French engineer Nicolas Léonard Sadi Carnot identified an upper limit on the efficiency of heat engines – and he designed an engine cycle that could achieve this ideal efficiency. So thermodynamics, especially at first, was inspired by concerns about performing useful work.

CPA MEDIA PTE LTD/ALAMY

"Tipu's tiger" is an 18th-century musical automaton with moving arms

There's been a surge of interest in what happens when concepts in thermodynamics collide with the quantum realm. Why?

The laws of thermodynamics were developed by people who had in mind steam engines and other classical systems of everyday size. In quantum thermodynamics, we are extending and reformulating these laws to see how they govern quantum systems such as atoms, single particles of light and other minuscule systems. We have long known that energy is intertwined with information. Thermodynamics, for example, famously features entropy, a measure of uncertainty, which also features in information theory. Naturally, quantum systems can have their own version of this: quantum information. It features in phenomena like entanglement, where two particles can behave as if they are connected even when separated by vast distances.

We can look at a system that is processing information and energy and ask: what behaviours does it exhibit only if it's quantum? Thermodynamics can thereby help us understand better where the border is between the classical world and the quantum world. Pinpointing this border has both fundamental and practical implications. First, it elucidates the nature of our universe, which is ultimately quantum but which – a bit mysteriously – appears classical in our everyday experiences. Second, pinpointing the border can guide us towards building new quantum technologies, akin to quantum computers, and identifying their limitations.

Why have you sometimes referred to all this as "quantum steampunk"?

Steampunk is of course that genre of literature, art, and film that features 19th-century settings, such as smoky Victorian London and the Wild West and embeds futuristic technologies in those throwback settings. It conveys a sense of adventure and exploration. To me, quantum thermodynamics is the real-world version of steampunk. Thermodynamics developed during the Victorian era, inspired by steam-powered technologies. In contrast, quantum information science is partially cutting-edge and partially futuristic, as quantum technologies remain under development. Plus, quantum thermodynamics is a fast-moving field full of opportunities, so it shares the steampunk spirit of adventure.

Getting back to practical matters, can an improved understanding quantum behaviour help us build better machines?

Yes, we already know that quantum phenomena such as entanglement can enhance information-processing tasks such as computing and cryptography. Quantum computers have already been claimed to outperform classical computers in certain tasks. But it's not all about information. There are energy-processing tasks, such as powering factories and charging batteries and refrigerating, where we can use quantum phenomena to get an enhancement. People have designed – and to some extent experimentally realised – quantum engines, quantum batteries, quantum refrigerators and more.

Most of the quantum machines built so far aren't very useful, though. For example, in one ground-breaking experiment, researchers intentionally wasted the work outputted by an engine because otherwise they would have had to devise a whole other plan for capturing it. Also, quantum phenomena such as entanglement usually come into play only at temperatures close to absolute zero, so experimentalists have to spend a lot of energy cooling down the system. Because of things like this, much more work is often spent on operating quantum machines than you actually get out of them.

It sounds like we are still at the "digesting duck" stage when it comes to quantum machines...

Yes, very much so. Most of the machines I just mentioned don't even qualify as automata because they are driven by external control that changes over time. But I'm advocating for leaving the duck stage! Since we have experienced such great successes with the fundamental research aspect of quantum thermodynamics,

JONAS MLYNEK, QUANTUM DEVICE LAB, ETH ZURICH

The components of a quantum computer are much smaller than an ant

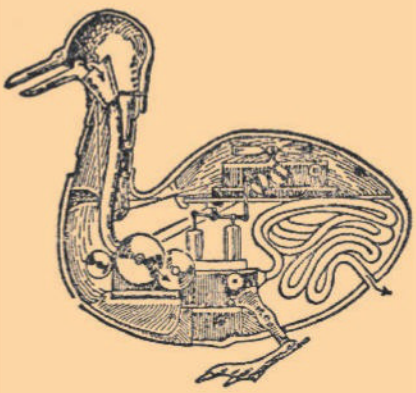
we can start to look beyond it. Now is the time to shift our attention to realising useful autonomous quantum machines.

What would a really transformative quantum machine be like?
A good example would be around quantum computers. Large-scale quantum computers will be able to solve certain problems far, far more quickly than ordinary computers, even supercomputers. They could be used for things like advanced cryptography, as well as for discovering new materials and drugs. But our current models are too small to do these things. So we would like to free quantum computers, as much as possible, to perform each step of their computations on their own. If we are to build an autonomous quantum computer, we need to include an autonomous quantum clock, which would tell the computer when to begin and end each step. These autonomous quantum computers would be scalable and use fewer resources.

Tell me about your recent call to arms...
In November, my collaborators and I published a manifesto for how to achieve useful autonomous quantum machines. It's a call to arms that echoes the DiVincenzo criteria for quantum computing. In 2000, David DiVincenzo published seven guidelines for building a quantum computer or material. These criteria have steered the construction of quantum computers for decades.

Inspired by the DiVincenzo criteria, we looked at a lot of examples of existing or proposed autonomous quantum machines, such as autonomous quantum refrigerators, and also looked at natural, autonomous quantum machines found in biochemistry. For example, our bodies contain molecular switches and enzymes that speed up chemical reactions. Then we abstracted eight criteria that we thought more or less united them.

What are these criteria?
The first four core criteria concern the components you need to build quantum automata, and how to engineer the right interactions amongst them. The next four concern questions such as: Is the output of the machine worth the input? How will the machine shut itself down after completing its task? How can autonomous quantum machines communicate with each other and navigate a landscape?



Jacques de Vaucanson's "digesting duck" contained hidden pulleys and pipes

BETTMANN/GETTY IMAGES

"We would like to free up quantum computers to perform calculations on their own"

You and your collaborators recently developed a useful quantum machine, which could help reset quantum computers between calculations. How did that come about?
I described my frustrations about how quantum thermodynamics should be more useful to my colleague Simone Gasparinetti at the Chalmers University of Technology in Sweden. I explained that I was looking for an environment that was already cold, so that a machine in it could behave quantum mechanically. This environment should include a hot sub-environment and a cold sub-environment, so that the machine could essentially extract its own work. Moreover, there should already be a need for an autonomous quantum machine here so that we could just slot it in. Simone said: "Oh, I already have this environment in the quantum computer being built at my university!"

Simone is developing a quantum computer made of superconducting qubits. These already have to be kept extremely cold with a large refrigerator, so if we put an autonomous quantum refrigerator in there, it won't require much extra energy to stay cold. There was also a need in this setting: if you have finished a quantum computation and you want to perform another, you need to reset or erase qubits by cooling them down a great deal. My colleagues recently tried doing this with an autonomous quantum refrigerator we designed – and I was surprised at how well it performed. Now I am on the lookout for more of these opportunities.

In your wildest dreams, what do you imagine autonomous quantum machines could look like someday?
One could draw inspiration from the small autonomous machines that operate in biological systems, though these are not necessarily quantum. Molecular motors carry cargo across cells, and RNA uses DNA construction manuals to build proteins, for instance. We can wonder whether adding quantum coherence or entanglement could enhance these processes. Or you could imagine quantum drones delivering atoms here and there, or quantum sensors that might be able to move around and report on what they encounter. ▮

Thomas Lewton is a features editor at *New Scientist*

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Mathematics of life

Three in a row

Noughts and crosses, or tic-tac-toe, is a simple game – but tweak the rules and there is plenty of fun to be had, says **Peter Rowlett**

Peter Rowlett is a mathematics lecturer, podcaster and author based at Sheffield Hallam University in the UK. Follow him @peterrowlett

ON THE beach, scratching marks in the sand with a stick, my 4-year-old son was already good enough to force a draw in noughts and crosses, also known as tic-tac-toe.

In case there is anyone on the planet unfamiliar with this game, it is played on a 3 × 3 grid, with players taking turns to add their symbol – an X or an O – in one of the spaces. The winner is the first to place three of their symbols in a row horizontally, vertically or diagonally.

We can prove that two good players will always end the game in a draw by using an algorithm called an exhaustive search that examines all possibilities to come to a conclusion. In this case, we can use it to work out all the moves that each player could make in turn, until we get to a series of possible future endgames. These are evaluated as either a win, loss or draw. Then we work backwards, looking at the decisions that led to those endgames. At each decision point, we look at which player will be offered the choice and assume they will act in their own best interest, until we find out the optimal next move.

On a blank board, there are nine spaces in which the first symbol can be placed. For each of these possibilities, there are eight places where the second symbol can go, and for each of those, there are seven ways for the first player to respond, and so on. This leads to almost a million positions, which isn't very many for a computer to search. Doing this analysis starting from a blank board, we find that, if both players play perfectly, the outcome is always a draw.

MIKHAIL RUDENKO/ALAMY

Knowing that you can only win if your opponent does something silly can make the game somewhat boring to play. However, some fun twists can spice things up.

A simple tweak is to reverse the game's goal. Here, players place Os and Xs in the usual way, but the first to get three in a row loses. Have a go! You might be surprised that such a simple change results in really quite different gameplay.

Another twist is to play the game wild. This means that, each turn, players choose whether to place an X or an O, with the person who adds the third matching symbol in a row declared the victor, whichever symbol that is. It can be really hard to get into the mindset that your opponent can win using the line you are starting to create.

You can also enlarge the grid – try four in a row on a 4 × 4 grid. Or play on a larger grid than the winning line, like the classic game Connect 4, which requires four in a row, but is played on a 7 × 6 grid, with the added twist of gravity. You can even play on an infinite board. Take turns to place your symbol, aiming to get five in a row, enlarging the grid as needed.

There are many more varieties – maybe you can think of your own. For me, tweaking the rules and examining the result is the creative heart of mathematical thinking, and it is lovely to find so much to explore in this simple game. ▮

Mathematics of life appears monthly

Next week
Debunking gardening myths

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

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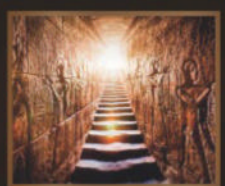
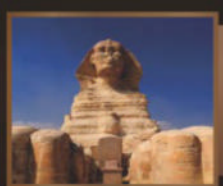

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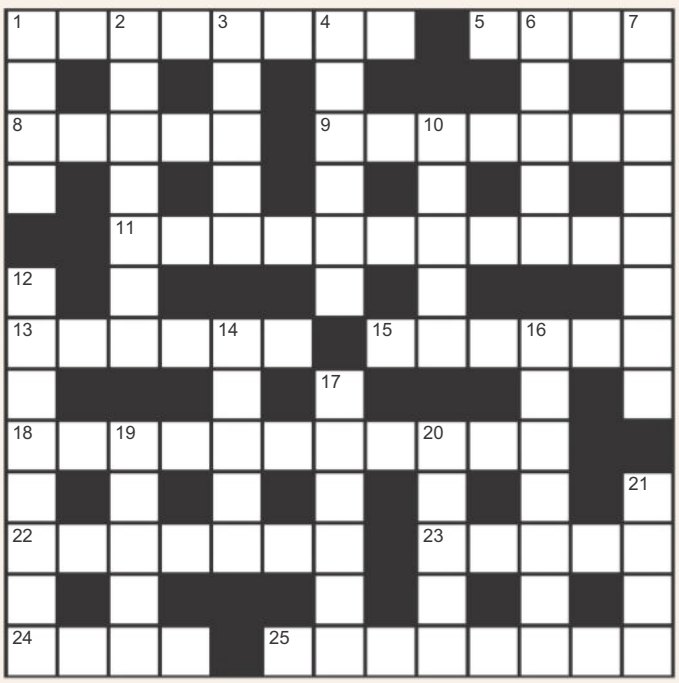
Cryptic crossword #157 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Something missing amid boxing match power failure (8)
5 Copyright part of a glass fastener (4)
8 Shift left into sturdy metal monument (5)
9 Visionary beginning to develop juicing gadget (7)
11 Ring new oyster bar, securing very good place to watch stars (11)
13 Band on the radio puts a stop to restitution (6)
15 Test to some extent detects candour (2,4)
18 *Star Trek* device prepares dark beer after dropping one (11)
22 Filming site employs luxury cars (7)
23 Pair of chemists following nitric oxide temperature mark (5)
24 Starting late, pick up win (4)
25 Choose peculiar natural alloy (8)

DOWN

1 Einstein collaborator plays violin for the audience (4)
2 An entity primarily hiding clownfish! (7)
3 Boat bottoms polished up (5)
4 Dairy suppliers reduce shakes by 25 per cent (6)
6 Uncertain state of tyre hanging from branch? (5)
7 Celebration is last of many inspired by *Severance* (8)
10 Praise reformulated latex (5)
12 Prior, feeling unwell, finally ate lozenge (8)
14 Looks for prints of the French saints (5)
16 Museum manager put Egyptian deity in renovated court (7)
17 Liner inside metal wrapping palaeontologist's find (6)
19 Raise nonsense about player (5)
20 Little jerk takes on mixer (5)
21 Certain salmon mate (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #293
set by Corryn Wetzel

1 How many teeth does an adult African lion (*Panthera leo*) usually have?

2 What was the first video game console released for commercial sale?

3 Blood makes up roughly what percentage of an adult human's body weight?

4 When was the first module of the International Space Station launched?

5 What is the Drake equation used to estimate?

Answers on page 47

BrainTwister
set by Colin Beveridge

#64 Matching tiles

A game is played with a set of tiles. Each tile is one of three shapes (circle, triangle or square), is one of three colours (red, blue or yellow), is one of three sizes (small, medium or large), is one of three textures (smooth, rough or ridged), and has one of three letters on it (A, B or C).

Given that each combination of attributes is used on exactly one tile, how many tiles are there?

A meld consists of three tiles in any order, such that each attribute is either the same on all three tiles or different on all three. For example, the big, red, rough circle labelled A; the small, red, smooth square labelled A; and the medium, red, ridged triangle labelled A form a meld. How many melds include the big, red, rough circle labelled A?

How many possible melds are there?

Solution next week

Making space

At the big bang, matter formed from the initial energy when it cooled enough for particles to form. But how was space formed?

Chris Daniel
Glan Conwy, UK
Space began in the first 10^{-35} of a second after the big bang, when the universe was thought to have been smaller than an electron, but then expanded rapidly, according to the widely accepted theory of cosmic inflation.

At that time, the universe consisted of a soup of particles, antiparticles and photons as well as anything else that could exist in the unimaginable temperatures of around 10^{22} kelvin. Particles collided, sometimes annihilating each other and sometimes creating new types of particles as the universe continued to expand, but at a much slower rate than the initial cosmic inflation.

In the first fractions of a second after the big bang, protons and neutrons formed, and not long after, they coalesced to form hydrogen and helium nuclei. After 300,000 years, electrons were captured to form atoms of hydrogen and helium. Another 80,000 years later, they left behind photons, which filled space and which are detectable today in the form of microwave background radiation. As the universe continued to grow and cool, the distances between particles increased, and the collisions between them became less frequent.

"Even now, the so-called vacuum of space isn't empty. It continues to teem with particles such as hydrogen and helium atoms"

Even now, the so-called vacuum of space isn't empty. It continues to teem with particles such as hydrogen and helium atoms, cosmic dust, mostly carbon and silicon, from planets and stars. Space is also permeated by gamma rays and X-rays from supernovae, gravitational and magnetic fields from stars and planets, plus the microwave background radiation. Unseen dark matter is likely to account for much of the universe's mass, while dark energy may be driving its continual expansion. Space – the gaps between particles, planets and galaxies – is simply a consequence of the energy that powered and continues to power the growth of the universe.

Dave Rowsell
Gowerton, Swansea, UK
In short, we neither know nor truly understand how space was formed. As I see it, space (or better, space-time) either formed at the big bang or it didn't. If it arose from a point singularity, relativity theory predicts this point would have started off with infinite density, thus curling space-time so tightly it wouldn't have existed. In this scenario, the big bang created space-time.

We should also ask, if space-time is expanding, what is it expanding into? A balloon expands to take up more of the space around it. But that can't apply to a universe that contains space. On the other hand, if the universe didn't originate from a point singularity, but from something very close to it, it would have had a measurable size and hence must have occupied space-time. Then the big bang would have occurred within a pre-existing continuum, which means that our universe is contained within a possibly infinite and eternal space-time. In this case, is the universe wrongly called the multiverse? To make matters worse, the famous twin paradox complicates it further. This concerns time dilation. One twin is sent on a space journey at close to the speed of light. After the twins reunite, they would each have a different but "objective" calculation of when exactly the big bang happened. All of which leads me to wonder that perhaps the question is wrong, and we are caught in an infinite regress.

Pat French
Longdon Upon Tern, Shropshire, UK
The answer to this question very much depends upon the definition of space. The word is used in many ways. For instance, outer space is said to start beyond the Kármán line, an imaginary boundary 100 kilometres above Earth's surface.

If we take space to mean the volume occupied by the universe, then this is the entity within which we commonly experience four dimensions. Along with length, width and height (that make up volume), we experience time. These four dimensions together make up the fluid space-time continuum known as Minkowski space.

If space is defined as the volume occupied by the universe, it would seem reasonable that space came into existence at the moment in time when the universe extended beyond its big bang singularity.

KONRAD WOTHE/IMAGE PROFESSIONALS GMBH/ALAMY

Why do so many animals, such as this inquisitive weasel, have white undersides?

This week's new questions

Patchy puzzle **Why do many animals, such as some mammals and birds, have white underbellies?**
***Michael Morris**, Hendersonville, Tennessee, US*

The right note **Why do some pieces of music give us goosebumps? Is this indicative of particular personal traits?**
***John Grant**, Shelly Beach, Queensland, Australia*

Feeling bubbly

Is the volume of gas at the top of a beer bottle the same for all beers, and how is it optimised?

Ron Dippold
San Diego, California, US
I am a brewer, so this is dear to my heart. The unfilled area at the top

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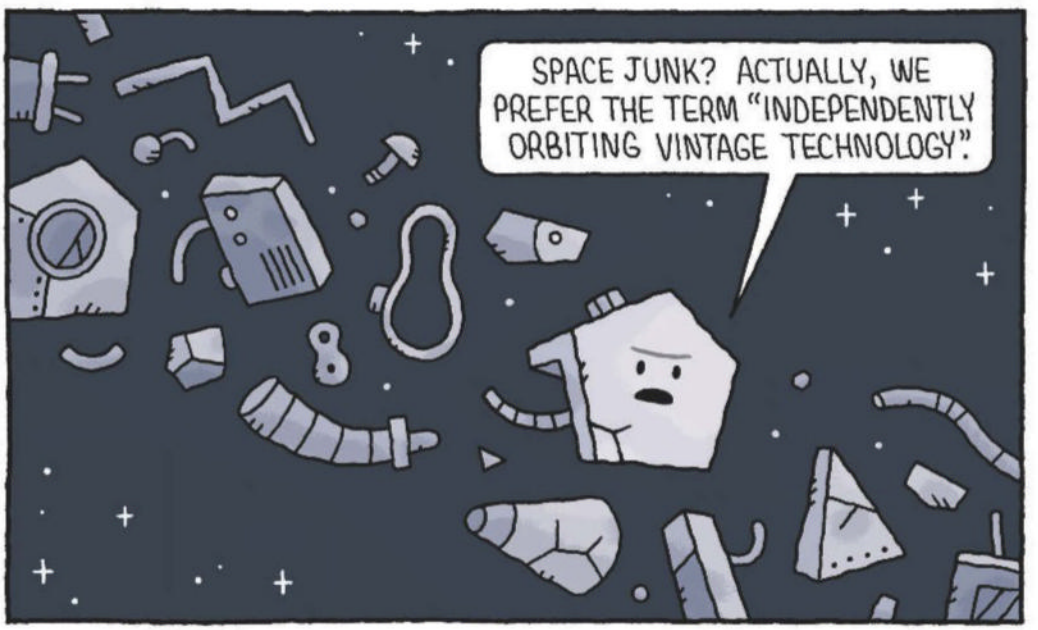
for New Scientist



of any container is known as headspace or ullage. In a beer bottle, it serves a couple of purposes. It prevents beer from squirting out when you put a cap on. It prevents the beer from breaking the cap seal and leaking out if the beer gets hot and the liquid expands. Since the space ends up mostly containing carbon dioxide, if filled properly, this protects the beer from oxygen leaking in through the cap seal – oxygen is very bad for beer. You don't want too much headspace: gas is more explosive than liquid, which can cause pressure to build up enough for the bottle to break. Too much headspace also exposes your beer to more oxygen during filling, and, well, it means less beer! You're looking for about 2 centimetres at the top of a bottle, which is about 7 per cent of the volume of a typical 12-ounce, or third-of-a-litre, bottle.

If you are bottling commercially, industrial bottling lines make it easy. The machines used push a "counterflow" or "isobaric" filling nozzle onto several empty bottles

"You're looking for a gap of 2 centimetres at the top of a bottle, about 7 per cent of the volume of a typical 12-ounce container"

at once. This temporarily seals them, with tubes going to the bottom of the bottles. The tubes suck the air out of the bottle. They then pressurise it with CO_2 and/or nitrogen. They may do this twice, at which point, hopefully, all the oxygen is gone!

Beer around 5°C then flows down the tubes into the bottles, filling each to the desired level from the bottom up. Because the beer is cold and the pressure in the bottle is the same as the pressure in the filling tank, there is no foaming. Once full, the nozzles are retracted and the bottles quickly capped. With a decent bottling line, you will have a very uniform fill. However, if the bottles heat up or are shaken at any point after this step, CO_2 can come out of suspension in the beer and go into the headspace. Some CO_2 will go back into the beer, if given enough time and rest, but this can give you some variation, even if the bottle was filled perfectly. If you are homebrewing, you can also use a counterflow filler, though they are usually 100 per cent manual.

Most commercial beer is filtered and pasteurised, removing and killing yeast. It is "dead" and will produce no more CO_2. It is also force-carbonated, which means high-pressure CO_2 is applied to the beer, and the degree of carbonation is very controlled.

However, most homebrew beers aren't pasteurised or filtered. In an unpasteurised beer, the yeast is still alive and slowly continues to turn grain sugar in the beer into alcohol, also producing CO_2, which creates a little more headspace. Homebrew bottlers often leave carbonation entirely up to the yeast in the bottle, so CO_2 levels and headspace can be wildly variable. If you seriously misjudge things, you can have boxes of exploding bottles.

Answers

Quick quiz #293 *Answers*

1 30
2 Magnavox Odyssey
3 7 per cent
4 1998
5 The number of active, detectable extraterrestrial civilisations in our galaxy

Quick Crossword #178 *Answers*

ACROSS 1 Water shortage, **8** Blob, **9** Virologist, **10** Violet, **11** Agenesis, **12** Isomorphs, **14** Frog, **15** Gage, **16** Logrunner, **20** Beriberi, **21** Tethys, **23** Aglutition, **24** Rare, **25** One in a million

DOWN 1 Wilkins, **2** Tubal, **3** Riveter, **4** Hermaphroditism, **5** Roller, **6** Angle iron, **7** Easting, **13** Magnitude, **15** Grey goo, **17** Retinol, **18** Elytron, **19** Median, **22** Tarsi

#63 A 2025 puzzle *Solution*

The number 3025 also works: $(30 + 25)^2 = 55^2 = 3025$.

If a square number ends in a 1, it must be the square of a number ending in 1 or 9.

The only other four-digit number with the split-sum-square property is 9801, since $(98 + 1)^2 = 99^2 = 9801$.

Retraction action

On 25 February, there appeared one of the most spectacular retraction notices it has ever been Feedback's pleasure to read. A retraction notice is when a scientific journal decides that a study it has published is so flawed and unreliable that it effectively unpublishes it.

The new retraction notice covered not one, not two, but five articles in *Perceptual and Motor Skills*, all by Nicolas Guéguen at the University of Southern Brittany in France.

The five studies were published between 2002 and 2009. To pick just one, in 2007 Guéguen was the sole author of a study entitled "Bust Size and Hitchhiking: A field study". It purports to show, using real-world experiments, that women with larger breasts are more likely to be picked up when hitchhiking. Two years later, this time with a colleague, he found that blonde women were also more likely to be able to hitch a ride.

With results like that, it is no wonder Guéguen's work became a popular subject for news stories. Alas, this does include *New Scientist*, which in 2008 covered a study (not yet retracted) claiming women were more receptive to chat-up lines when at their peak monthly fertility.

It took almost another decade for the house of cards to start shaking. In 2017, researchers Nick Brown (who blogs as "steamtraen") and James Heathers began writing about Guéguen's work. They found he was prolific, often publishing "10 or more sole-authored empirical articles per year... many of which include extensive fieldwork". Immediately raising the question: how did he find time? They also became suspicious of the large effects claimed.

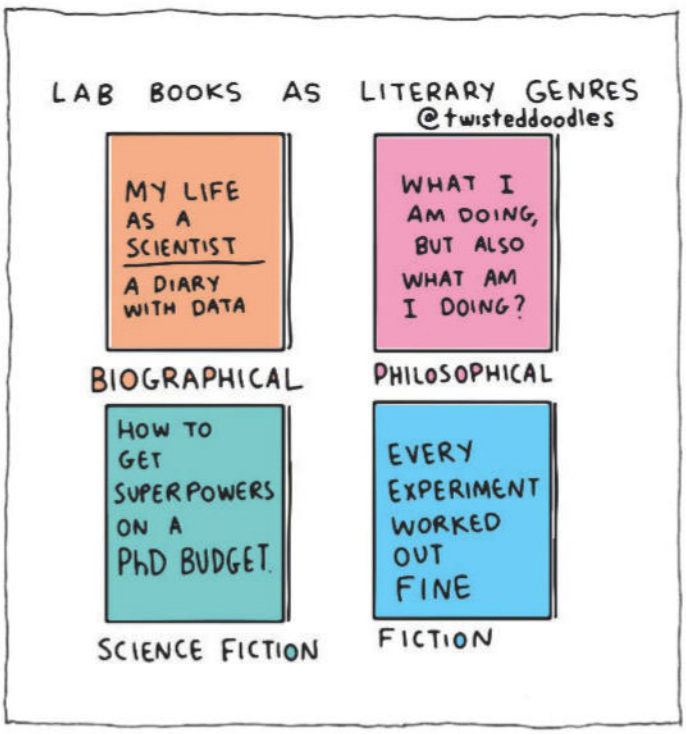
And then the house of cards started to crumble. In 2019, the *International Review of Social Psychology* added "expressions of concern" to six of Guéguen's papers. In 2022, *The Journal of Social Psychology* retracted a study claiming that men perceived women as having stronger sexual intent if they were wearing red, noting that "table one in the manuscript had four combinations of means and standard deviations that were impossible given the reported sample sizes". That same year, the *Scandinavian Journal of Psychology* slapped an expression of concern onto a study claiming that men were more likely to help a woman "when her hair fell naturally on her neck, shoulders and upper back".

And now come the latest retractions. The notice explaining them is a doozy, albeit couched in academic language. It warns of "low confidence that the study designs were implemented as described" and that "much of the data in these articles are implausible or were incorrectly analyzed". In other words: we don't believe he did what he said, and in any event, he did it wrong.

The editors say Guéguen didn't respond to their queries. Frankly, given the nature of his work, Feedback suspects his only reply would have been: "Infamy! Infamy! They've all got it in for me!"

It seems only right to let Heathers have the last word: "Just remember that if you write unreliable, embarrassing, Benny-Hill-ass studies and someone finds out just how badly you did that... then you, too, could be pretty much OK for seven years or so before there are broader consequences."

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

Botticelli xxx peacock

A few weeks ago, Feedback wrote about the vexatious Scunthorpe problem: the difficulty of blocking offensive words online, when the same letter strings are often found within completely innocuous words, such as the names of English towns. Three readers have managed to tell us, without falling foul of our email filters, about similar experiences.

Richard Black relates his time as a university technician in the early 2000s, when a student asked for help setting up a Hotmail email account. (Note for younger readers: Hotmail is an old name for Outlook, the email system your parents use at work because Microsoft has a stranglehold on the business software market.) Richard writes: "I tried all sorts of permutations of his name without success and we finally gave up and managed to set up a Yahoo account." (Note for younger readers: Yahoo was... oh, actually, Yahoo is still around.) Anyway, the student's surname was Peacock.

Around the same time, Richard Hind "was given a budget to implement an email filtering solution". It worked pretty well, barring "some curious US slang terms that were deemed offensive". But many "innocent emails" were also stopped. The only pattern was that they were sent by staffers to friends elsewhere. "Eventually it clicked," says Richard. The blocked emails were all signed with three kisses, or Xs, "which the email filter interpreted as adult material".

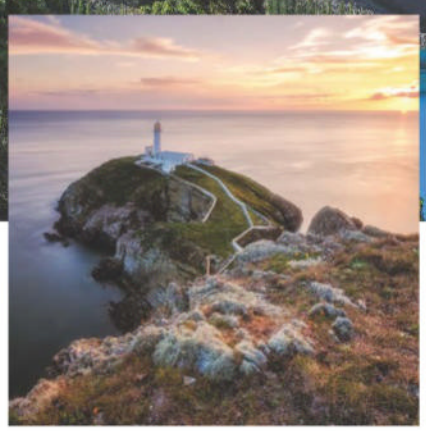
Spare a thought also for Patricia Finney, who wrote a blog about optimism in the face of climate change, and illustrated it with a reproduction of Botticelli's *The Birth of Venus*. Facebook rejected it for "nudity and nipples". "I'm still waiting for the apology," she says.

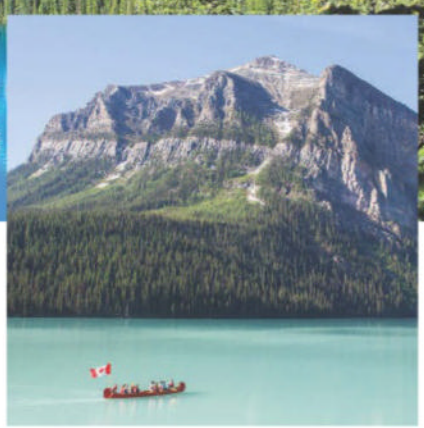
Sweet treats

Feedback's reading pile is teetering like an experimental spaceship in a *Thunderbirds* episode, so we are reluctant to add to it. But a series of books by a food historian did catch our eye. *A Dark History of Sugar* is about the not-remotely-sweet colonial adventures underpinning the sugar industry. On a lighter note, *The Philosophy of Puddings* sounds delightful, and we were impressed by the title of *Knead to Know: A history of baking*. The author of all these calorific tomes? Neil Buttery.

Discovery Tours
NewScientist

Explore breathtaking geological wonders





Retracing Charles Darwin's travels across North Wales

5 May and 1 September 2025
6 days

Uncover the best of Wales on an in-depth journey through the stunning landscapes of Eryri (Snowdonia) National Park, where dramatic mountains and valleys reveal a geological story shaped by volcanic and glacial forces over millions of years. Walk in the footsteps of Charles Darwin and discover the inspiration he found in the rugged terrain when he visited in 1831 and 1842.

- Discover sites from Charles Darwin's childhood and the places where he prepared for his legendary voyage on HMS Beagle
- Enjoy the spectacular landscapes of north Wales, including the mountains of Eryri (Snowdonia) National Park, the tranquil Llyn Ogwen lake and the rocky coasts of Anglesey
- Learn how Darwin unravelled the origin of these landscapes

Land of fire and ice: Iceland

9 June and 18 October 2025
8 days

Explore Iceland's incredible landscapes that offer otherworldly vistas. On this unforgettable tour, days are filled with volcanic and geological adventure. Discover the awe-inspiring might of the planet and marvel at the sights, sounds and smells of erupting geysers, hot springs and bubbling fumaroles. Get up close to majestic glaciers, waterfalls and tectonic plates as they pull apart and learn about remarkable geological processes and volcanology from the accompanying expert.

- Visit a spectacular ice cave, located underneath Europe's biggest ice cap, Vatnajökull, which has around 30 glaciers flowing out from it
- Explore the famous Jokulsarlon Glacier Lagoon, a beautiful sea of floating icebergs with blues that contrast vividly with the charcoal-coloured sand of the beach
- Spend time exploring the Reykjanes Peninsula to see where two tectonic plates meet and volcanic fissures are created

The Rockies and the Badlands: Geology and dinosaurs in Canada

16 June 2025
7 days

Be wowed by the phenomenal scenery and geology of the majestic Rocky mountains west of Calgary and the otherworldly Alberta Badlands to the east and discover the geological processes that created them. Delve into 420 million years of history and find out how geology influenced the development of Alberta.

- Enjoy the astonishing scenery and geology of southern Alberta as our experts bring to life the history of settlements in this remote but beautiful land
- Traverse the spectacular scenery of the Canadian Rockies and marvel at the colossal forces that shaped them
- See dinosaur excavation sites normally off-limits to the public while at Dinosaur Provincial Park

Find out more at
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