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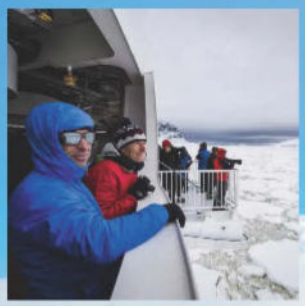

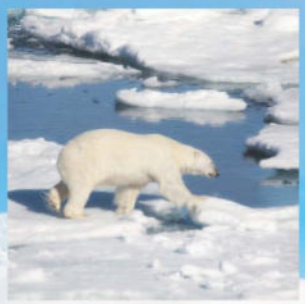

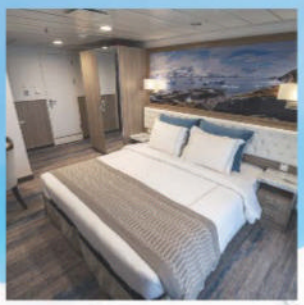

Arctic expedition cruise with Dr Russell Arnott: Svalbard, Norway

17 June 2026 | 12 days

Explore the northernmost region of Earth, the realm of the polar bear and the midnight sun, whilst travelling aboard the Greg Mortimer which is at the cutting edge of nautical technology. This cruise will be a truly enriching trip of a lifetime.

Enjoy a full programme of talks, shore visits and Zodiac boat safaris covering topics including glaciology, botany, marine biology, astronomy and the history of polar exploration, deepening your connection to this remote and rugged archipelago. Accompanied by Dr Russell Arnott and speakers from *New Scientist*, along with the highly knowledgeable and supportive expedition team, experts in exploration, science and wildlife.

Witness polar bears on substantial ice flows (June is one of the best months to spot them) as well as a plethora of other wildlife species on land, sea and in the air. June is when Minke, humpback and fin whales arrive back to the Arctic having spent the winter in warmer tropical waters. During this time, the tundra and hillsides are in bloom as the ice melts away and endemic flowers begin to blossom. The towering cliffs and dramatic mountain ranges are teeming with millions of sea birds laying their eggs.

Explore the Arctic town of Longyearbyen, the world's northernmost settlement, situated in a valley on the shores of the idyllic Adventfjord, surrounded by steep mountains and several glaciers.

This unique cruise will be hosted aboard a new state-of-the-art polar expedition vessel, the Greg Mortimer, the first passenger ship to feature the revolutionary Ulstein X-BOW® allowing a sleeker cruising experience and reducing fuel consumption.
You will experience the majesty of Norway's Svalbard with its ancient glaciers, glass-still fjords, imposing pack ice and distinct landscape where wildlife thrives at nearly 80° north. With no more than 128 guests, amazing viewing space and a ship-build designed to minimise negative environmental impacts, the Greg Mortimer guarantees a far more enjoyable guest experience than the other older and larger expedition ships.

Travel with like-minded people, who love to connect with the natural world and the wonder of science. An ideal environment for curious-minded couples, friends and solo travellers to relax.

Highlights include:

- Venture close to 80° north, searching for polar bears on pack ice.
- Fascinating talks from marine biologist Dr Russell Arnott plus *New Scientist* contributors and expedition crew.
- Discover the thrill of seeing species such as walrus, seals, whales, reindeer, arctic fox, guillemots and puffins.
- Cruise along blue glacier fronts and through stunning fjords on a purpose-built intimate powlar expedition ship.
- Enjoy tundra hikes amid stunningly beautiful scenery.
- Daily Zodiac boat safaris exploring fjords and glaciers.

Watch the video of this year's cruise at
newscientist.com/arctic

This week's issue

On the cover

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The surprising reason why many foods are bad for us – and how to balance them out

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Cover: Tomasz Woźniakowski

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ZSL/COVER IMAGES

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A note from the editor

Dear reader,

This week is one of the most exhilarating in the *New Scientist* calendar. On 18 and 19 October, tens of thousands of people will gather in London to experience our annual extravaganza, New Scientist Live.

We have an incredible line-up of some of the world's most exciting scientists, authors and big thinkers who will be sharing their ideas with attendees across five huge stages. In between talks, the show floor is a whirlwind of activity, with hands-on demos, robots, insects and even a virtual-reality rollercoaster. This year, we have also added small, in-depth workshops on everything from whisky tasting to forensics. And, as always, we have a dedicated schools day on 20 October complete with plenty of explosions and talks from inspiring scientists to get the imagination racing.

New Scientist Live is one of the highlights of my year and I hope to meet many of you there (please say hello!). If you can't make it to London or are reading this after the show is over, all is not lost: the talks will be live-streamed throughout the weekend and will then be available to watch on demand at your leisure. All the information you need to join in the fun is available at newscientistlive.com.

Catherine de Lange
New Scientist editor

Point of no return

A warning that we have triggered Earth's first tipping point must be heard

ALMOST two years ago, at the COP28 climate summit in the heart of the United Arab Emirates petrostate, governments pledged to start "transitioning away from fossil fuels in energy systems" in a bid to achieve net-zero emissions by 2050. Since then, the share of energy generated by fossil fuels globally has remained stubbornly above 80 per cent, as indeed it has done for decades.

As a result of our failure to decarbonise, researchers now believe we have triggered the first of Earth's "tipping points" – moments where we have changed the climate so extensively that it can never fully recover. Ocean water is now so warm that the world's coral reefs are at risk of extensive dieback (see page 9).

What is holding up the energy transition? This question has no easy answers, but an oft-repeated one is that just a handful of companies, mostly fossil fuel firms, are responsible for the vast majority of emissions. Such statements are open to criticism because they place the blame elsewhere, away from us, the customers, who are using their energy.

"Big players in the tech sector are downplaying previous promises to reach net zero"

However, it is fair to point the finger at oil and gas firms that trumpet their green ambitions while failing to deliver. Many of these companies tout their investment in renewables, but the reality is that they have made almost no contribution to what we must insist to be the future of energy production (see page 16).

Unfortunately, things look set to get worse before they get better. Emboldened by the Trump administration, many oil and gas firms have pledged to up production, while big players in other industries like the tech sector are downplaying their promises to reach net zero.

Next month will see governments meet again to talk climate policy, this time at COP30 in Brazil – well, sort of. The US is unlikely to be out in force, while the UK prime minister, Kier Starmer, is yet to confirm his attendance. At this point, it is reasonable to wonder whether any of our political or business leaders are taking the threat of climate change seriously. If they are, they must start acting like it. ▮

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News

Zoology

A new hope for numbats

These adorable baby numbats are among a group of seven that have been recently spotted across two different wildlife sanctuaries in New South Wales, Australia. Conservationists are working to reintroduce the species, which has been extinct in the wild in New South Wales for more than 100 years. These sightings raise hopes that one of the world's rarest marsupials might be making a comeback.

COVER IMAGES/JULIE KERN/AUSTRALIAN WILDLIFE CONSERVANCY

Human evolution

Did our intelligence come with a cost?

Tracing when variations in the human genome first appeared reveals how advances in cognition may have led to our vulnerability to mental illness, finds **Christa Lesté-Lasserre**

A TIMELINE of genetic changes in millions of years of human evolution shows variants linked to higher intelligence appeared most rapidly around 500,000 years ago, and were closely followed by mutations that made us more prone to mental illness.

The findings suggest a "trade-off" in brain evolution between intelligence and mental health conditions, says Ilan Libedinsky at the Center for Neurogenomics and Cognitive Research in Amsterdam.

"Mutations related to psychiatric disorders apparently involve part of the genome that also involves intelligence. So there's an overlap there," he says. "[The advances in cognition] may have come at the price of making our brains more vulnerable to mental disorders."

Humans split from our closest living relatives, chimpanzees and bonobos, more than 5 million years ago. Since then, our brains have tripled in size, with the fastest growth over the past 2 million years. While fossils allow scientists to study such changes in brain size and shape, they can't reveal much about what those brains were capable of doing.

Recently, however, genome-wide association studies have examined many people's DNA to determine which mutations are correlated with traits like intelligence, brain size, height and various kinds of illnesses. Meanwhile, other teams have been analysing specific aspects of mutations that hint at their age, providing estimates of when those variants first appeared.

Libedinsky and his colleagues pulled both methods together for the first time to create an evolutionary timeline of humans' brain-related genetics.

"We don't have any trace of the cognition of our ancestors with regard to their behaviour and their mental issues – you can't find those in the palaeontological records," he says. "We wanted to see if we could build some sort of 'time machine' with our genome to figure this out."

500,000

How many years ago, on average, genetic variants linked to higher intelligence first appeared

The team investigated the evolutionary origins of 33,000 genetic variants found in modern humans that have been linked to a wide variety of traits, including brain structure and various measures of cognition and mental health conditions, as well as physical and health-related features like eye shape and cancer.

They found that most of these genetic variants emerged between about 3 million and 4000 years ago, with an explosion of new ones in the past 60,000 years – around the time *Homo sapiens* made a major migration out of Africa (*Cerebral Cortex*, doi.org/p8wk).

Variants linked to more advanced cognitive abilities evolved relatively recently compared with those for other traits, says Libedinsky. For example, those related to fluid intelligence – essentially logical problem-solving in new situations – appeared about 500,000 years ago on average. That's about 90,000 years later than variants associated with cancer, and nearly 300,000 years after those related to metabolic functions and disorders. Those intelligence-linked variants were closely followed by variants linked to mental health problems, about 475,000 years ago on average.

That trend repeated itself starting around 300,000 years ago, when many of the variants influencing the shape of the cortex – the brain's outer layer, responsible for higher-order cognition – appeared. In the past 50,000 years, numerous variants tied to language evolved, and these were closely followed by variants linked to alcohol addiction and depression.

"Mutations related to the very basic structure of the nervous system come a little bit before the mutations for cognition or intelligence, which makes sense, since you have to develop your brain first for higher intelligence to emerge," says Libedinsky. "And then the mutation for intelligence comes before psychiatric disorders, which also makes sense. First you need to be intelligent and have language before you can have dysfunctions on these capabilities."

GOUPI CHRISTIAN/ROBERT HARDING/ALAMY

As early humans became smarter, they may have been more prone to mental illness

A deeper insight

The dates also line up with evidence suggesting *Homo sapiens* acquired some variants linked to alcohol consumption and mood disorders from interbreeding events with Neanderthals, he says. Why evolution hasn't weeded out variants that predispose for mental health conditions isn't clear, but it might be because the effects are modest and confer advantages in some contexts, says Libedinsky.

"This kind of work is exciting because it allows scientists to revisit longstanding questions in human evolution, testing hypotheses in a concrete way using real-world data gleaned from our genomes," says Simon Fisher at the Max Planck Institute for Psycholinguistics in Nijmegen, the Netherlands.

But this study only examines genetic sites that still vary among living humans – meaning it misses older, now-universal changes that may have been key to our evolution, says Fisher.

Space

General relativity could help aliens survive on planets around dead stars

Jonathan O'Callaghan

PLANETS orbiting dead stars known as white dwarfs might be able to remain habitable thanks to general relativity subtly altering their motion.

When stars like our sun run out of fuel, they expand and become red giants before expelling their outer layers, leaving behind only their dense, hot core – known as a white dwarf. Giant planets have been found orbiting these remnants, suggesting worlds can survive the expansion of the star.

It is also possible that rocky planets could orbit close to these stars inside their small habitable zones, the region around a star where liquid water can exist on the surface of a planet, although none have yet been found. Here they could remain liveable for long periods of time because white dwarfs cool very slowly, possibly over trillions of years.

The habitable zone would be extremely close to the star, within a few million kilometres – tiny compared with Earth's orbit of 150 million kilometres. However, prior research suggests that any larger planet orbiting nearby might make it impossible for life to survive due to tidal heating: the pull of the larger planet would generate internal friction that heats up the smaller one, triggering a runaway greenhouse effect akin to that on Venus.

But this might not always be the case, according to Eva Stafne and Juliette Becker at the University of Wisconsin-Madison. They show that, under the right conditions,

White dwarfs have a habitable zone that is very close to the star

SHUTTERSTOCK/MURATART

Albert Einstein's general theory of relativity can save the inner planet (arXiv, doi.org/p8wc).

General relativity explains how massive objects curve space-time, which we can visualise as a dip or "well" in a flat sheet. Essentially, the gravitational well of the host star would cause the planet's orbit to precess – or slowly rotate – and be misaligned with any companion as the planet dipped in and out of the well.

"Precession happens that decouples the outer planet from the inner planet," says Stafne, preventing extreme tidal effects on the planet.

Without general relativity, any outer planet that is at least the mass of Earth and within an orbit 18 times that of the innermost planet would cause this runaway greenhouse effect, says Becker. But "if you add general relativity in, it's not that dire," she says, with the inner planet able to remain habitable even if the outer planet were as big as Neptune up to a similar distance.

Mary Anne Limbach at the University of Michigan says the prospects of finding such a system are unclear. "We don't even know if there are habitable planets around white dwarfs," she says, let alone one where general relativity is playing a role.

However, the research does provide an unusual set of plausible circumstances where, in the right conditions, inhabitants of a distant world might be kept alive thanks to the curvature of space-time. "Maybe they would have an easier time figuring out what general relativity was than we did," says Limbach.

Health

Behavioural therapy could be the best way to treat IBS

THERAPIES that alter the behaviour of people with irritable bowel syndrome (IBS) may be more effective than standard treatments.

IBS commonly results in bloating, diarrhoea, constipation and abdominal pain. While its causes are unclear, disordered gut-brain signalling is thought to play a major role. Gut infections or certain foods may trigger the gastrointestinal tract to send alarm signals to the brain, while psychological stress can send them the other way, hence why people with IBS are encouraged to find ways to relax.

As somewhat of a last resort, doctors often turn to behavioural therapies, which a 2020 review suggested may be more effective than routine care.

These can include cognitive behavioural therapy (CBT), which helps people change how they think and act to manage their symptoms, and gut-directed hypnotherapy, where people are put into a trance-like state before receiving suggestions that their symptoms are improving.

Alexander Ford at the University of Leeds, UK, and his colleagues – some of whom were involved in the earlier review – have now sifted through 67 randomised-controlled trials, involving more than 7000 participants. These compared behavioural therapies that lasted between four and 12 weeks with various control groups who received standard interventions like dietary advice or laxatives, or who were on a waiting list for therapy.

"These therapies should be rolled out much earlier, with digital approaches helping to deliver at speed"

The researchers found that CBT and gut-directed hypnotherapy – delivered either in-person or via an app or the internet – were more effective than standard treatments, based on the participants comparing their symptoms before and after (*The Lancet Gastroenterology & Hepatology*, doi.org/p8wd).

The findings suggest that behavioural therapies should be rolled out much earlier, with digital approaches helping to deliver at speed, says Ford.

Carissa Wong

Health

Hidden ecosystem of the ovaries plays a surprising role in fertility

Helen Thomson

A NEW imaging technique has revealed a previously unexplored ecosystem within the ovary that may influence how fast human eggs age. The discovery could open new possibilities for slowing ovarian ageing, preserving fertility and improving health after menopause.

Women are born with millions of immature eggs, one of which fully matures each month after puberty. From their late 20s, however, fertility falls sharply – a decline long attributed to dwindling egg number and quality.

To better understand what drives this decline, Eliza Gaylord at the University of California, San Francisco, and her colleagues developed a 3D imaging technique that lets researchers visualise eggs without slicing the ovary into thin layers, the standard approach.

These images showed that eggs aren't evenly distributed, as we thought, but cluster in pockets, which suggests that the local environment within the ovary might shape how eggs age and mature (*Science*, doi.org/g958gh).

"The discovery could open new possibilities for slowing ovarian ageing and preserving fertility"

By combining this imaging with single-cell transcriptomics, a technique that identifies cells based on the genes they express, the team analysed more than 100,000 cells from mouse and human ovaries. The samples came from mice aged between 2 and 12 months, and from four women aged 23, 30, 37 and 58.

In doing so, the researchers found 11 major cell types, and a few surprises. One surprise was finding glial cells, normally associated with the brain – where they nourish neurons, clear debris and aid repair – as well as sympathetic nerves, which mediate the body's fight-or-flight response. In mice whose sympathetic nerves had been removed, fewer eggs matured, suggesting these nerves play a role in deciding when eggs grow.

They also found that fibroblasts, cells that provide structural support, decline with age, which seemed to trigger inflammation and scarring in the ovaries of the woman in her 50s.

All this suggests ovarian ageing isn't simply about the eggs, but also the whole ecosystem, says team member Diana Laird. But the most important thing, she says, is the similarity between mice and human ovarian ageing.

"The similarity lays the foundation for using laboratory mice to model human ovarian ageing," says Laird. "With that road map, we can begin understanding the mechanisms that maintain the rate of ageing in the ovaries so that we can develop therapies to slow or even reverse the process."

One potential route, she says, is to modulate sympathetic nerve activity to slow the loss of eggs, potentially extending the reproductive window and deferring menopause.

In theory, this would not only preserve fertility, but also reduce the risk of conditions that are more common after menopause.

Evelyn Telfer, at the University of Edinburgh, UK, whose team was the first to grow human eggs outside an ovary, points out that interpretation of the results is limited by the cell samples coming from just four women, with a relatively narrow age range. ▮

Palaeontology

'Sword Dragon' ichthyosaur had a lethal snout

MEET the "Sword Dragon", a newly named species of ichthyosaur – predatory prehistoric reptiles that dominated the oceans while dinosaurs ruled the land.

The beautifully preserved fossilised skeleton was found on the UK's Jurassic Coast near an area called Golden Cap back in 2001. Dean Lomax at the University of Manchester, UK, and his colleagues have now prepared and identified the specimen, which has an enormous eye socket and a long, sword-like snout (*Papers in Palaeontology*, doi.org/g96bbm).

"You can get a good sense of how this thing would have been in life, basically relying on really good vision to hunt, probably in dim conditions," says Lomax.

DR DEAN LOMAX

Researchers Dean Lomax (left) and Judy Massare (right) with the fossilised skeleton

The animal would have been around 3 metres long – about the size of a common bottlenose dolphin – and lived during an age of the Early Jurassic called the Pliensbachian, some 193 million to 184 million years ago.

It has features that have never before been seen in an ichthyosaur, including a unique bone around the nostril called a lacrimal with prong-like structures. Because of the lethal-looking snout, the researchers have named the ichthyosaur *Xiphodracon goldencapensis*, or the Sword Dragon from Golden Cap.

The specimen also reveals something about ichthyosaur evolution. "Triassic ichthyosaurs were notoriously weird," says Neil Kelley at Vanderbilt University in Tennessee. "And their Jurassic descendants have often been seen as a bit more 'samey' in sharing a superficially similar dolphin-like appearance.

"*Xiphodracon* adds another hue to the broader ichthyosaur rainbow," he says, by contributing to the evidence Jurassic ichthyosaurs pursued a variety of lifestyles, with differing diets, swimming speeds and preferred habitats. ▮

Chris Simms

Climate change

Coral reefs are at a tipping point

The bleaching of warm-water corals has reached a critical threshold, which could have far-reaching consequences for the climate, discovers **Madeleine Cuff**

A RECENT surge in ocean temperatures has caused the widespread bleaching and death of warm-water corals around the world, officially triggering the first climate tipping point for one of Earth's ecosystems, scientists have declared.

The collapse of one of the world's most diverse and fragile ecosystems poses a "human health and security hazard" that governments are unprepared for, warns Melanie McField at Healthy Reefs for Healthy People, a conservation programme operating in Central America.

Warm-water coral reefs support up to one-third of all known marine biodiversity and provide food, coastal protection and a source of income for up to a billion people around the world. Reef services contribute up to $9.9 trillion annually in goods and services worldwide.

Yet corals are highly sensitive to changes in water temperature. Record-breaking global temperatures documented since 2023 have pushed ocean heat levels to new highs, triggering a mass bleaching event that has affected more than 80 per cent of all the world's corals. Bleaching is when corals expel the algae living in their tissues in response to high water temperatures, which turns them white. This leaves corals vulnerable to disease, and prolonged bleaching can kill them off altogether by depriving them of their primary food source.

"This demands immediate action from leaders at COP30 and policy-makers worldwide"

The latest bleaching event has been a "different order of magnitude" to anything scientists have previously witnessed, says McField. "We're in the tipping point." This is generally defined as a critical threshold that, if passed, could cause dramatic and probably irreversible changes in the climate system.

JURGEN FREUND/NATURE PICTURE LIBRARY/ALAMY

Bleaching turns corals white and leaves them vulnerable to disease

McField was one of the authors of the chapter on corals in the Global Tipping Points Report 2025, released this week. The report, the first update since 2023, is compiled by 160 scientists from around the world and co-ordinated by the University of Exeter in the UK and campaign group WWF. It warns that warm-water corals are the first Earth system to cross over into their tipping point and are now in the throes of an "unprecedented crisis".

Estimates suggest that the thermal limit of warm-water corals is reached when global atmospheric temperatures hit 1.2°C above pre-industrial levels, with an upper threshold of 1.5°C. In 2024, global average temperatures exceeded 1.5°C above pre-industrial levels for the first time in recorded history, an event that has pushed the world's coral reefs beyond the limits of their endurance, according to Tim Lenton at the University of Exeter, who led the report.

Mitigating the risk

"We've taken a sample of the 1.5°C world, and we have seen the consequences," he told reporters at a press briefing ahead of the report's launch. "A majority of coral reefs are under risk of extensive dieback [or bleaching] and tipping into the alternative seaweed-dominated, algal-covered state."

The best hope of saving the world's warm water corals from almost complete extinction now lies in bringing global average temperatures down to 1.2°C above pre-industrial levels as soon as possible, he says. Whether or not such an ambitious goal – which goes well beyond the demands of even the 1.5°C temperature target – is feasible to achieve is a separate question, says Lenton.

Terry Hughes at James Cook University in Australia warns there are now "almost no unbleached reefs left anywhere in the world". But the situation can still be mitigated. "Where coral reefs end up in the next few decades is under our control, if global greenhouse gas emissions are rapidly curtailed," he says.

Often the point at which climate tipping points could be triggered is highly uncertain, but researchers warn the widespread decline of the Amazon rainforest, the melting of polar ice sheets and the collapse of the crucial AMOC ocean current could all happen at warming levels below 2°C.

But people can also trigger "positive tipping points" to mitigate the risk, Lenton stresses, highlighting the exponential growth of renewable energy over the past decade and the quick take-up of electric vehicles. Rapid adoption of cleaner technologies has the potential to deliver emissions cuts at the scale needed to keep warming below 2°C, the report notes.

In a statement, Lenton said urgent action is needed from world leaders at the upcoming COP30 summit in Brazil to minimise the amount of time global temperatures spend above 1.5°C. "We are rapidly approaching multiple Earth system tipping points that could transform our world, with devastating consequences for people and nature. This demands immediate, unprecedented action from leaders at COP30 and policy-makers worldwide," he said. ▮

Analysis Conservation

Would a ban on genetic engineering of wildlife hamper conservation?

Some groups are calling for an effective block on genetic modification, but others say it is crucial for preserving biodiversity, explains **Michael Le Page**

SHOULD we genetically modify wild lions? Of course not, might be your instant response. But what if lions were being wiped out by a devastating disease introduced by people? What if the genetic change was a tiny tweak that makes them immune to this disease, of the sort that might evolve naturally given enough time?

These kinds of questions are dividing conservationists, and matters are about to come to a head. As *New Scientist* went to press, delegates at a meeting of the International Union for Conservation of Nature (IUCN) – the world's leading conservation organisation – were preparing to vote on a motion that would "pause" any form of genetic engineering of wildlife, including the introduction of modified microbes.

"I have no idea how the vote will go," says Piero Genovesi at the Institute for Environmental Protection and Research in Italy, who helped draft an open letter opposing the proposed motion.

An IUCN moratorium on synthetic biology would have no legal force, but it could still have far-reaching effects. For instance, many conservation organisations might stop funding work involving genetic engineering, and some countries could make such a ban part of national laws.

"The moratorium would certainly be problematic on many levels," says Ben Novak at Revive & Restore, a US-based non-profit organisation that aims to use biotechnologies to rescue endangered and extinct species.

Why is this happening now? In a word, CRISPR. In 2014, it was shown that CRISPR gene-editing technology can be used to create gene drives – basically, a piece of DNA that gets passed down to all offspring, rather than the usual half. This means a gene drive can spread even if it is harmful and could, in theory, be used to wipe out invasive species. Gene drives could also be used to spread beneficial traits, such as disease resistance.

At a conference in Hawaii in 2016, there was talk of using gene drives to get rid of the invasive mosquitoes that have wiped out half of Hawaii's native bird species, says Genovesi. Some conservationists were enthusiastic; others were horrified.

That triggered the events leading to the proposed moratorium. "Gene drives are being pushed quite strongly by some as the panacea for dealing with all sorts of environmental problems," says Ricarda Steinbrecher at EcoNexus, a research organisation among those backing a moratorium.

But the broad wording of the proposed motion applies to far more than gene drives. It would rule out most de-extinction efforts, for instance, and could also be seen as banning live vaccines.

Steinbrecher says a moratorium is a pause, not a permanent block, and that there could be another vote to end it "when we have more data". But some of those backing the ban are campaign groups opposed to any genetic engineering, so it is hard to see what would change their minds. "I am afraid it could be a very long ban," says Genovesi.

> **"We are facing a crisis of biodiversity. We shouldn't close the door to new tools that could help us"**

Take the idea of using gene editing to make wild animals resistant to diseases. Steinbrecher says gene editing could have unintended side effects. But the evidence we have suggests the risks are low – which is why several gene-edited foods are already being eaten, and why the first CRISPR treatment for people was approved last year.

SERGEY GORSHKOV/NATUREPL.COM

Wild lions are one species that could benefit from genetic modification

The same benefits-versus-risks considerations apply with conservation. Is it really better to stand by and watch coral reefs being wiped out by global warming than to, say, release genetically engineered algal symbionts that give corals more heat tolerance?

A key issue is scalability, says Novak. Divers transplanting corals by hand are never going to save reefs. "This is where synthetic biology tools are vital," he says. "The overall goals of restoring 30 per cent of land to nature, of saving species, etc., will not be attainable without synthetic biology."

Ultimately, this is about competing visions of nature. Some see nature as sacrosanct, and are appalled by the idea of any genetic meddling. But humans have been transforming nature ever since we wiped out most megafauna.

Hunting, pollution, pesticides, invasive species and introduced diseases are forcing many plants and animals to change to survive. Some elephant populations are nearly tuskless, for instance.

Of course, this doesn't mean that more meddling will make things better. There are indeed serious risks to releasing gene drives – for example, gene drives designed to wipe out invasive species might spread to the native range of the target species.

But researchers are very aware of the risks. And there are ways to reduce them, for instance by making gene drives self-limiting so they cannot just spread indefinitely.

"We are facing a dramatic crisis of biodiversity," says Genovesi. "We shouldn't close the door to new tools that could help us combat some of the major threats." ▮

Technology

Robotic underwater glider sets out on five-year voyage

David Hambling

A SMALL robot submarine is circumnavigating the globe for the first time. Teledyne Marine and Rutgers University New Brunswick in New Jersey launched an underwater glider called Redwing on its Sentinel Mission from Martha's Vineyard in Massachusetts on 11 October.

Rather than a propeller, gliders have a buoyancy engine, a gas-filled piston that slightly changes the craft's overall buoyancy. An electric motor pushes the piston in to make the glider heavier than water so it slowly sinks, coasting downwards at a shallow angle. On reaching the bottom of the dive at around 1000 metres, the piston is pulled out and the submarine, now buoyant, glides upwards.

"Redwing will be gliding with the currents rather than fighting them, travelling at an average speed of 0.75 knots", or almost 1.4 kilometres per hour, says Shea Quinn at Teledyne Marine, who is leading the Sentinel Mission. At 2.57 metres long, Redwing is no bigger than a surfboard, but weighs 171 kilograms.

"The historic Sentinel Mission aims to achieve its circumnavigation in around five years," says Brian Maguire at Teledyne Marine.

Redwing will follow the path of explorer Ferdinand Magellan's 1519-1522 circumnavigation, calling at Gran Canaria off north-west Africa, Cape Town in South Africa, Western Australia, New Zealand, the Falkland Islands in the South Atlantic and possibly Brazil, before returning to Cape Cod, a trip of around 73,000 kilometres.

Redwing will gather data on ocean currents and sea temperature in relatively unknown regions, transmitting it via satellite several times a day. This will be shared with universities, schools and other institutions, but the main aim is to highlight the capabilities of gliders and inspire future missions. ▮

Archaeology

King Richard III may have had a severe gum disease

Chris Simms

CARL VIVIAN/UNIVERSITY OF LEICESTER

The skull of King Richard III, which was discovered in 2012

THE oral microbiome of King Richard III of England has been assembled by investigating the plaque on his teeth, and it suggests he had a disease that can destroy the jaw.

In 2012, skeletal remains were discovered beneath a car park in Leicester, UK, on the grounds of the former Greyfriars church. The remains were suspected to belong to Richard III – who was killed in the battle of Bosworth Field in 1485 and brought to lie in state in Leicester. Genetic analysis confirmed it was him.

To learn more about him, Turi King at the University of Bath, UK, and her colleagues scraped off samples of the dental calculus, or hardened plaque, on three of his well-preserved teeth.

They did this because plaque can work like a time capsule, preserving the DNA of microbes or food. "The amount of DNA recovered from the calculus of King Richard III is among the highest we have ever measured from an archaeological context," they wrote in a paper where they reported detecting more than 400 million DNA sequences.

"No one has sequenced ancient DNA to 400 million sequences, that's just astronomical," says Laura Weyrich at Pennsylvania State University. "It shows to us that we can probably do things with ancient DNA that we didn't think we could do before."

King and her colleagues identified nearly 400 microbial species from the DNA. The

"Oral hygiene in the 15th century was poor, and King Richard III had cavities when he died"

number and types of species were similar to those detected in well-preserved dental calculus samples from England, Ireland, Germany and the Netherlands from the past 7000 years, spanning the Neolithic period to the present (bioRxiv, doi.org/p8wh). "It's telling us that elite people have the sort of same microbial strains [as everyone else], despite this extravagant lifestyle, despite the travelling he would have done and the wars," says Weyrich.

The team couldn't recover enough plant or animal DNA to investigate Richard's diet. But a previous analysis of his bones revealed that, in the last two years of his life, he consumed non-local wine and many game animals, fish and birds such as swans, herons and egrets.

However, Weyrich says the microbiome results might be different if the team were to zoom in on a sample from one part of one tooth and compare that against samples from the equivalent tooth in other populations, like those in Germany or the Netherlands. We also have different bacteria in the front of our mouth versus the back, and inside teeth versus outside, so the team's limited samples can't tell us too much about Richard's oral microbiome as a whole, she says.

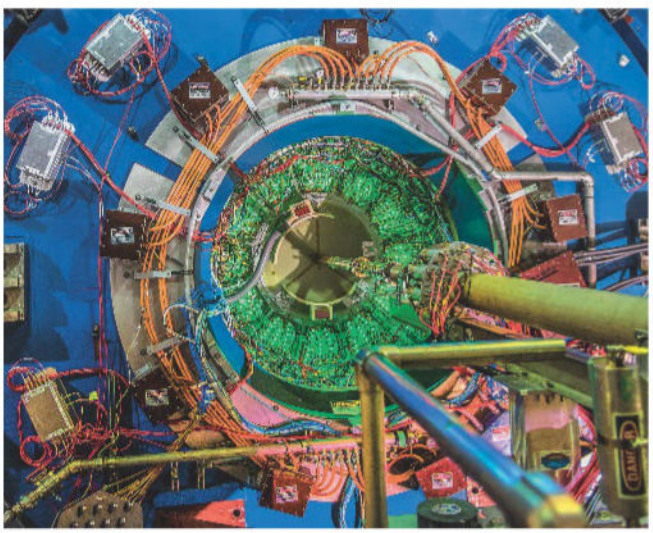
Nevertheless, one abundant bacterium was *Tannerella forsythia*. This has been linked to periodontal disease, a serious gum infection that destroys the bone that supports teeth. Oral hygiene in the 15th century was poor, and Richard had cavities when he died aged 32, but this doesn't mean he necessarily had periodontal disease.

"One person can be colonised by potentially pathogenic bacteria and they will never cause any disease, whereas other people may have an infection," says Pierre Stallforth at the Leibniz Institute for Natural Product Research and Infection Biology in Germany. Weyrich says an analysis that looks for bone loss in his jaw would be needed to tell whether Richard had periodontal disease. ▮

Physics

Uncovering when nature's strongest force falters

Karmela Padavic-Callaghan



BROOKHAVEN NATIONAL LABORATORY

The STAR detector at the Relativistic Heavy Ion Collider

WE ARE getting closer to understanding when the strong nuclear force loosens its grip on the most basic constituents of matter, letting quarks and gluons inside particles abruptly turn into a hot particle soup.

There is a special combination of temperature and pressure at which two phases of water – liquid and vapour – exist simultaneously. For decades, researchers have been looking for a similar "critical point" for matter governed by the strong nuclear force, which binds quarks and gluons into protons and neutrons.

Smashing ions in particle colliders can create a state where the strong force breaks down and allows quarks and gluons to form a soupy "quark-gluon plasma". But it remains murky whether this transition is preceded by a critical point. Xin Dong at Lawrence Berkeley National Laboratory in California and his colleagues have now got closer to clearing it up.

They analysed the number and distribution of particles created in the aftermath of a smash-up of two very energetic gold ions at the Relativistic Heavy Ion Collider at Brookhaven National Laboratory in New York state. Dong says they were effectively trying to create a phase diagram

"Smashing ions in particle colliders can create a state where the strong force breaks down"

for quarks and gluons – a map showing what types of matter the strong force allows to form under different circumstances. The new experiment didn't pin down the critical point on this map with great certainty, but it significantly narrowed the region where it could be (*Physical Review Letters*, doi.org/g95ccr).

There is a part of the phase diagram where matter "melts" into plasma gradually, like butter softening on the counter, but the critical point would align with a more abrupt transition, like chunks of ice suddenly appearing in liquid water, says Agnieszka Sorensen at the Facility for Rare Isotope Beams in Michigan. The new experiment will serve not only as a guide for where to look for this point, but it has also revealed which particle properties may offer the best clues that it exists, she says.

Claudia Ratti at the University of Houston in Texas says that many researchers have been excitedly anticipating this new analysis because it yielded a precision that previous measurements couldn't achieve, and did so for a part of the phase diagram where theoretical calculations are notoriously difficult. Recently, several predictions for the critical point location have converged, and the challenge for experimentalists will be to analyse the data for the even lower collision energies corresponding to these predictions, she says.

An unambiguous detection of the critical point would be a generational breakthrough, says Dong. This is in part because the strong force is the only fundamental force that physicists suspect has a critical point. Additionally, this force has played a significant role in shaping our universe: it governed the properties of hot and dense matter created right after the big bang, and it is still dictating the structure of neutron stars. Dong says collider experiments like the new one could help us understand what goes on inside these exotic cosmic objects once we complete the strong force phase diagram. ▮

Ageing

We've found a new reason why naked mole rats live so long

Michael Le Page

NAKED mole rats live for up to 37 years – far longer than other rodents their size. Their longevity could be down to a variant of an immune protein that boosts DNA repair. This discovery might lead to therapies that extend human lifespans, says Zhiyong Mao at Tongji University in Shanghai, China.

The immune protein cGAS is found in many animals and sounds the alarm when it detects DNA outside the nucleus of a cell, which could be a sign of cancer or a viral attack.

But cGAS is also found in the nucleus of cells. In humans and mice, it suppresses DNA repair, increasing the mutation rate and risk of cancer.

Mao's team has found that the cGAS in naked mole rats has the opposite effect in the nucleus, boosting DNA repair (*Science*, doi.org/p8vx). This is due to differences in four of the amino acids that make up the cGAS protein. If these amino acids are altered in mole rat cells, cGAS no longer boosts DNA repair. And if these are changed in human cGAS, it no longer inhibits DNA repair.

What's more, when the team genetically engineered fruit flies to produce the naked mole rat version of cGAS, they lived nearly 10 days longer than unmodified flies.

Making human cells produce the naked mole rat cGAS could be a way to extend our lives, says Mao. But altering enough of the key cells in our bodies wouldn't be easy, he says. ▮

Naked mole rats live far longer than other rodents their size

TENNESSEE WITNEY/ALAMY

Health

First pig-to-human liver transplant

Breakthrough operation shows how animal organs could help prolong, or even save, lives

Carissa Wong

TRANSPLANTING organs from non-human animals into people could potentially save thousands of lives that are lost while people wait for organs. Scientists have experimented with giving people pig hearts and kidneys, and have now reported transplanting the animal's liver into a living person for the first time.

"This is really, really groundbreaking," says Heiner Wedemeyer at Hannover Medical School in Germany, who wasn't involved in the procedure. "The patient was close to dying, but due to the transplant, he survived for half a year."

The liver's complexity meant such surgeries had been trialled only in brain-dead people, with signs of success. "The heart is just a muscle pumping blood," says Wedemeyer. "The kidney is also easy, because it needs only to clear things from the body. But the liver is different because it produces so many different proteins involved in so many metabolic processes."

The heart and kidney transplants in living people also showed signs of early success, but complications later arose.

Now, Beicheng Sun at Anhui Medical University in China and his colleagues have reported the transplantation of a pig's liver into a 71-year-old man (*Journal of Hepatology*, doi.org/g9558c). The recipient's liver function was considered too poor for a conventional transplant, due to a large tumour and heavy scarring from a hepatitis B infection.

Surgeons transplanted a pig liver into the body of a 71-year-old man

DR. XIANFU LU

The man still required some form of transplant, though, as his tumour could have fatally ruptured at any moment, says Sun. With the recipient's permission, in May 2024, the team conducted a five-hour operation to replace the right part of his liver, containing the tumour, with one from an 11-month-old miniature pig. To stop the liver being rejected by his immune system, three genes were deactivated in the pig and seven genes were introduced, so the organ functioned more like a human one. The man also took immune-suppressing drugs.

Almost immediately, the liver began secreting bile, a fluid the organ produces to help break down fat from food. Within weeks, the man's levels of bile and albumin – a protein made by the liver that prevents too much fluid leaking from blood vessels – had increased to healthy amounts, says Sun.

But about a month later, he developed life-threatening clots in his blood vessels, forcing the team to remove the transplant. That was probably partly caused by it excessively activating part of the recipient's immune system and producing abnormal levels of some blood-clotting proteins, which healthy livers also make. This is probably more likely to occur with pig transplants, due to how different the animal is from a human, says Sun.

The man lived for another five months with his remaining liver, then died from stomach bleeding, which is common with liver scarring, says Sun. Both Sun and Wedemeyer say the bleeding was probably unrelated to the transplant. ▮

Space

A black hole fell into a star – then ate its way out again

A BLACK hole that was eaten by a star seems to have gotten revenge by consuming the star from the inside, producing a gamma-ray burst spotted about 9 billion light years from Earth.

The burst, called GRB 250702B, was first spotted by NASA's Fermi Gamma-ray Space Telescope in July. Such bursts are bright flashes caused by jets fired out from energetic events, such as massive stars collapsing into black holes, and they usually last for a few minutes.

GRB 250702B, however, lasted for 25,000 seconds – or about 7 hours – making it the longest-known gamma-ray burst. Scientists had struggled to explain it, but Eliza Neights at NASA's Goddard Space Flight Centre in the US and her colleagues now suggest an unusual and rare possibility.

"The only [model] which naturally explains the properties observed in GRB 250702B is the fall of a stellar-mass black hole into a star," the researchers write.

In more-typical long gamma-ray bursts, a massive star collapses to form a black hole, launching jets as it dies. In this case, the team suggests the reverse – a pre-existing black hole spiralled into a companion star whose outer layers had expanded late in its life, causing the black hole to lose angular momentum and fall towards the star's core.

The black hole would then have consumed the star from the inside out, producing the powerful jets seen as GRB 250702B and possibly triggering a faint supernova, albeit one that was too dim to detect at this distance, even with the James Webb Space Telescope (arXiv, doi.org/p8wp).

"The black hole consumed the star from the inside out, possibly triggering a faint supernova"

This explanation makes sense for how an ultra-long burst like this might occur, says Hendrik van Eerten at the University of Bath in the UK.

Neights and her colleagues hope that more events like this might be observed in the future. For now, this gamma-ray burst remains "an absurdity", says Van Eerten. ▮

Jonathan O'Callaghan

Health

What type of sleeper are you?

Scientists have identified five sleep profiles, each linked to distinct patterns of brain activity

Grace Wade

PEOPLE may experience one of five types of sleep, and these profiles each highlight how our shut-eye affects our health.

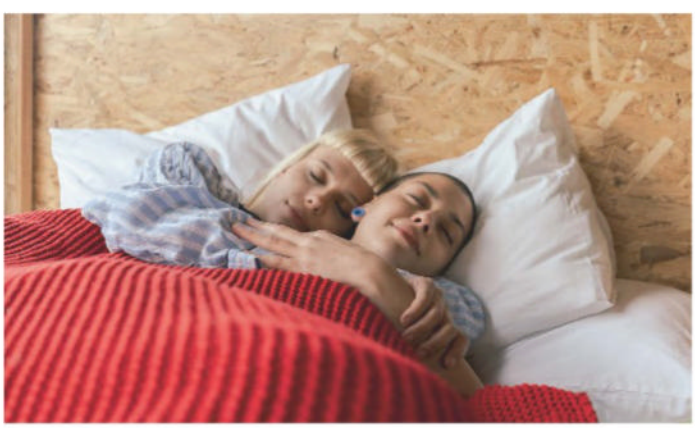
Valeria Kebets at Concordia University in Montreal, Canada, and her colleagues analysed the association between seven factors related to sleep – such as sleep satisfaction and the use of sleeping aids – and 118 other measures, including cognition, substance use and mental health. They collected data including cognitive tests, sleep surveys and brain scans from 770 healthy adults aged between 22 and 36 in the US.

From this, they identified five distinct sleep profiles (*PLoS Biology*, doi.org/g953f9). The first was characterised by a general pattern of poor sleep – greater sleep disturbances and taking a longer time to fall asleep – and worse mental health, such as depression and anxiety symptoms.

The brain scans of people in this group showed decreased connectivity between networks involved in self-reflection and those responsible for attention.

People in the second sleep profile also showed signs of worse mental health, particularly related to inattention, but had decent sleep overall. "We have interpreted this as sleep resilience," says Kebets. "So worse mental health, which doesn't necessarily affect sleep." People who fit this profile also lacked the brain connectivity patterns seen with the first group, which suggests these patterns are specifically related to sleep issues, rather than overall mental health.

Some people enjoy more restful sleep than others



LAJST/GETTY IMAGES

Meanwhile, the third profile exhibited a relationship between using sleep aids – such as prescription medication or even teas marketed as helping sleep – and poorer memory and emotional recognition, which is the ability to identify someone's emotional state through cues such as their body language. This could explain why people who fit this profile had decreased connectivity in brain regions involved with vision, memory and emotion.

The fourth profile was distinguished by getting fewer than 7 hours of sleep a night, the minimum recommended amount. This was associated with worse accuracy and longer reaction times on cognitive tests measuring emotional processing, language and social skills. It was also associated with more aggressive behaviours and increased connectivity across brain networks.

Aggression also occurred in the fifth profile, characterised by sleep disturbances, such as waking multiple times a night. These disturbances were associated with worse language processing and working memory, as well as signs of poorer mental health, such as anxiety symptoms and substance use.

But not all of the participants fit neatly into one profile, says Kebets. They also didn't find evidence of causal relationships between sleep profiles and traits. There will be a significant proportion of people who regularly experience good-quality sleep. Also, the participants were mostly white, so the study may have missed profiles that exist among other ethnicities. ▮

Physics

Swirly lasers control an ungovernable cousin of magnetism

RESEARCHERS have taken control of a previously elusive material behaviour, similar to magnetism, that could be used to build better hard drives in the future.

If you place a bar magnet in a magnetic field, it will rotate under the field's influence, but a material that has a property called ferroaxiality remains unmoved in every field that physicists know of. Now, Zhiyang Zeng at the Max Planck Institute for the Structure and Dynamics of Matter in Germany and his colleagues have figured out how to control ferroaxiality with a laser.

You can think of common magnetic materials as made of many tiny bar magnets. Zeng says that for ferroaxial materials, it is more accurate to imagine a collection of dipoles – two opposite electric charges separated by a small distance – that swirl around in tiny whirlpools.

Zeng and his colleagues realised that they could control these whirlpools with pulses of laser light, but only if that light also contained some swirliness.

They tuned their lasers to produce circularly polarised light, which, when it hit a ferroaxial material – in this instance a compound of rubidium, iron, molybdenum and oxygen – imparted some rotation onto the material's atoms. This switched the direction of motion of the dipoles (*Science*, doi.org/p8vw).

"As a proof of principle, this is a beautiful result," says Theo Rasing at Radboud University in the Netherlands. He says it adds the material to a growing array of options for building more efficient and stable memory devices – hard drives where information is stored in patterns of electromagnetic charge.

"Controlling this material's behaviour could help us build more efficient and stable memory devices"

But the experiment currently requires cooling the material to about -70°C (-94°F) and the team's laser was rather large, so more work is needed before building practical devices becomes a real possibility, says team member Michael Först. ▮

Karmela Padavic-Callaghan

Space

We may have just solved a cosmic matter mystery

UNEXPECTEDLY violent black holes may explain why some matter in the universe seemed to have been missing.

Most of the universe is filled with mysterious dark matter, but even ordinary matter has stumped cosmologists. Some of this normal matter – made up of particles called baryons – seemed to have been missing for a long time. Researchers recently worked out where it was hiding (arXiv, doi.org/p8qd), and now Boryana Hadzhiyska at the University of California, Berkeley and her colleagues have learned how black holes may have shaped its distribution and kept it hidden.

"Black holes at the centre of galaxies are ejecting matter in a surprisingly violent way"

"Matter consists of dark matter, which is the predominant component, and baryonic matter or, essentially, gas. For that gas, only about a few per cent is in the form of stars, and the rest of it is in the form of diffuse gas," she says. Diffuse gas is dim and hard to observe, but her team combined several observations to track it down.

One dataset they used shows how baryon matter casts a shadow on the leftover radiation from the big bang, the cosmic microwave background. Another key piece of the puzzle came from analysing the way that afterglow is distorted by the gravitational fields of massive objects. By combining these, the team determined where dark matter and baryonic matter stick together and where they diverge, both within and between galaxies (*Physical Review D*, doi.org/p8qc).

Hadzhiyska says it was exciting to find that baryonic matter is a lot more spread out than dark matter, which indicates supermassive black holes at the centres of galaxies must be ejecting it in an unexpectedly violent way.

"Understanding exactly how this process happens and how strong it is, so how much of the matter can actually get ejected from a given galaxy has [so far] remained extremely uncertain," says Colin Hill at Columbia University in New York. Researchers can use computer simulations to model galaxies and their evolution, but to get this detail right, analyses like this new one are crucial, he says. "It gives us a complementary probe to understand the role of supermassive black holes in moving gas around galaxies," says Alex Krolewski at the University of Waterloo in Canada.

Hadzhiyska says such analyses could also help resolve ongoing disputes about the universe's clumpiness – how ordinary matter and the invisible dark matter scaffolding of the universe bunch together across space thanks to gravity. Her team is now looking to add even more types of observations to their analysis – for instance, the way short bursts of cosmic radio waves pass through the diffuse baryon gas. An even better "baryon census" with fewer uncertainties is still necessary, says Michael Shull at the University of Colorado Boulder.

Could this uncover some oddity in matter distribution that sends theorists back to the drawing board? "My hope is that dark matter is the thing where we start seeing deviations [from the standard model of cosmology]," says Hadzhiyska. ▮

KPC

Chemistry

Bamboo is fantastic used as plastic

Alex Wilkins

CAROLYN FRANKS/ALAMY

HARD plastic made from bamboo is as strong as conventional plastics for uses such as household appliances, but is also recyclable and biodegradable.

Plastics derived from biological matter, or bioplastics, only make up around half a per cent of the more than 400 million tonnes of plastics produced each year. This is, in part, because they lack the mechanical strength of many oil-based plastics and can't be easily used in common manufacturing processes.

Now, Dawei Zhao at Shenyang University of Chemical Technology in China and his colleagues have developed a way to produce plastic from cellulose derived from bamboo, which can replicate or surpass the properties of many widely used plastics.

"Bamboo's rapid growth makes it a highly renewable resource, providing a sustainable alternative to traditional timber sources, but its current applications are still largely limited to more traditional woven products," says Zhao.

Zhao and his team first treated the bamboo by adding zinc chloride and a simple acid, which breaks down the strong chemical bonds and produces a soup of smaller cellulose molecules.

Bamboo's rapid growth makes it a highly renewable resource

They then added ethanol, which makes the cellulose molecules rearrange into a strong, solidified plastic (*Nature Communications*, doi.org/g953gb).

The plastic's toughness is comparable to commonly used engineering plastics – strong plastics used in vehicles, appliances and construction, says Andrew Dove at the University of Birmingham in the UK.

"It's not something that's going to challenge the use of the main plastics we use in packaging, like polyethylene and polypropylene," says Dove. "But while it's targeting a smaller set of engineering plastics, it could still help alleviate some of the sourcing concerns of the incumbent [plastics] in that area."

Although it isn't as cheap as some of the most commonly used plastics, Zhao and his team found that it can be completely recycled while keeping 90 per cent of its original strength. They also report that it is biodegradable within 50 days, although this claim has failed to stand up to scrutiny for other biodegradable plastics. ▮

Green energy

Oil and gas firms aren't living up to renewable power promises

Chris Stokel-Walker

LEADING oil and gas companies own less than 1.5 per cent of the world's renewable power capacity – raising questions about how committed they are to the green energy transition, despite their public claims.

Marcel Llavero Pasquina and Antonio Bontempi at the Autonomous University of Barcelona looked at ownership records of more than 53,000 wind, solar, hydroelectric and geothermal projects worldwide, as tracked by Global Energy Monitor, a non-governmental organisation. They then cross-checked these to see what proportion of them were owned by the world's 250 biggest oil and gas companies, which are collectively responsible for 88 per cent of global hydrocarbon output.

Many fossil fuel firms have pledged to invest in renewable energy sources as the world attempts to transition away from oil and gas, but the researchers found that the top firms own just 1.42 per cent of the total operating renewable capacity globally (*Nature Sustainability*, doi.org/p8sp). More than half of that – some 54 per cent – was owned via acquisitions, rather than companies developing their own projects. By calculating the total energy output of the 250 firms, the pair found that renewable power accounts for just 0.13 per cent of the energy produced by these companies.

1.42%
How much of the world's renewable power belongs to the top 250 oil and gas companies

"The results were surprising, even for me," says Llavero Pasquina. "I knew they were playing a very little role in the energy transition. I knew it was only for show. It was only for dressing their narrative. But I didn't expect this low number."

CITIZEN OF THE PLANET/ALAMY

Large fossil fuel companies have only small solar investments

Llavero Pasquina and Bontempi are both part of a group called Environmental Justice, which aims to produce research to "study and contribute to the global environmental justice movement". Llavero Pasquina says his campaigning position strengthens his research. "You have the biggest interest in being as rigorous as possible, because you have to convince and you have to show what's true."

The fact that big energy firms, which have made their fortunes through oil and gas exploitation, aren't massive players in renewables is unsurprising, says Thierry Bros at Sciences Po in Paris. "At the end of the day, [the energy transition] has to be something disruptive, and it's not going to be in the hands of those companies."

However, Bros does think the big energy firms are unduly promoting their work on the energy transition. "They are portraying themselves [as] doing something, but I think if they were to do something, it would be more the carbon capture and sequestration," he says, which involves capturing carbon as it is emitted, for instance when burning fossil fuels.

Offshore Energies UK, an industry body that represents the UK's offshore energy industry, including oil, gas, wind, carbon capture and hydrogen, declined to comment directly on the study's findings. However, it pointed to a previous statement from its chief executive, David Whitehouse. "Far from being in conflict, oil and gas, wind, and emerging low-carbon technologies are part of one integrated system. It is the skills of our people, the same people who built the North Sea that will deliver this transition," he said. ▮

Technology

Ultra-thin memory chips could boost data storage

Matthew Sparkes

WORKING memory chips just 10 atoms thick could lead to radically larger storage capacity in electronic devices like smartphones.

After decades of miniaturisation, current computer chips often cram tens of billions of transistors into an area the size of a fingernail. But while the size of components on a silicon wafer has become extremely small, the wafers themselves remain relatively thick – meaning there are limits to how much you can increase chip complexity by stacking multiple layers together.

Scientists have been working on thinner chips made from so-called 2D materials such as graphene, which is formed of a single layer of carbon atoms and is theoretically as thin as a material can be. But until now, only simple chip designs could be constructed with such materials, and it has been tricky to connect them to traditional processors.

Now Chunsen Liu at Fudan University in Shanghai and his colleagues have combined a 2D chip around 10 atoms thick with a type of chip currently used in computers called CMOS. The way these chips are manufactured leaves a rough surface, which makes it difficult to lay a 2D sheet over it. Liu and his team overcame this by separating the 2D chip from the traditional CMOS chip with a layer of glass, which isn't part of current processes and would need to be industrialised before mass production.

The team's prototype working memory module achieved more than 93 per cent accuracy in tests (*Nature*, doi.org/p8st). Although this falls far short of the reliability needed for consumer devices, it is a promising proof of concept.

"This is a very interesting technology with huge potential, but still a long way to go before it is commercially viable," says Steve Furber at the University of Manchester, UK. ▮

Health

Selfish sperm pose genetic risk

DNA analysis finds older fathers have more chance of bestowing disease-causing mutations

Michael Le Page

OLDER fathers' chances of passing on disease-causing mutations to their children is higher than we thought. Genome sequencing has revealed that among men intheir early thirties, around 1 in 50sperm have a disease-causing mutation – which rises to nearly 1in 20 by the age of 70.

Would-be parents may want to take this into account, says team member Matthew Neville at the Wellcome Sanger Institute in the UK. For instance, younger men could consider freezing their sperm if they think they are unlikely to have children until they are much older, while older men could consider the various screening techniques available.

Recent studies have shown that each of us has around 70 new mutations that neither parent has in most of the cells of their body, with 80 per cent of these mutations arising in the testes of fathers (this isn't counting large-scale chromosomal abnormalities, which are more common in the mother's eggs). It was thought that the number of mutations in sperm rose steadily as men age, due to random mutations. But a few genetic conditions including

"The emphasis was on the mother. Now we know that both parents contribute to the health of their children"

achondroplasia, or dwarfism, are more common than would be expected from random mutations.

In 2003, Anne Goriely at the University of Oxford realised this is probably a result of some of the stem cells that give rise to sperm turning selfish. This means that certain mutations can make these stem cells proliferate more than normal, so the proportion of sperm carrying these mutations rises exponentially as men age, rather than at a steady rate. Goriely went on to show that mutations in several different genes can turn sperm stem cells selfish, but she suspected there were more.

Now Neville and his colleagues have sequenced more than 100,000 sperm from 81 men of various ages, along with sequencing their blood cells. With standard sequencing methods, the error rate is too high to reliably identify mutations in single DNA molecules, but the team used a new technique that involves sequencing both strands of the double helix – if a mutation is found on both strands, it is very unlikely to be an error.

This approach allowed them to identify a wide range of mutations in more than 40 genes that turn sperm stem cells selfish (*Nature*, doi.org/p8qv).

While these selfish mutations account for only a tiny proportion of all mutations, they have an outsize effect. That's because most of our genomes are junk, meaning that most random mutations have no effect.

By contrast, selfish mutations affect key genes and can thus have major effects. With at least two of the 40 genes, potential conditions include autism, while some of the mutations greatly increase the risk of cancers.

Goriely says it is a good study that involved a lot of effort. "We have known for a long time that being an older parent is not a good idea," she says. "The emphasis used to be really associated with the mother. Now we understand that both parents contribute to the health of their children." ▮

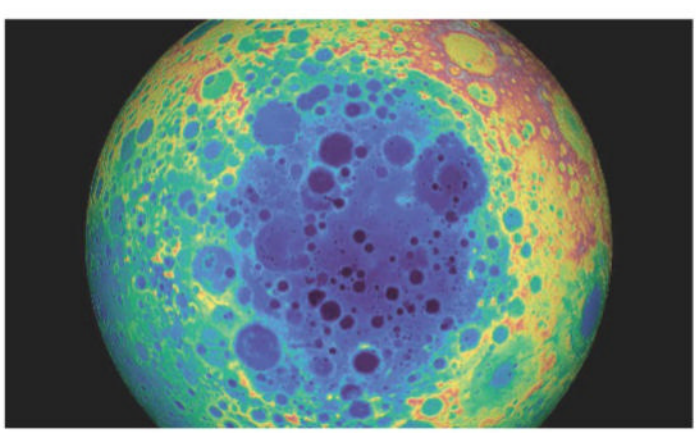
Solar system

Moon crater's creation story gets turned upside down

THE moon's oldest and largest crater didn't form in the way astronomers thought, according to a detailed analysis of its shape, which would rewrite the moon's early history.

The South Pole-Aitken (SPA) basin formed around 4.3 billion years ago. Astronomers think it was created by a massive asteroid, which carved out a crater thousands of kilometres wide and 12 kilometres deep.

The crater, which is found on the moon's far side, contains thicker piles of ancient rubble towards its northern rim. This is a pattern you would expect if the asteroid barrelled into the surface from a southerly direction, below its south pole.



NASA/GSFC/UARIZONA; ANNOTATIONS: P. JAMES (BAYLOR UNIVERSITY)

The blue area at the centre of this topographic map is the moon's oldest and largest crater

But Jeffrey Andrews-Hanna at the University of Arizona and his colleagues have found that the crater is tapered, narrowing in width as you travel southwards. This teardrop shape suggests the impact came from the opposite direction, he says.

"We used topography, gravity, models of the thickness of the crust. We tried different choices of how to trace the basin and no matter how we traced it, it was always a shape that's tapering towards the south," says Andrews-Hanna.

Next, they compared the shape to well-known craters from other celestial bodies, such as Mars's Hellas and Utopia craters, for which we have better geological evidence of how they formed. From this, they concluded that the shape of the SPA basin was probably caused by an asteroid coming from the north (*Nature*, doi.org/p8qz).

Such an impact would change how the moon's interior matter was scattered around and help scientists understand how the lunar surface was cooling from a vast ocean of magma at that time. It would also mean that some material around the SPA basin's rim contains rocks that originate from the moon's deep interior, which are otherwise inaccessible. ▮

Alex Wilkins

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1025NEW

Views

Comment

Tipping the scales

Our experiments show there is a flaw in how society punishes people, and this is undermining cooperation, say **Raihan Alam** and **Tage Rai**

PEOPLE transgress. They get punished. They start cooperating. This basic intuition that people are rational, and so respond to punishment by changing their behaviour, lies at the heart of Western legal systems, economic theories of crime and evolutionary theories of cooperation. The only problem is that decades of research suggest that punishment doesn't actually seem to work.

Analyses of previous studies consistently find that harsher penalties, like "three strikes and you're out" laws, don't reliably reduce crime. In its report on the death penalty, the US National Research Council could draw no conclusion about its efficacy. Meanwhile, the US, home to one of the world's most punitive criminal justice systems, has high rates of incarceration and recidivism.

SIMONE ROTELLA

These real-world findings are at odds with much experimental literature. In a famous study, economists Ernst Fehr and Simon Gächter created a game in which players were given money and the option to contribute to a shared pool. The pool was multiplied and redistributed to the players, meaning that everyone benefited most when everyone contributed. But each individual was better off not contributing while others did. When participants couldn't punish free riders, cooperation declined – but when punishment was introduced, contributions to the pool rebounded dramatically.

So what is happening in the real world that experiments aren't capturing? We explored this puzzle in a recent paper in *PNAS*. We began with the observation that, in society, people with a punishment role often have incentives that undermine their legitimacy and erode our trust in them. In Ferguson, Missouri, officials used fines to fund city services, disproportionately targeting Black residents. Across the US, billions of dollars have been seized through civil asset forfeiture, which allows police to confiscate property from those suspected of involvement in a crime.

We hypothesised that these kinds of self-interested motives for punishment can break down cooperation because they muddy its moral signal. Unlike other animals, humans possess "theory of mind" – we are hyper-attuned to the intentions and motivations of others. Punishment sends a message of disapproval that demands behavioural change. But that signal works only if we believe the punisher's motives are just. Humans are social beings who ask, "Why are you doing this to us?" If the answer seems self-serving, punishment loses its power to foster cooperation.

To test this idea, we ran a series of experiments using the same games that had shown how punishment boosts cooperation. In these games, one player (the dictator) decides whether to share money with another (the receiver), while a third (the punisher) can choose to remove money from the dictator. But we added a twist: we paid the punishers. As is the case if a police department relies on ticket quotas to boost revenue, our punishers received a financial bonus every time they punished the dictator. And when we did that, the classic effect flipped – instead of boosting cooperation, punishment undermined it. People were less willing to cooperate because their trust in punishers declined.

Our findings suggest we need to rethink crime control. When punishers are seen as self-interested, punishment breeds distrust and undermines the cooperation it is meant to uphold. If we want to build safer, more collaborative communities, we need to dismantle practices that compromise the moral message of punishment. That includes ending policies like speeding-ticket quotas and for-profit incarceration – practices that signal punishment is driven by profit, not justice. ▮

Raihan Alam and Tage Rai are at the Rady School of Management at the University of California, San Diego

This changes everything

Who cards the carders?

Who cards the carders? The British government isn't the only one looking to introduce digital ID cards. There are so many things to be concerned about here, says **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest book is *Automatic Noodle*. They are the co-host of the Hugo-winning podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is techsploitation.com

Annalee's week

What I'm listening to
Our Ancestors Were Messy, *a podcast about Black celebrity scandals from a century ago, torn from the pages of Black newspapers.*

What I'm reading
A Philosophy of Thieves *by Fran Wilde, a futuristic caper where rich people hire thieves as entertainment at their parties.*

What I'm working on
Researching the history of "review bombing", where a piece of media or product receives a barrage of one-star reviews from users with a political agenda.

This column appears monthly. Up next week: Rowan Hooper

THE first ID card I ever had was the flimsy piece of laminated paper that made up my driver's license. In the US, a driver's license includes a photo, biometric information (eye colour, height, etc.) and birthdate. This led to usage creep: people used the cards as much more than a mere license to drive. Bars and liquor stores would "card" kids trying to get a drink, taking the information on it as proof that we were the proper legal drinking age of 21. Needless to say, I was 18 when I figured out how to doctor the birthdate on my card with a pencil so I could buy cheap cocktails.

This story sounds like a wee fairy tale from the 20th century, but it is deeply relevant to current debates over whether to implement digital ID cards in the UK and beyond. Sure, the cards themselves may be dramatically different, but the problems are the same. First, ID cards are always prone to usage creep. And second, they are incredibly easy to hack.

The British government is hardly the first to suggest that its citizens all carry a little ID app on their phones to access government or other public services. Digital IDs are currently required by the Chinese government, as well as those of Singapore, India, Estonia and many more. Proponents of digital IDs generally give similar reasons for using them: to cut down on fraud, to make it easier to buy things or travel and to prove who you are without carrying a bunch of physical cards or papers.

"It will be safer for you with this digital ID," a government might say. "You can use it to make purchases or get healthcare, and as a fun bonus, nobody will ever mistake you for an immigrant and throw you in a detainment centre without proper food, sanitation or medication for weeks." Oops, sorry – that got oddly specific for no particular reason. But you get what I'm saying. These cards are proffered as fixes for problems that aren't problems (it's not hard to carry my health insurance card) or require a lot more than an ID to solve (immigration is a huge, multifaceted issue).

But back to my point about usage creep. What happens when a government implements a digital ID on your phone that is supposed to be for verifying your citizenship status when you apply for a job or social services? At a basic level, it snuggles up to all your other apps, possibly sharing data with them. Some of these apps have access to sensitive information, like bank accounts, doctor's appointments, personal conversations and photos.

> **"A government might start using its digital ID in much more invasive ways than originally promised"**

As journalist Byron Tau chronicles in his excellent book *Means of Control*, many apps are already gathering information about you that you don't realise, such as your location, spending habits and even what other apps are on your phone. There are companies that specialise in extracting this data from, say, your dating apps and selling it to third parties, including government agencies.

In the US, this is largely legal, which is super creepy. In the UK and Europe, there are regulations that prevent some of this rampant data-sharing. Still, the tech is there. The only thing protecting you from a government ID app that tracks your location by tapping into an unrelated app is the government itself. And governments change. Regulations change. Yet, once you start using that digital ID to get jobs, get into bars, pay for chips and ride the tube, it is unlikely you'll chuck it.

This is the usage creep trap. A government might start using its digital ID in much more invasive ways than originally promised. Meanwhile, citizens might start using it for so many things that they decide the trade-off is worth it. Who cares if the government knows where you are every second of the day if it is easy to buy gum without a credit card? That's great until the government decides you are a bad guy.

And I haven't got to the hacking part yet. Even if a government doesn't start using its digital ID to spy on you, a malicious adversary might. Someone could find a backdoor into government servers and gain access to your ID that way, or they might get your information through a phone app laced with spyware. This is why security experts have been warning the British government about the dangers of digital IDs. Even Palantir, the infamous US surveillance firm, has backed away from supporting digital IDs because, as one of its executives recently put it, they are "very controversial".

You shouldn't be worried about this stuff because someone might steal your identity. You should be worried in case they can track your location, read your texts, break into your bank account and listen to your phone calls. The fact is, there is nothing wrong with old-fashioned ID cards. Yes, they can be lost or tampered with. But at least when that happens, all you lose is the card. You don't lose everything else with it. ▮

FRIENDLY BACTERIA

The gut experts for 90 years

Yakult has a long heritage and an amazing amount of science behind its iconic little bottle. Founder, Japanese scientist Dr Shirota, spent many years investigating the benefits of intestinal bacteria.

In 1930, he succeeded in selecting and cultivating a unique strain of lactic acid bacteria that was robust enough to reach the gut alive and increase the bacteria in the gut.* He used this strain, now known as *L. casei* Shirota, to make a fermented milk drink. And so, in 1935 the first bottle of Yakult was produced.

Fast forward 90 years, Dr Shirota's work is continued with passion by hundreds of scientists and researchers seeking future applications for this unique bacteria.

Yakult

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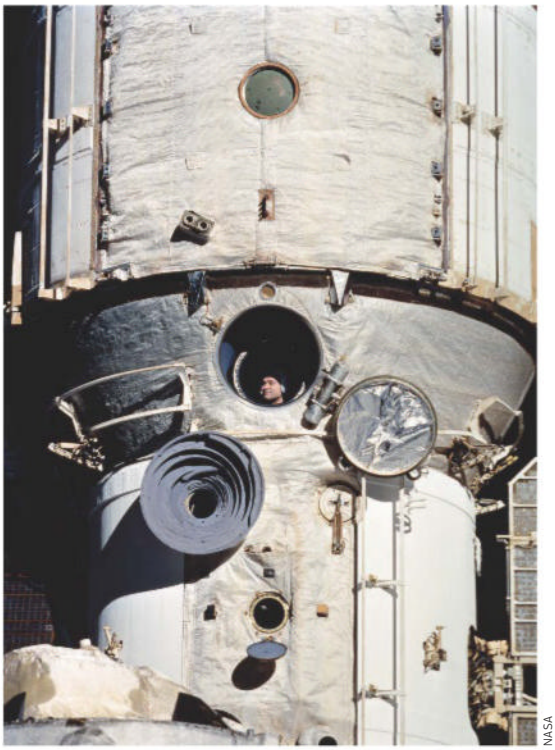
*Yakult's bacteria *L. casei* Shirota, increase both the lactobacilli and bifidobacteria in the gut.

NASA



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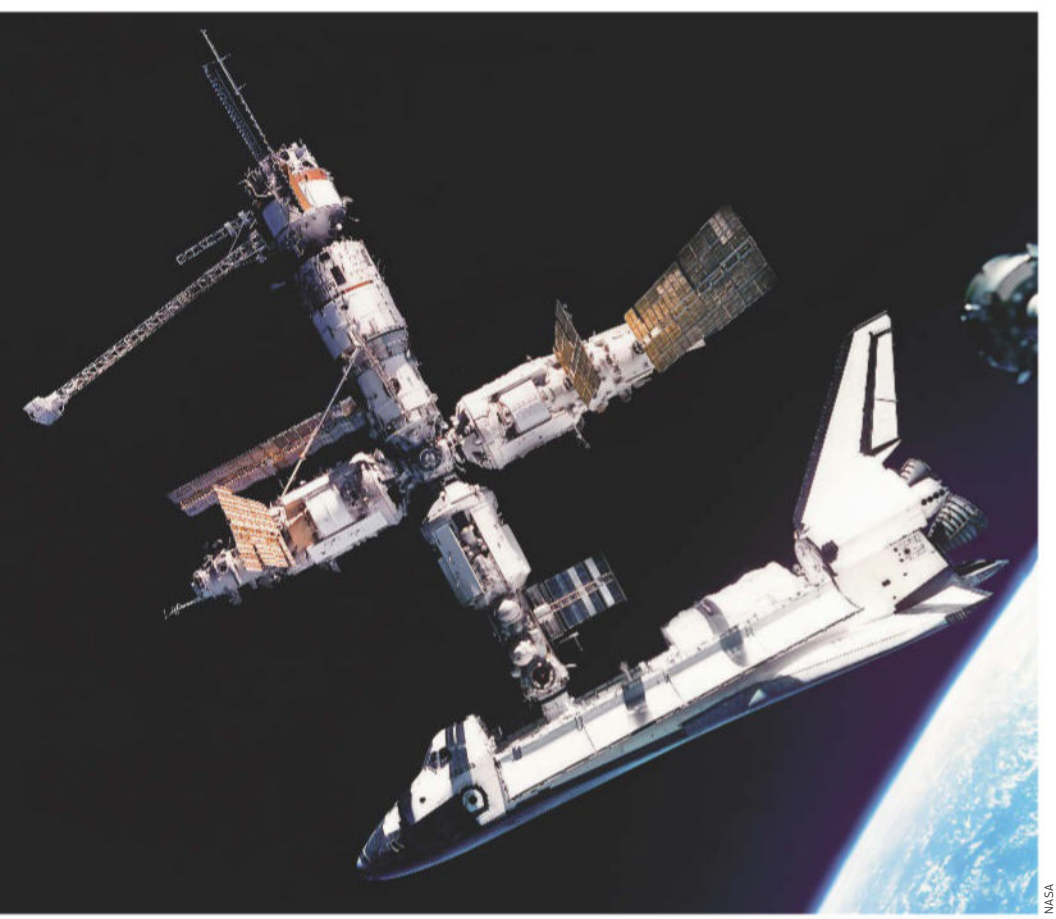


NASA

To boldly go...

BBC Books

IN THE 64 years since Yuri Gagarin became the first human in space, fewer than 700 people have followed him. But space flight becomes more affordable and accessible every year, and that number is set to rise dramatically.

James Bluemel's new book *Once Upon a Time in Space* recounts the space race so far in photographs, released to accompany his BBC documentary of the same name. It features images from astronauts' collections and NASA archives, and stories from astronauts, scientists, engineers and space tourists alike.

"To see our planet from space affects everyone that has had that opportunity," says Bluemel. "Uniformly, astronauts and cosmonauts are filled with an admiration of the beauty of our planet, the swirling blues and whites set against the dark void of space. I think some of those emotions are transmitted through the photographs they take."

On the far left, NASA astronaut Jessica Watkins enjoys a view of Earth from the International Space Station's cupola in 2022. The domed window has been a popular spot for astronaut photography since it was installed in 2010. Before then, only small portholes were available.

The middle-left image shows the landing site for the Apollo 17 moon landing, taken from the orbiting command module in 1972. The mission was the sixth to put humans on the moon, and the last. In the upper near left shot, cosmonaut Valeriy Polyakov is framed by the Russian space station Mir's window, taken from the space shuttle Discovery in 1995. The bottom near-left image shows the space shuttle Atlantis connected to Mir, shot in 1995 by cosmonauts in a Soyuz spacecraft.

Matthew Sparkes

Rebirth of a classic

Guillermo del Toro brings a sumptuous aesthetic to his film adaptation of *Frankenstein*, despite its overindulgent first act, says **Davide Abbatescianni**

Film

Frankenstein

Directed by Guillermo del Toro

Out now in select UK and US cinemas, streaming on Netflix from 7 November

GUILLERMO DEL TORO has long been fascinated by the borderlands where science, myth and monstrosity meet. In his new film, *Frankenstein*, he turns at last to Mary Shelley's foundational text: the 1818 novel that many argue gave birth to both science fiction and modern horror.

The result is visually sumptuous, performed with intensity and, at times, philosophically acute – even if its pacing and some design choices betray the heavy hand of Netflix, the film's financier.

Shelley's story of Victor Frankenstein – a brilliant but reckless scientist who dares to bring dead matter to life – remains one of the most potent cautionary tales about the promise and peril of scientific ambition. In del Toro's film, Oscar Isaac plays Victor as a charismatic, obsessive figure whose wounds, both personal and intellectual, propel him into uncharted territory.

Isaac's performance balances arrogance with fragility, and the ensemble around him adds texture: Christoph Waltz as Harlander, the industrialist who funds Victor's research; Charles Dance as Victor's authoritarian father; and Mia Goth's standout turn as Elizabeth Lavenza, a tragic and compassionate figure.

The film is most compelling when it lingers on the laboratory. Del Toro and production designer Tamara Deverell have created an environment that nods to 19th-century anatomy theatres, with towering apparatuses and crude, galvanic machines. The depiction of dissection and experimental medicine is stylised but not wholly implausible: sparks of credibility lie in the detail of ligatures, scalpels and surgical protocols.

Victor's cadavers, however, may stretch credulity – the sheer number and freshness of bodies at his disposal certainly strains realism. Yet his activities reflect the debates of the Romantic era about electricity, vitalism and the boundary between life and death.

The Creature (Jacob Elordi), created and abandoned by Victor, isn't the hulking figure with bolts in its neck of the 1931 film *Frankenstein*. Here, we see a leaner, scar-stitched body rendered through prosthetics and CGI. The combination is effective, though some close-ups – such as when the Creature lies motionless – falter at the jawline. His appearance also jars: the brooding, "emo" aesthetic feels closer to modern tastes than to Shelley's early 19th-century milieu.

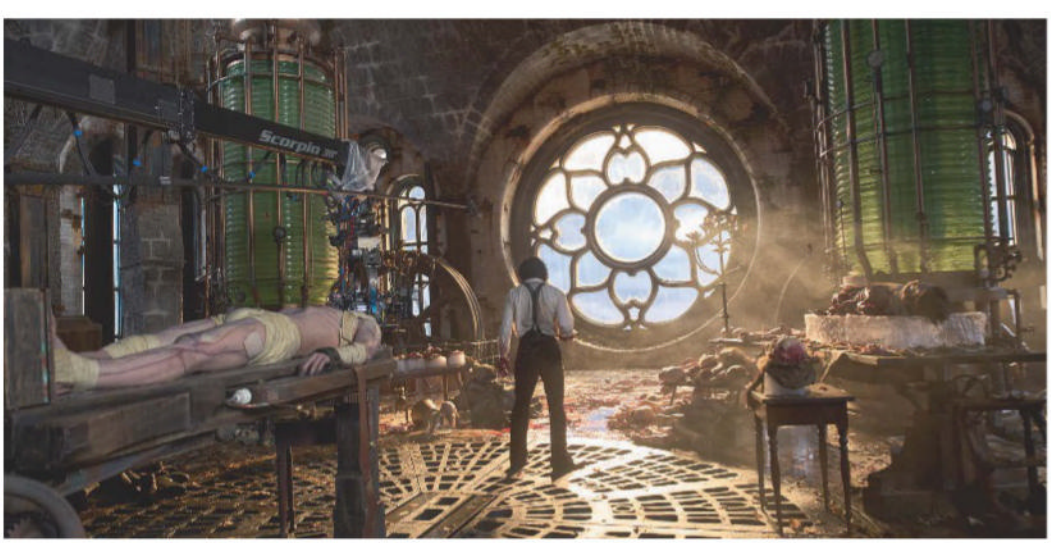
> **"The film's visuals are enthralling, drenching laboratories and landscapes alike in chiaroscuro"**

In a way, this design is a continuation of del Toro's interest in biology as bricolage, the body as a site for reinvention, as seen in his earlier films, such as *The Shape of Water*. Even filtered through a modern lens, the Creature reflects our enduring fascination with reconstructing life from fragments – a scientific dream as seductive now as it was in Shelley's time.

Narratively, *Frankenstein* falters somewhat. Del Toro devotes the 150-minute run-time to Victor's upbringing, intellectual formation and slow seduction by the dream of conquering death. While this material grounds the film in Victor's psychology, it means the pacing drags, and some viewers may find the long first act an overindulgence. What's more, the Creature's strength – sufficient here to heave a ship as if it were driftwood – risks tipping into exaggeration, undermining the film's otherwise sober exploration of scientific possibility.

Still, the underlying themes remain urgent. *Frankenstein* is ultimately less about the mechanics of reanimation than about society's reaction to the unfamiliar. And the film's visuals are consistently enthralling, with Dan Laustsen's cinematography drenching laboratories and landscapes alike in chiaroscuro, while Alexandre Desplat's score alternates between ominous rumbles and delicate motifs of yearning.

Del Toro's oeuvre includes more ambitious works, but *Frankenstein* is nonetheless a serious, sometimes stirring exploration of one of science's greatest parables. It asks us to consider not simply whether we can create life, but whether we can live with what we create. ▮



KEN WORONER/NETFLIX

Oscar Isaac makes for an obsessive and charismatic Victor Frankenstein

Davide Abbatescianni is a film critic based in Rome

Fabulous felines

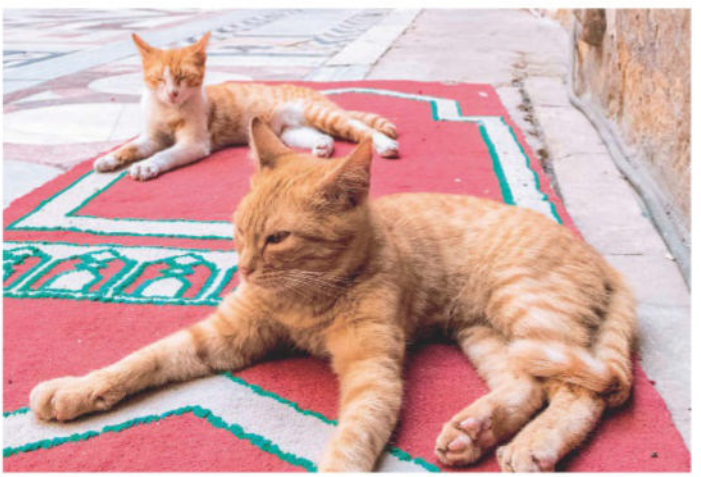
A great guide to cats captures their complex and evolving relationship with humans, finds **Bethan Ackerley**

Book

Cat Tales: A history

Jerry D. Moore

Thames & Hudson



EMAN KAZEMI/ALAMY

Did these cool creatures pull off the ultimate power play by domesticating themselves?

OVER the course of a weekend, I once saw one of my family's cats, a Byronic individual named Solomon, maul my sister under the guise of play, throw up on my bedsheets and polish off a goldcrest before my bird-loving father's eyes. Yet we forgave Solomon, because there is nothing we would begrudge him or his sister. Such is the cognitive dissonance of cat lovers.

House cats (*Felis catus*) are among the most popular pets in the world. But it is unclear why people sought to domesticate them – if they can be said to have been domesticated at all. How did we come to love them in all their forms, especially when so many species across history have counted humans among their prey?

The roots of that question are ancient, as archaeologist Jerry D. Moore reveals in *Cat Tales: A history*. Yet more important than that "history" subtitle is a further piece of cover text: "How we learned to live with them". It isn't clear whether this is from the perspective of a human or a disaffected house cat; either way, the book is less a study of our feline friends and more a portrait of the evolving relationship between our species.

The story of cats' domestication goes that, once humans built permanent settlements and stored grain, mice began nibbling at our hard-won supplies, luring in African wild cats (*Felis lybica*). A beneficial arrangement emerged, in which humans kept their grain and cats scored a free lunch.

Yet, says Moore, the truth is more complex. Domestication typically involves breeding a species for a particular purpose, something that emerged only in the past 100 years or so for cats, as we began desiring particular looks or exotic qualities. Herding is another common reason for domestication, though the old joke about cats comes to mind.

Mutualism is a more helpful lens through which to examine our relationship with cats, argues Moore. Even then, cats tend to be mercurial and aloof, and their mousing abilities are equalled or bettered by other animals – dogs like terriers, for example. In a masterstroke of confidence, cats appear to have appointed themselves to a cushy position in human homes – in other words, they self-domesticated.

Moore draws a clever link between the prominence of big cats in ancient cave art and their centrality in public outreach campaigns by conservation groups. A 2018 study found that big cats were consistently ranked the most charismatic animals.

Moore also positions cats as some of history's greatest seafarers, travelling with African and Arab navigators along trade routes to Asia and the Mediterranean. Their later voyages aboard European colonial vessels would wreak havoc in places such as Australia and New Zealand, whose fauna fell prey to feral felines.

At times, Moore's writing trips along splendidly, but there are also circuitous sections that dull the book's impact. Take an early passage on 20th-century concepts of hominin tool use. It isn't clear why Moore included it until the end of the chapter, when he argues that portraying ancient humans as supremely capable hunters caused us to downplay the power of ancient cats – as major predators of our ancestors, they shaped how our bodies and brains developed.

The cat-human relationship may have been more diverse than our bond with any other animal, says Moore: "Cats have been agents of terror and subjects of adoration, revered in religious ceremonies and cruelly massacred for entertainment".

For me, *Cat Tales* doesn't contain that much new information, but it is a great round-up of archaeological insights paired with some beautiful photography. Even if cats remain a little mysterious after this book, that's probably how they like it.

New Scientist *recommends*

Alison Flood
Culture editor
London

I have a penchant for old sci-fi with trashy covers so terrible they are brilliant. My dream is that someone creates a wallpaper of them so I can use it to paper my downstairs bathroom.

In the meantime, I recently came across a book in a charity shop I ended up loving: Sheri S. Tepper's **Grass**. This was published in 1989; the edition I found (below) is from the 1990s, and has a pleasingly weird jacket.

It also turned out to be a great read, of the dense, "messagey", 1980s sci-fi sort. It's set in a far future in which humanity has settled many planets. A plague might wipe them

out, unless they discover why the inhabitants of a world called Grass, covered in multicoloured prairie, are immune.

The Grassians are insular and weirdly obsessed with hunting the planet's alien "foxen". The secrets of the hunt are enjoyably disturbing, and Tepper's world-building is superb. I'm going to track down her other works – especially ones with standout covers.

The sci-fi column

Chasing dreams In Ken Liu's cyberpunk thriller *All That We See or Seem*, a once-famous hacker must track down a missing dream-weaver. It will fascinate those with a deep interest in AI – but it didn't quite work for **Emily H. Wilson**

Emily H. Wilson is a former editor of *New Scientist* and the author of the *Sumerians* trilogy, set in ancient Mesopotamia. The final novel in the series, *Ninshubar*, is out now. You can find her at emilyhwilson.com, or follow her on X @emilyhwilson and Instagram @emilyhwilson1

SHUTTERSTOCK/AGSANDREW

***All That We See or Seem* is set in a near future filled with personal AIs**

Book

All That We See or Seem

Ken Liu

Head of Zeus (UK); Saga Press (US)

Emily also recommends...

Film

Enemy of the State

Directed by Tony Scott

The connection may be tenuous, but Ken Liu's book put me in mind of this excellent film from 1998, starring Gene Hackman and Will Smith. It was way ahead of its time in its depiction of tech-based surveillance techniques, as well as being a lot of fun.

THE latest novel by Ken Liu, *All That We See or Seem*, is the near-future story of the mysterious disappearance of a professional dream-weaver called Elli. It is being marketed as a cyberpunk thriller.

Full disclosure: I don't generally seek out thrillers or cyberpunk books, so I may not be the target audience for this. But I was keen to read it because Liu has not one but two claims to fame: as well as being the author of a celebrated fantasy series called *The Dandelion Dynasty*, he is also the translator of the sensationally good *Remembrance of Earth's Past* trilogy by Cixin Liu.

And so, to Ken Liu's version of our near future. In the world we find ourselves in, personal artificial intelligences are ubiquitous and Elli makes a good living by using her AI to craft communal dream experiences for her thousands of adoring followers. For Elli, such work is the creation of art, and something she is very proud of.

Then, one night, Elli ups and leaves her beloved husband with no warning. After that, she simply disappears... until a gangster claims to be holding her hostage. Could it be that Elli has learned something about this terrible man, perhaps in a one-on-one dream session, that has put her life at risk? And does the gangster really have her, or is he using his AI to create a deepfake version of her?

"Elli uses her personal AI to craft communal dream experiences for her thousands of adoring followers"

Elli's husband, Piers, a mild-mannered lawyer with hidden backbone, is determined to get his wife back. He tracks down a once-famous hacker known as Julia Z and begs for her help. He is certain that Elli wouldn't have disappeared without a word, unless she did it to protect him.

Off we go on an adventure, as Julia, with Piers in tow, tries to find the truth about our missing dream-weaver, while various goons attempt to cause them serious harm. I say adventure, but most of the action involves detailed descriptions of online activity. Which isn't to complain: the sequences in which Julia and her AI helper piece together clues about what happened to Elli are really enjoyable.

The intricate work that Julia does online is superbly imagined, and it builds into what feels like a realistic sketch of how AI could be employed very soon. I particularly liked the clever ways in which Julia uses tiny details about an environment to either work things out or hide her actions.

In the biography in my copy of the novel, Liu is described as a consultant on futurism and technology history. His knowledge and experience certainly show in these online sequences, and I think people with a deep interest in AI will really enjoy the book.

For me, though, *All That We See or Seem* didn't quite land. The thriller aspects didn't thrill me. The criminals were oddly cartoonish. And the offline part of the plot didn't feel very believable, particularly in the novel's long final section.

Perhaps there is also a basic problem with setting a book in a future so very near to the present that it isn't entirely clear to the non-expert reader what is currently possible and what isn't. It takes some of the fun out of the conceit if you keep thinking: "Can't they do this already?" But perhaps that is just me.

I will give *The Dandelion Dynasty* a go, though. Liu is clearly a talented and thoughtful writer, and I look forward to seeing what he does next. ▮

Editor's pick

The long history of superluminal motion

27 September, p 34

From Peter Holness, Hertford, UK

I have read your fascinating article on the phenomenon of superluminal shadows in astronomical contexts. It is truly captivating to explore these cosmic curiosities. However, I would like to point out that apparent superluminal motion isn't just confined to the depths of space.

Engineering equipment capable of demonstrating similar effects on Earth has been around for decades. For instance, with an old cathode ray oscilloscope, once considered cutting-edge, you would often see the illuminated spot on the screen travel at speeds that appeared to exceed the velocity of light, due to its extremely fast horizontal sweeping.

The key term here is "apparent". Nothing physical is travelling faster than light, of course. The spot on the oscilloscope simply moves so quickly across the screen that it creates the illusion of superluminal motion, much like a shadow may appear to travel faster than light during certain astronomical events.

No need for violence to finish off Neanderthals

27 September, p 26

From Bruce Finlayson, North Queensferry, Fife, UK

You looked at a book discussing Neanderthals' extinction at a time when a separate species, *Homo sapiens*, moved into their areas. Both populations were distinct prior to interbreeding, and today a vestige of Neanderthal DNA remains in our species.

The current genetic mix we see in *Homo sapiens* today can be fully explained without an "extermination" having taken place. The word over-dramatises things and exaggerates the importance of violent interactions and diverts attention from the very likely collaborative nature of much human interaction.

A shining beacon for good public transport

Letters, 6 September

From Ian Glendinning, Vienna, Austria

Rosemary Sharples feels that public transport doesn't go everywhere and doesn't allow for the user's choice of time, route or travel companions, and says the most flexible form of public transport, a taxi, is the most expensive. But look at Vienna, where public transport does indeed go everywhere and is very frequent, including late into the night. The cost of an annual season ticket for unlimited travel is currently €365, so €1 per day!

There are other factors to consider in living to 100

20 September, p 34

From John Bell, Berkhamsted, Hertfordshire, UK

In your look at how to live to 100, Bryan Johnson states that he doesn't need to worry about how long he will live because it won't be long before he can upload himself to an AI.

This is, of course, massively optimistic, requiring not only the technology, but also that AIs can be sentient, that the experience of being a human doesn't require a body and that the AI subjectively feels like it is a continuation of Johnson. If he's just saying this to avoid ruminating and get a good night's sleep, then fair enough.

From Peter Slessenger, Reading, Berkshire, UK

Why was there no mention of posture in "How to live to 100"? The typical depiction of older people is of someone bent over while using a walking stick, but good, upright posture aids breathing and mobility, and helps to avoid injuries when exercising.

How useful is the brain chaos hypothesis?

6 September, p 30

From Lawrence Ryan, Wilsonville, Oregon, US

The idea that our brains are always on the verge of disorder seems to me to have quite limited explanatory value. Criticality in the brain may describe seizure states well mathematically, but it doesn't explain them. If it also describes Alzheimer's disease, in which there is widespread and progressive loss of neuronal function, akin to an oil painting flaking paint until the image is no longer discernible, it doesn't explain the condition. And if it describes creativity, consciousness, perception, etc., it explains none of them.

Criticality is a limited measurement. You could liken it to a thermometer: you can use it to measure the temperature of a bowl of soup, but it wouldn't tell you the kind of soup in the bowl, nor the ingredients the chef used.

The paradox of being an otrovert

Letters, 13 September

From Graeme Buckley, Wellington, New Zealand

I concur with Robert Sugden's views. As an otrovert, I find no particular attraction in interacting with others solely because they are also otroverts. Interesting conversations come from people with different points of view. I am Russell's paradox, part of a set that doesn't include myself.

On the truth about narcissists

27 September, p 38

From Matthew Stevens, Sydney, Australia

David Robson's article on narcissism is enlightening and a reminder that we can all get carried away with trying to appear cleverer than we are. But the final paragraph sidesteps the elephant in the room: we may well be better off without narcissists, but when we grant them power, they destroy lives and economies. Avoiding them is easier said than done.

From Peter Brooker, London, UK

Congratulations! An article about narcissists without mention of a certain president!

Is quantum supremacy really here, right now?

27 September, p 8

From Peter Sutton, Guildford, Surrey, UK

I read your story "Quantum supremacy is here at last". Yes, I agree that the advances reported on build on ideas that have been explored for decades. But is quantum supremacy here yet? I think not. It is still beginning.

A vote in favour of standardised packaging

20 September, p 20

From Don Taylor, Cheadle, Staffordshire, UK

In addition to improving recycling, Saabira Chaudhuri's call for standardised plastic packaging across brands for similar products could solve quite a problem for me, especially in strange stores. Very few products clearly tell you what they are for – the brand name outshines all such useful information. Standardised packaging would be a great help, along with clearer labelling. ▮

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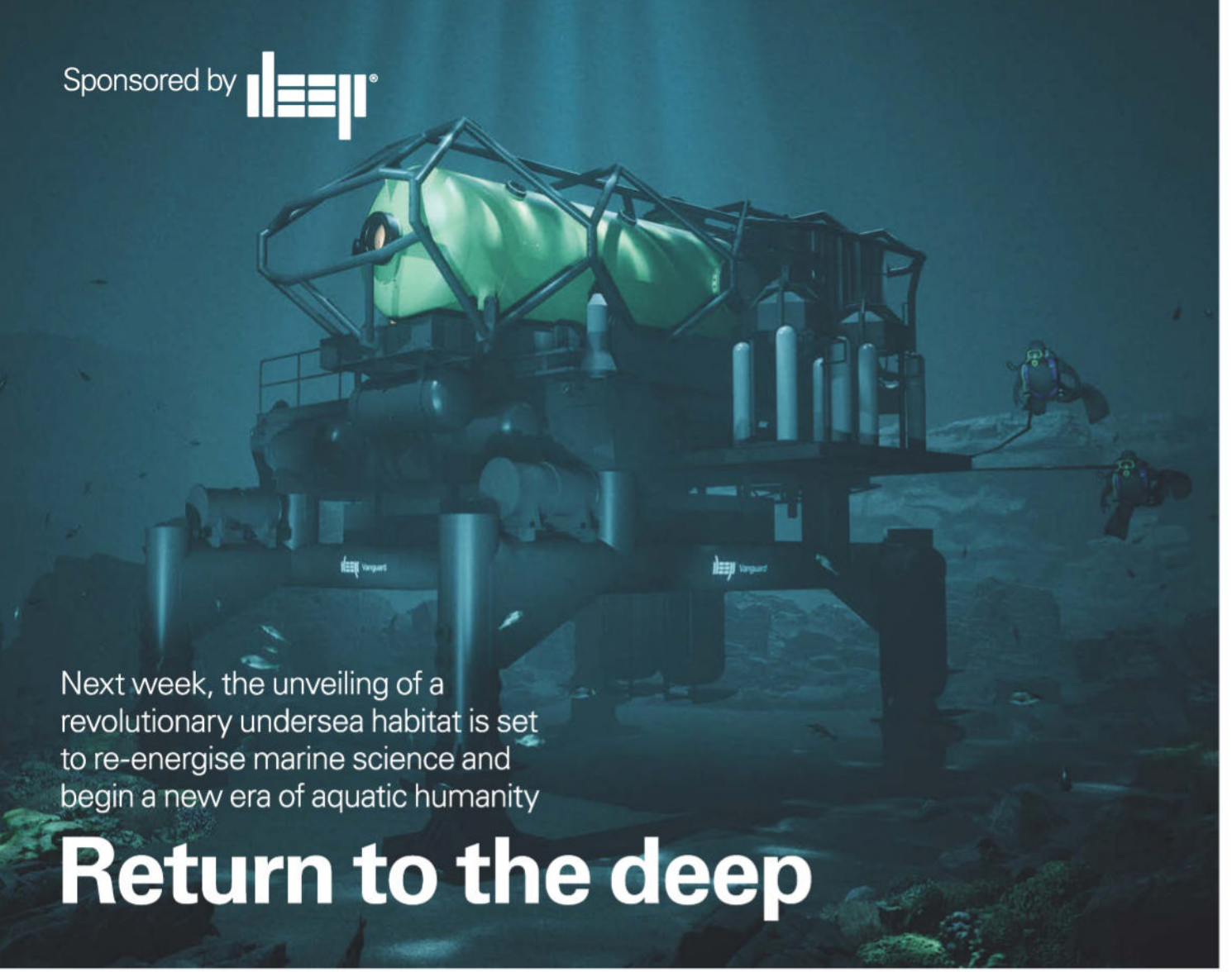


Next week, the unveiling of a revolutionary undersea habitat is set to re-energise marine science and begin a new era of aquatic humanity

Return to the deep

"IT'S an amazing moment, a proud moment." Norman Smith is talking about the imminent launch of *Vanguard*, an advanced living space on the ocean floor that provides a home and work environment for researchers. *Vanguard*, he says, is designed to pave the way for a new era of marine science.

Smith is chief technology officer at DEEP, an international design and engineering organisation, whose main mission is to make humans aquatic by establishing subsea habitats that will allow people to live underwater for extended periods.

That's important because the ocean is a vast source of potentially revolutionary scientific discovery, but has been largely inaccessible to scientists. DEEP plans to change that. "Science and exploration are the primary goals here," says Scott Olson, DEEP's US Program Manager.

The company's vision for a new generation of aquatic scientists will begin with the unveiling of *Vanguard* in Florida next week. *Vanguard* is a small habitat, roughly the size of a shipping container, that will provide a testbed for all kinds of new subsea technologies, facilities and opportunities. It, and the future habitats that will be deployed once *Vanguard* has blazed the trail, will allow scientists to remain at depth for extended periods of time.

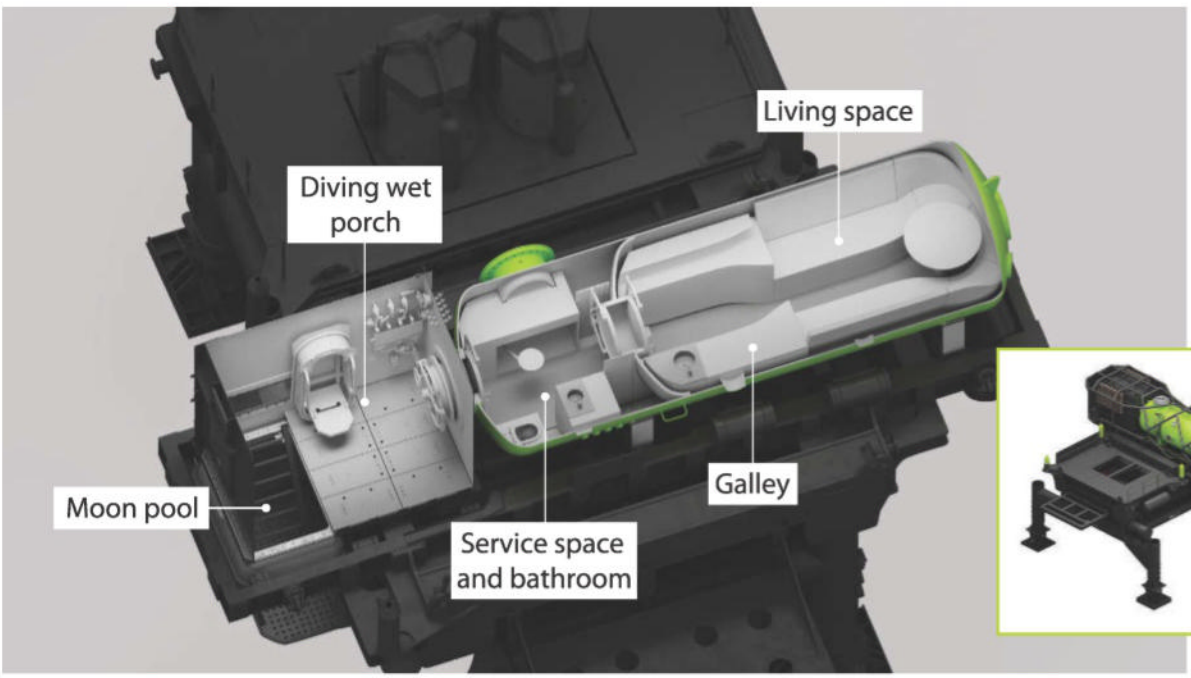
Undersea innovation

The company's engineering innovations will bring a new "hotel-like" accommodation opportunity to the deep ocean, and remove the current time restrictions on human ocean exploration. That opens up the potential for comfortable long-term living at depth, with scientists able to do their undersea fieldwork for months on end— or maybe even years. "There's really no limit: it's more about how long they'll want to be down there," Olson says.

DEEP's daring mission to make humans aquatic ends a long hiatus in the development of undersea habitats. In the 1960s, several were built and deployed, including Jacques Cousteau's *Conshelf*, the US Navy's *SEALAB* and the research station *Helgoland*, which allowed German scientists to explore the Baltic. However, the last undersea research laboratory was Florida International University's *Aquarius*, which was built in the mid-1980s. All contributed to advances in marine science and in our understanding of how humans cope with extended periods of relative isolation. NASA used *Aquarius*, in particular, to prepare crews for space missions.

So *Vanguard* is, essentially, the first step forward in this area for four decades. It has space for four occupants and can be placed on the seabed down to depths of 50 metres. It is designed to withstand the subsurface effects of a category 5 hurricane.

"In any emergency situation the crew would be evacuated, but we have to be mindful of the equipment and minimise damage that could take place," says Jim Williamson of Unique Group, an international diving systems firm working with DEEP to deliver *Vanguard*. Hurricane-proof safety is mostly achieved through *Vanguard's*



The *Vanguard* habitat provides long term accommodation at depths of up to 50 metres

anchoring weight. "The current design is more than 200 tonnes, and there's a couple of piles that will be drilled into the sea floor to keep it from shifting during bad weather," Williamson says.

Before *Vanguard* is deployed, it will have its initial commissioning on a Florida dockside, and once the dry tests are done, it will be immersed in deeper waters. That's when engineers will test features such as the electrics.

Olson is confident about *Vanguard's* engineering: in the past few decades underwater exploration technology has been developing fast, and *Vanguard* incorporates the latest innovations. "The underwater vehicles that are used in the oil and gas industry have improved and matured dramatically," he says. "We're benefiting from all that development."

Once all the systems are tested and approved, the real fun begins. "After about two weeks it will be on the bottom, and we'll run drills: operational and emergency procedures," Olson says. "After that it will be the training period, and then it will be ready for general occupation."

Vanguard will be deployed at a location that is yet to be announced. With undersea habitats a scarce resource for so long, there's no shortage of occupiers-in-waiting. As well as its own scientists, DEEP has an extensive list of collaborating institutions hoping to get their scientists some *Vanguard* time in the next few months. That will enable everyone planning to spend serious time under the ocean to get acquainted with the subsea lifestyle and procedures while DEEP's next habitat — a multi-module, larger undersea habitat called *Sentinel* — is being built. "*Vanguard* is essentially a prototype for developing our experience," Olson says.

"Nothing quite like this has ever existed before in our industry"

Even though bigger and better things are coming down the line, *Vanguard* will still be a destination that marine scientists are keen to visit time and again. That's because it has been constructed with comfort in mind.

First, it will seem bigger than it is. "You have to keep things like sight lines, windows and lighting in mind in the design: you don't want it to feel claustrophobic," Smith says.

And where previous subsea habitats have been no-frills, practical, maybe even brutal, environments, *Vanguard* has soft furnishings, such as privacy curtains around the beds.

"It's very inviting," Williamson says. The commission to provide a touch of luxury was "very refreshing", he adds; diving systems have tended to be functional, bare bones installations. "Nothing quite like this has ever existed before in our industry," he says.

The high-spec interior has also been a novel experience for Smith, who is a veteran design engineer for NASA's crewed spaceflights. "We engineers are used to working with astronauts, aquanauts, manufacturers and subject matter experts, and now we're working with architects too and getting into interior design and choices for upholstery fabrics."

Touches of luxury

Of course, there were people on the wider team who could step forward with fabric swatches. But the chosen textiles all had to be tested for compatibility with a pressurised subsea environment for factors like flammability and what volatile chemicals they would release. "We're very careful about what materials we put inside the habitat," Smith says.

Proud as he is of what his team has achieved with *Vanguard*, Smith is already preparing for DEEP's next project. "My job leading engineering is to make sure we're ready to go when this team ramps off of *Vanguard*," he says. "It's like, thank you guys — great job. Guess what? It's time to build *Sentinel*."

Find out more at: www.DEEP.com

Does your diet pass the acid test?

The food we eat has a surprising effect on the body that could lead to chronic illness – but luckily there's an easy fix, finds **Graham Lawton**

I AM standing in the bathroom with a strip of litmus paper in my hand. I am going to pee on it and hope that it doesn't turn red, which would indicate acid. This isn't for a bet – it is a (ahem) litmus test of whether my diet is slowly killing me. Acidic urine is a crude sign that something called my dietary acid load is too high. If it is, I am opening myself up to a range of ills. Luckily, there is a simple cure: a change of diet. So, if I do see red, I am going to eat some spinach and try again.

This might sound like medical woo-woo, and there are worrying echoes of a discredited fad called the alkaline diet. But nutrition scientists increasingly think that by ignoring dietary acid load we are missing a trick when it comes to healthy eating. "The higher the dietary acid load, the higher the risk of developing chronic diseases," says Hana Kahleova at the Physicians Committee for Responsible Medicine, a not-for-profit research centre in Washington DC. These include kidney disease, liver disease, cancer, obesity, hypertension and even anxiety and depression.

Shockingly, almost all of us are getting this wrong – especially if we eat a regular Western diet. But the good news is that, unlike the damage caused by consuming too much salt or more calories than we need, this can be quite easily reversed, provided you know which foods and drinks make your body too acidic. What's more, the new science of dietary acid load is throwing fresh light on why certain diets promote chronic diseases.

The idea that the food we eat affects the acid-alkaline balance of our bodies was established in the 1960s when doctors discovered that, although human urine is usually acidic, the pee of vegetarians tends to be slightly alkaline. This was later shown to be correlated with the amount of "acid ash" in people's diets. A now-obsolete measure, the acid-ash test entails incinerating foodstuffs and analysing the resulting ash, a process that supposedly mimics metabolism and indicates whether the final breakdown products of digested foods are acidic or alkaline.

In 1968, two doctors at Harvard University proposed that too much dietary ash was the cause of two major diseases of old age: osteoporosis, or bone loss, and sarcopenia, or muscle wasting. Their hypothesis was that to buffer the effect of excess acid, bones and muscles are broken down to release alkaline compounds such as carbonates, phosphates and ammonia. The result, they proposed, is a reduction in bone density and muscle mass. The acid-ash hypothesis has long fallen out of favour, largely because there is no evidence that an acidic diet is a risk factor for osteoporosis. However, the basic idea lives on in the form of dietary acid load – a phoenix from the flames.

Measuring acidity is Chemistry 101. You probably remember using litmus paper in a school science lab to assess the pH of various substances on a scale from 0 to 14, with 7 being neutral, anything below being acidic, and anything above being alkaline. As with my pee test, the paper will turn red to indicate acid and blue for alkali. A more sophisticated version of this test reveals that the pH of human blood and the intracellular fluids derived from it is kept on a tight leash – ideally within the range of 7.35 to 7.45, so slightly alkaline.

"Our body needs to keep the pH very constant," says Kahleova. Stray outside this and things go quickly downhill, especially if it drops below the lower limit. This is a state called acute metabolic acidosis, which manifests as a rapid heartbeat, confusion, fatigue, nausea, dizziness, headaches and, in extreme cases, death. Nasty, but rare. Normally, our bodies have little difficulty staying on their pH leash. Most cases of acute acidosis are caused by underlying conditions such as kidney and liver disease, cancer and diabetes, although it is not unknown in people eating an extremely high-protein diet, exercising to exhaustion, experiencing acute diarrhoea or overdosing on laxatives.

The two main sources of acid in the bloodstream are respiration, which generates carbon dioxide (which becomes carbonic acid when dissolved in water) and the digestion and metabolism of food and drink, which produces many other acidic compounds. The lungs deal with the former and the kidneys the latter. Carbon dioxide doesn't cause acidosis, because the lungs easily excrete it. But, depending ›

TOMASZ WOŹNIAKOWSKI

on your diet, acids derived from things you consume can: the overall balance as a result of food and drink is referred to as the dietary acid load, or DAL.

To maintain its preferred mildly alkaline state, our body must excrete the same amount of acid as it gains. When acid predominates, the kidneys filter out the excess and dump it into the urine. If more must be done to get back on track, they also retrieve alkaline bicarbonate ions from the filtrate and return these to the bloodstream. For most people, most of the time, this system is perfectly capable of keeping their body in the Goldilocks zone. Unfortunately, staying out of acute metabolic acidosis isn't enough, though. Even hovering on or around the lower pH limit of 7.35 can cause problems, pushing us into a state called low-grade metabolic acidosis, which, despite not being as dangerous as acute acidosis, is still a health risk.

What determines whether a food is acidic isn't its pH when it is on your plate, but the pH of its metabolites. The final breakdown products of what we eat and drink range enormously in pH, from quite acidic through to quite alkaline. They can be surprising. Many relatively acidic foods, such as citrus fruits, are actually alkaline in the context of DAL because the abundant citric acid they contain is metabolised to bicarbonate, which is alkaline. They, and other fruits and vegetables, are also rich in proteins that produce alkaline metabolites.

This is in sharp contrast to animal proteins. They are rich in the sulphur-containing amino acids cysteine, homocysteine and methionine, plus three other amino acids, namely lysine, arginine and histidine, all of which lead to acidic metabolites. Many grains and nuts contain these acid-generating amino acids too. Indeed, proteins are the main determinant of DAL. Other notable sources of acid in our diets are the chloride ions in table salt (sodium chloride) and the food additive phosphoric acid, which is put into fizzy drinks and a wide variety of processed fare such as meats, dairy products and cereal bars.

VITALII KIT/ALAMY; SERGII KOVAL/ALAMY

Above: Surprisingly, acidic citrus fruits, such as oranges, are more alkaline when your body digests them than blackberries and raspberries

Below: A typical Western diet has hidden dangers beyond fat and salt intake

MARTIN PARR/MAGNUM PHOTOS

> "If you're consuming more animal protein, automatically your dietary acid load will be higher

At this point, alarm bells may be ringing. Western-style diets are notoriously rich in animal products, salt, refined grains and ultra-processed foods, and low in fruit and vegetables – the perfect recipe for low-grade metabolic acidosis. Indeed, researchers believe that among people consuming the typical Western diet, it is very common, if not ubiquitous. "We have a chronic exposure to a high dietary acid load, so that's something that we all have," says Ilias Attaye at Erasmus University Medical Center in Rotterdam, the Netherlands.

But addressing this isn't as straightforward as simply switching away from a Western diet – there are many factors to take into account. One is that some fresh fruits and vegetables contain compounds that are metabolised to oxalic acid, which pushes them towards the acidic column. This makes things like beets, blackberries, cherries, grapes and raspberries much less alkaline than you might hope, according to Gabriela Leal-Escobar at the Ignacio Chávez National Institute of Cardiology in Mexico City. Many plant-based processed foods, meanwhile, include acid-forming additives such as phosphoric acid. "You have to be very careful about additives, make sure vegetables don't have anything added to them, because that can really

> The first organs to feel the burn are the kidneys. Persistent overwork gradually grinds them down

FINDLAY/ALAMY

Eating leafy greens is the best way to reduce your body's pH

promote the acid load," says Attaye.

Another problem is that assessing DAL is notoriously difficult. The pH of your urine is too crude a measure to be of clinical use. There is no gold standard measure for DAL, but there is a method to calculate it more accurately. Potential renal acid load, or PRAL, was developed in the early 1990s to replace the acid-ash test. It is calculated with an equation that estimates the amount of acid or alkali that will be produced when 100 grams of a given foodstuff or drink are metabolised, measured in a unit called milliequivalents per litre (mEq/L). The outcome is a number ranging from about minus 15 to around plus 35. In contrast with the pH scale, however, the more negative the PRAL score, the more alkaline the food; the more positive, the more acidic. In this case, 0 is neutral.

What not to eat

PRAL is calculated from the content of just five nutrients: total protein, phosphorus, calcium, magnesium and potassium. Protein and phosphorus add to the score, while calcium, magnesium and potassium subtract from it. That may seem plain wrong, as proteins are the major determinant of DAL and can be acid or alkali-producing. But this is compensated for by the fact that animal products contain more phosphorus than plant products do, which, in turn, are richer in calcium, magnesium and potassium, says Kahleova. "So, if you're consuming more animal protein, automatically your dietary acid load will be higher."

In general, the mEq/L of an animal-derived food is acidic and plant products are alkaline. "Meat's dietary acid load is roughly between 8 and 10. Cheese is even more acidic, at around 30 – Parmesan being the highest at 34," says Kahleova. "Rye bread is about 4 – still slightly acidic. Legumes tend to be around 0 or slightly negative, and most vegetables and fruits are in the negative numbers, like minus 4 or 5. The champion is the leafy greens, at minus 14. So leafy greens are the most effective way to make your diet more alkaline." Alcoholic drinks, meanwhile, are effectively neutral. Wine has a PRAL score of +0.03 per 100 millilitres, spirits +0.11 and beer -0.2.

PRAL can be adjusted to take account of people's height and weight, but it isn't a perfect measure. A major weakness is that it doesn't include salt, so it probably underestimates the true DAL. However, the assumption is that the chloride ions that salt produces are mostly consumed in processed foods, many of which have PRAL scores that take account of salt. Also, since people on Western diets tend to eat roughly the same amount of salt, it has a similar impact on everyone and so can be ignored. Nevertheless, for everyday purposes, PRAL can give a pretty good sense of whether your diet has an acidic or alkaline outcome, and to what extent – and hence offer guidance about healthier eating.

If you are interested in the acidity question, you don't have to calculate PRAL from scratch. There are tables available containing the scores of hundreds of common foodstuffs, so all you need to do is make a note of what you ate and how much, then tally your PRAL score per day, which is expressed in units of mEq/d. If the number that pops out is below 60, you are almost certainly fine. An overall negative score – unlikely, given the Western diet is overwhelmingly acidic – is also nothing to worry about. Although there is an alkaline version of acidosis, called alkalosis, there are no known cases of it being caused by an excessively alkaline diet, according to Kahleova. However, if your score is over 60 mEq/d, that is a problem.

I did this for a few days – not easy, as the tables only feature raw ingredients – and found that my PRAL figure was consistently around 70 mEq/d. That is on the low side of what is typical for somebody eating a Western-style diet. But then, I am vegetarian – albeit one with a passion for cheese.

My score still isn't good, though. Attaye notes that healthy kidneys can eliminate between about 40 and 60mEq of acid per day without any trouble. Admittedly, they can deal with a lot more, but that takes a toll. "They will always find a way to keep the pH where it's supposed to be. But it places a huge demand on them," says Kahleova. Overloaded kidneys work hard to raise the pH above the lower threshold – but only just. The result is low-grade metabolic acidosis, and its attendant health problems.

The first organs to feel the burn are the kidneys themselves. Persistent overwork gradually grinds them down, leading to mild chronic kidney disease. This then starts a vicious cycle, says Attaye. Diseased kidneys are less efficient at eliminating excess acid, so have to work ever harder to maintain a healthy pH. Eventually, they can't keep up and low-grade metabolic acidosis can develop into full-blown acidosis. People with kidney disease are already often advised to eat a low-PRAL diet. But it is probably better for your kidneys to take action before the problems start. "The lighter we can make their work, the better for us," says Kahleova.

The link between a high DAL and kidney ›

disease is pretty much nailed down. Now, there is a growing suspicion among nutrition scientists that the acid inside our bodies eats deeper. Low-grade metabolic acidosis has been tentatively linked to multiple chronic conditions, including diabetes, obesity, liver disease, cardiovascular disease, hypertension, cancer, anxiety and depression. As yet, these are just associations from small-scale studies. Bigger ones are needed before DAL can be built into dietary guidelines, says Attaye. But they are coming. For example, he has just received funding for a clinical trial to look at how low and high-acid diets affect the metabolic health of people with diabetes.

CUM OKOLO/ALAMY

Beer and wine, when metabolised, have little effect on pH

Low-acid diet

The link with obesity is quite robust too. Kahleova recently completed a trial in which overweight adults followed either a Mediterranean-style diet or a low-fat vegan diet for 16 weeks, then swapped over. Participants could eat as much as they wanted as long as they didn't eat the wrong things. The Mediterranean diet had a negligible impact on weight loss, but when on the vegan diet, participants lost an average of 6 kilograms of body fat. That was mainly because they consumed fewer calories – but this only accounted for about three-quarters of the weight loss.

Kahleova believes DAL accounts for the rest. She measured the acidity of the diets using PRAL, with an adjustment for weight and height, and found that, although both were alkaline, the vegan one was much more so: its PRAL score was around -19.3 mEq/d, compared with -1.6 mEq/d for the Mediterranean diet. "The alkaline environment basically enables metabolic processes to run more efficiently," she says. "The vegan diet increases metabolism, so after each meal the body just burns more calories."

Other conditions that have been linked to high DAL need further testing. Nevertheless, Attaye sees a plausible mechanism by which an excessively acidic diet might lead to chronic diseases. "The fundamental studies are lacking, so we don't really understand what's going on," he says. "But my thought is that it contributes to low-grade inflammation." Overloading the kidneys causes the release of the stress hormone cortisol, which leads to inflammation. And chronic inflammation is a known risk factor for multiple conditions.

Given the known and suspected consequences of a high-acid diet, perhaps it is no surprise that it also increases the risk of premature death. Earlier this year, a team led by Mohammad Reza Pashaei at Urmia University of Medical Sciences in Iran published a review of the literature on DAL. The researchers found that each increase of 10 mEq/d raises the risk of dying from any cause by 3 per cent.

> "The damage from consuming too much acid-forming food can easily be reversed by choosing alkali-forming alternatives

All of this is pointing to a way of eating healthily that both Attaye and Kahleova believe will become as influential and well-known as the Mediterranean diet: the low-acid diet. To be clear, it isn't the same as the fad alkaline diet, which rests on the unscientific assumption that too much acid causes cancer and that an alkaline diet can prevent and cure it. This has been debunked repeatedly. In 2018, the British Dietetic Association went so far as to declare it as "nonsense".

A scientifically sound low-acid diet wouldn't be radically different from existing healthy eating guidelines. A focus on DAL strongly backs the message that cutting down on animal products, salt, refined grains and ultra-processed foods is good for you – as is eating more fruit and vegetables. "It reinforces the more general concept of eating less animal protein, less processed foods and more leafy greens," says Attaye. "But there are some nuances. It's not completely the same because also some vegetables and grains have a high acid load."

We have long understood that what we eat can contribute to chronic diseases. Our emerging understanding of DAL is bringing new insights into how these two things are linked. "The field of nutrition is working towards a more holistic view of food. DAL, I think, is one of the ways to look at it. It's not the only way, but it's one of the ways," says Attaye.

Better yet, there is an immediate win we can all take from this. The damage we do to ourselves by consuming too much acid-forming food and drink can quite easily be reversed by choosing alkali-forming alternatives. I can attest to this. My urine test did come up red, but after eating a bag of spinach, I tried again and this time the litmus paper was blue.

"This is something we can influence through dietary choices," says Kahleova. "It's a simple, simple intervention that everybody can do." ▮

Graham Lawton is a staff writer at *New Scientist* specialising in health, life sciences and the environment

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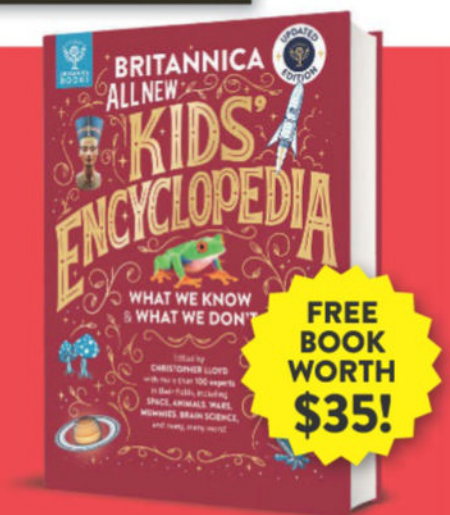


Secrets of the scrolls

Nearly 2000 years after a library was turned to charcoal by the eruption of Vesuvius, we are starting to read its lost treasures, reports **Hayley Bennett**

JOE WILSON

DEEP within a particle accelerator, theoretical physicist Giorgio Angelotti is hard at work. He sets a black cylinder on a mount, bolts it down, then runs through some safety checks before retreating from the chamber, known as "the hatch". "You have to be sure there's no one in the hatch before you close the door," he says. "So no one dies."

That's because he is about to blast the sample with a super-powerful beam of X-rays. You might expect the target to be some advanced new material or delicate crystal. But, at its heart, this isn't really a physics experiment – and the object protected inside the cylinder is far from pristine. You could easily mistake it for a misshapen lump of old charcoal.

It is in fact a priceless relic, a 2000-year-old papyrus scroll, scorched beyond recognition in the cataclysmic eruption of Vesuvius in AD 79. It is just one of the Herculaneum papyri, a cache of hundreds of scrolls that are too fragile to be opened by hand, meaning their contents have long remained a mystery. But with the help of particle accelerators, artificial intelligence and a crack team of coders assembled online, Angelotti and his team are starting to make these charred lumps talk. They could soon be uncovering entire lost works of Greek philosophy, or texts written by the earliest Christians.

Discovered near Angelotti's home city of Naples, Italy, in the 1750s, the scrolls come from the library of a partly excavated, 1st-century-BC villa in Herculaneum. The town, a smaller neighbour of Pompeii, was once a seaside holiday destination for rich Romans. The luxurious villa is thought to have been owned by Roman senator Lucius Calpurnius Piso Caesoninus – none other than Julius Caesar's father-in-law.

At least some of the 900 scrolls originally discovered were authored by the philosopher Philodemus of Gadara, one of those credited with bringing Epicurean philosophy from Greece to Italy. Classicist David Blank at the University of California, Los Angeles, explains that Philodemus had joined Piso's entourage, a cohort whose intellectual prowess publicly signalled the senator's importance. In turn, Piso became a patron of Philodemus's work, ensuring that a lot of his philosophical writings, including unique early drafts, ended up in Piso's personal collection.

Piso and Philodemus had been dead for decades when Mount Vesuvius blew, but the library remained. As hot mud and ash engulfed Herculaneum, heat dehydrated the scrolls, not burning them, but turning them to charcoal. "The fact they are carbonised is the only reason we have them," says papyrologist Federica Nicolardi at the University of Naples Federico II. Papyrus normally survives only in very dry

“The challenge was to discern an ink made mostly of carbon from a scroll that was also now mostly carbon”

climates. Other European examples rotted away centuries ago.

The Piso collection has since dwindled, however. The papyrus layers are tightly stuck together and early attempts to unwrap them resulted in a great many being mashed, sliced, peeled and otherwise processed in ways papyrologists would rather save for potatoes. Starting in the 1750s, the scrolls’ first curator, a man named Camillo Paderni, bashed out their insides to leave just the exterior layers. “He would take the roll, cut through it… then take the butt end of his knife and pound the middle of the roll into dust,” says Blank.

A little later, Antonio Piaggio, a manuscript restorer from the Vatican Library, subjected some of the scrolls to a homemade machine. By mounting each scroll and sticking the end of the papyrus to a sheet of animal guts using glue made from fish, he was able to carefully unroll about 18 of them. These early abuses did yield several volumes’ worth of readable texts. This is how we know that at least some of the scrolls were authored by Philodemus. But most of the charcoal lumps languished unread in the National Library in Naples.

That was how things stood for centuries, until Brent Seales at the University of Kentucky entered the frame. Seales had lived through the early wave of digitisation, when the internet was becoming a repository for knowledge of all kinds. He wasn’t much interested in the mass scanning of ordinary books, but he became gripped by the notion that parts of this global library might be left out due to damage to the physical works. “The idea that technology could create a representation of, or even extract new information from, the damaged stuff – that really appealed to me,” he says.

In 2000, Seales used 3D scanning and computer software to digitally uncrumple and flatten pages from fire-damaged medieval documents amassed by Sir Robert Cotton, part of the founding collection of the British Library. Some books in the trove, however, were too fragile to be opened, so couldn’t be restored using standard imaging techniques, which are based on visible light. Seales began to wonder whether the same methods we use to see inside bodies could be used to see inside books.

The first time he fired X-rays at a book from the Cotton collection, the ink showed up much like bones do in the black and white ›

CCINAR/SHUTTERSTOCK

The Roman town of Herculaneum was destroyed by the eruption of Mount Vesuvius in AD 79

images, he says. Immediately, he wanted to get his hands on other collections containing unopened texts, and his thoughts turned to the most famous example he knew of: the Dead Sea Scrolls. But when Seales described his plan to conservators, he was met with a "hell no". Meanwhile, the Herculaneum scrolls entered his radar, courtesy of a tip-off from classicist Richard Janko at the University of Michigan, who had studied the contents of some of the physically opened scrolls.

These particular papyri, though, presented some special challenges. For one thing, unlike medieval writers, who used metallic inks, Philodemus and his contemporaries often wrote in soot-based ink. That meant the challenge was to discern an ink made mostly of carbon from a scroll that was also now mostly carbon. It wasn't exactly easy. Sure enough, Seales failed to find any ink in initial attempts with a small CT scanner in 2009.

Many Hebrew and Egyptian scribes used easier-to-image metallic inks. By 2015, Seales was able to read unseen text inside a charred 4th-century-AD Hebrew scroll. And not long after, a European team including Verena Lepper at Berlin's Egyptian Museum and Papyrus Collection used X-ray-based scans to read the words "oh Lord" inside an ancient papyrus package from the island of Elephantine on the Nile river. But scans from inside the Herculaneum scrolls still hadn't revealed a single word.

The digital unwrapping process wasn't straightforward, either. The papyrus layers are so jammed together that it is tricky to peel them apart, even virtually. If the software doesn't know the difference between one layer and the next, Nicolardi says, "you produce something that's actually very similar to what happens with the mechanically opened scrolls". Pieces of text get spliced between layers, mangling the narrative.

By then, though, AI was on the rise and machines were starting to pick out features that human couldn't. It turned out that scans of the Herculaneum papyri were, in fact, picking up ink, but it was visible only to properly configured AI. Seales and his colleagues finally demonstrated this on unrolled Herculaneum fragments and fake scrolls inscribed with carbon ink in 2019. That was enough to help secure them use of the particle accelerator at Diamond Light Source near Oxford, UK. He used it as a supercharged CT scanner and obtained images of the insides of rolled-up, intact papyri. But still the scrolls taunted them. Seales's student Stephen Parsons taught AI software to spot ink on these high-resolution scans, but it struggled to see anything beyond mere traces.

Peeking between the layers

That was when things changed decisively. Seales had connected with tech investor Nat Friedman, previously CEO of Github, hoping to pitch for more research funding. But Friedman had a different idea: put out a public challenge to see if anyone could write a program that could read the scrolls. Seales initially struggled with the proposal. This kind of cash-for-code challenge might be commonplace in the tech world, but for academic researchers it was unfamiliar territory – and it meant opening the scan data and Parsons's algorithms to a wider community. "It wasn't an obvious right move for me," says Seales. "But we realised the only reason we were balking at the idea is that we might not get all the credit, and that was a really bad reason."

And so, in March 2023, the Vesuvius Challenge was born. Any prize-winning solutions would become public, the code released for the team or others to build on, in the hope that this would speed things up a bit. And so it proved: by Christmas, the challenge's Discord channel had more than 1000 users.

Angelotti was one of them. Fresh from a doctorate in AI, he had barely heard of the Herculaneum scrolls, despite being born and bred in Naples. But the more he learned about them, the more they intrigued him. Between consultancy work and founding an AI start-up, he poured over digitised papyrus sheets online. As he knew nothing about papyrology, it was a steep learning curve, but it turned out to be time well spent, resulting in cash prizes including $20,000 for work to speed up image processing – and a job offer. Now the research project lead for the Vesuvius Challenge, Angelotti says reading the scrolls has become "a sort of quest to restore the cultural heritage of my homeland".

Meanwhile, students began to steal the limelight. In December 2023, ink-detection algorithms developed by Youssef Nader and Luke Farritor helped reveal around 2000 Greek characters. Nader taught AI to see ink by carefully training it on broken-off scroll fragments where the papyrus surface was already exposed. At the same time, Farritor was picking out the first word, *porphyras* (purple), from inside an unopened scroll by using a separate AI model trained on sections where a faint, but just visible, "crackle" pattern seemed to be associated with the inked parts.

By pooling their code and working with Julian Schilliger, a student at ETH Zürich in Switzerland who had been successfully stitching digital papyrus sheets together from pixels, they were able to get better results, not to mention a nod in a peer-reviewed papyrology paper. The translated text uncovered ancient musings on food, music and pleasure, in which the author seemed to ponder the timeless question of what makes life worth living.

Their efforts won them the Vesuvius Challenge's $700,000 grand prize in 2023 – and, for Nader, a Mount Vesuvius cake (complete with scroll) baked by his family in Egypt. He, too, has since joined the challenge team, continuing to work on ink detection.

This image (above) of the text inside a scroll from Herculaneum won the Vesuvius Challenge's grand prize. Excavated scrolls like this one (left) were carbonised

THE DIGITAL RESTORATION INITIATIVE, THE UNIVERSITY OF KENTUCKY, VESUVIUS CHALLENGE

This is far from a fully solved problem, because the ink varies from one scroll to another. In the long term, the team aims to build a fast, general ink-detection software that works for everything. "So that we can, at some point, just upload a scan of a scroll and download the text," says Nader.

The unrolling problem hasn't been completely solved yet, either. Initially, the inked surfaces of the papyrus layers were painstakingly mapped to flattened sections of digital papyrus by humans. But, with help from community members like Schilliger, the team is now increasingly able to get AI to do the task, which should yield faster results.

Could solutions to these problems help researchers read other ancient papyri too? "I don't think there's one solution and there doesn't need to be," says Lepper, whose work on the Elephantine papyri used more traditional, non-AI software. Each collection has its quirks, she says. Elephantine papyri, for example, aren't charred, but many are folded instead of rolled, which can make unwrapping them more complex.

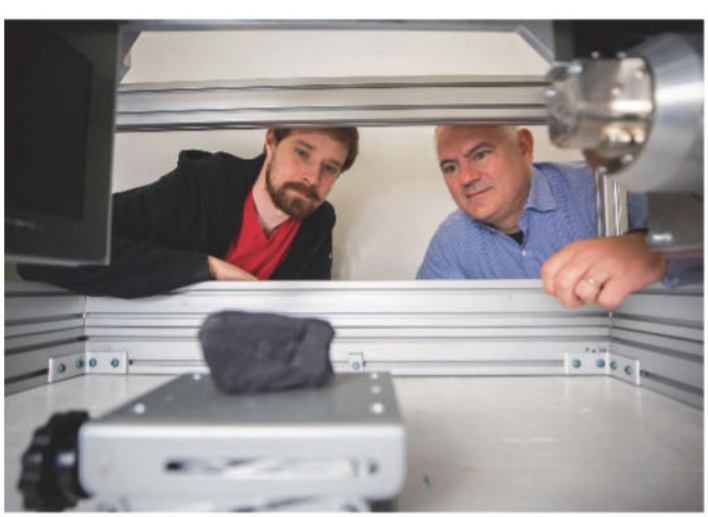
Revealing hidden text in ancient manuscripts is no trivial task. But for the Vesuvius Challenge, at least, progress continues to accelerate "as a direct result of the contest", says Seales, his initial reservations now seemingly forgotten. Both Seales and Angelotti are optimistic that there will come a time when it is as easy as pressing a button and letting the software do the rest. Right now, though, there are still plenty of scrolls left to scan, meaning more time spent kicking around in the control rooms of particle accelerators.

When *New Scientist* spoke to Angelotti in mid-July, he had just finished scanning more than 30 Herculaneum scrolls at Diamond Light Source and the European Synchrotron Radiation Facility, the particle accelerator in Grenoble, France, with "the hatch". He had also been carrying out crucial experimental work, the early results of which suggest that scanning at a higher resolution may help AI see features common to ink across all the scrolls. If so, the whole collection could become imminently readable. The only problem, Angelotti groans, is that it would mean the scans take about six times longer than usual – so more hours to kill in a control room.

Meanwhile, the Vesuvius Challenge team has been preparing to release more data to its community of coders, and successes have continued to mount up. In May 2025, computer science graduates Marcel Roth and Micha Nowak at the University of Würzburg in Germany adapted medical-imaging software to read the first-ever title from within the scrolls, winning themselves $60,000. Roth says the pair got hooked on the contest, at one point skipping university for nearly three months.

And the title? *Philodemus, On Vices*. "We were all very happy to see it was really Philodemus," says Angelotti, because it confirmed the AI wasn't hallucinating. It is unlikely to be the last we hear from Philodemus, either, because most of the scrolls read so far seem to come from the philosophy section of Piso's vast library.

Back in the Bay of Naples, there could be many more scrolls still to excavate. After all, part of the villa remains unexplored, obstructed by 20 metres of volcano spew and messy local politics. The New Testament puts Paul the Apostle on the scene around AD 50, before his execution about a decade and a half later. Could his movements have been recorded before Vesuvius's eruption? Perhaps, "if the Herculaneum library had a current events section," quips Seales. Until recently, of course, there wouldn't have been much point in looking for such long-lost treasures, since we couldn't unlock their contents. But now that we can, there's a good argument for getting out the shovels. ▮



UNIVERSITY OF KENTUCKY

Seth Parker and Brent Seales scan a replica of a Herculaneum scroll

Hayley Bennett is a science writer specialising in biology, chemistry, health and the environment

A numbers game

A long-running disagreement between physicists raises the deep question of how many numbers we need to describe reality, says **Jacklin Kwan**

IT ALL started one summer lunchtime in 1992 on the terrace outside the CERN cafeteria. If you had happened to be there at the physics research lab near Geneva at the time, you might have overheard conversations about the enormous new particle accelerator being planned – a machine that would become known as the Large Hadron Collider – or about a fledgling information-sharing project, the World Wide Web, which had launched a few months earlier. But on this particular day, there was also an argument going on among three physicists.

There was Gabriele Veneziano, the Italian who helped invent string theory; Lev Okun, the Soviet scientist who coined the term "hadron" to refer to particles made of quarks; and Michael Duff, a British theorist who had been instrumental in developing string theory's even more ambitious cousin, M-theory.

They were arguing over a deceptively simple question: how many numbers do you really need to describe reality? Veneziano had recently floated the idea that, if string theory were true, nature would contain only two fundamental constants. Okun disagreed. Three, he insisted, was the bare minimum any respectable theory needed. Duff scoffed at both of them. For him, the answer was obviously zero.

This lunchroom banter ballooned into a decades-long trialogue that took the trio of physicists into deep intellectual waters. After all, to ask how many numbers we need to properly define the universe is to ask what its true nature consists of. The debate still prompts a good deal of head-scratching today. Even recently, a new set of researchers stuck their oar in and gave their own unexpected answer to this enduring question.

Open any physics textbook and there will be no shortage of numbers floating around. Many will be what physicists call "constants", specific numbers that get plugged into equations to make them spit out useful answers. The mass of a proton. The charge of an electron. The radius of a hydrogen atom. The Committee on Data of the International Science Council, often seen as the keeper of fundamental constants, maintains an exhaustive list of hundreds of values. Yet how many are truly indispensable is a slippery question.

Is three the magic number?

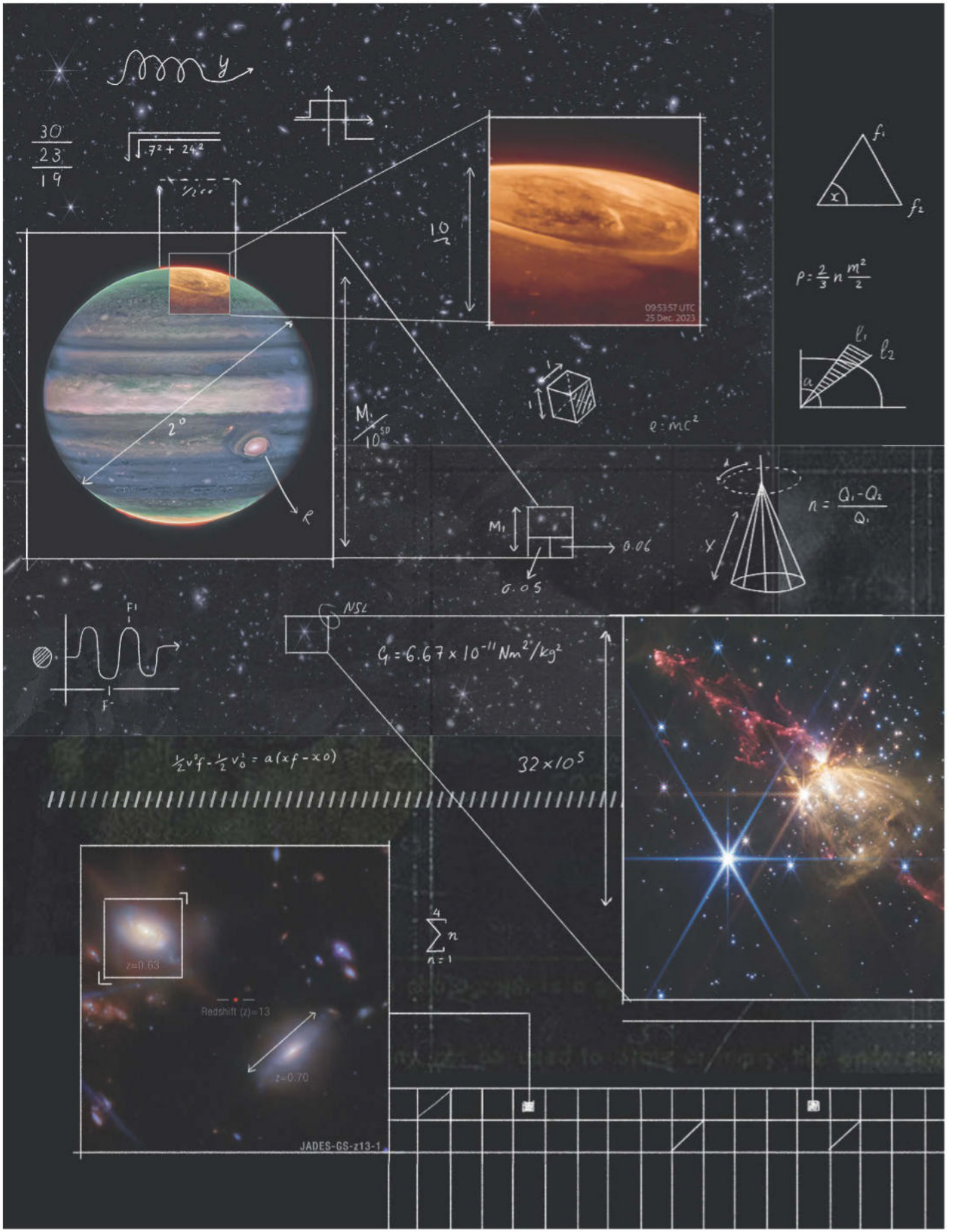
Around the time of the contretemps in the cafeteria, textbooks tended to put special emphasis on three constants because of their centrality to physics. One crops up as the last term in $E = mc^2$, Albert Einstein's famous equation that shows how the speed of light, a constant called c, connects energy and mass. It is a cornerstone of Einstein's special theory of relativity, which explains the workings of causality. Special relativity states that the speed of light is the same for all observers, regardless of their relative motion. This is only possible if space and time aren't independent of one another, so c also binds space and time into a single fabric: space-time.

The second number is Planck's constant, denoted with the letter h, which performs a similar kind of alchemy, this time between the energy and frequency of a wave. Physics paints waves and particles as interchangeable descriptions of the same phenomenon, and h can be used to toggle between the two, setting the foundations for quantum mechanics. Physicists also often use a related constant called h-bar, which can be used to define the scale at which quantum effects come into play.

And then there's Isaac Newton's gravitational constant, G – often fondly called "big G" – which quantifies the attractive force between masses and anchors our understanding of gravity. It shows how things with mass are affected by the curvature of space-time.

There is a pattern here. These constants don't just define relationships; they merge concepts together. Space becomes time, matter becomes energy, waves become particles. Physics, at its best, is minimalist and leaves us with the most essential features of nature.

That was partly the spirit behind Veneziano's 1986 paper, the one that lit the fuse on the squabble at CERN. He was inspired by string theory, which had seen huge advances in the previous few years and paints particles as just vibrations of one-dimensional strings. "There were big hopes that this was a theory of everything, and it could explain everything, the standard model and beyond," he says. Working from the logic of that theory, he argued that you don't need all three constants – c, h and G – to describe nature. Concepts like mass and energy could be reduced to the action of strings. As a result, he argued, there are just two essential constants: the length ›



PHOEBE WATTS/NASA

How many constants?

Three constants were traditionally thought to be needed in physics because they underpin the central concepts of relativity, quantum mechanics and gravity.

6.6743×10^{-11} m^3 kg^{-1} s^{-2}

The gravitational constant, *G*, which describes how much a given amount of mass deforms space-time. Known as "big *G*", it is used to calculate the strength of the force of gravity between masses.

$6.62607015 \times 10^{-34}$ kg m^2 s^{-1}

Planck's constant, *h*, a crucial number that allows us to calculate the energy of quantum particles, such as photons.

299,792,458 m s^{-1}

The speed of light in a vacuum, *c*. This constant can also be thought of as a kind of universal speed limit, as there is no form of matter, energy or information that can ever travel faster than this.

> "It is a kind of scandal that we know so much about basic physics but are still discussing this controversy"

of those strings and the speed of light.

Okun wasn't having it. He saw all three original constants as the irreducible core of physics. Together, they tied together relativity, quantum mechanics and gravity. Any theory of everything worth its salt would have to accommodate all three. Okun saw great value in keeping them well away from the abstractions of string theory. He proposed a conceptual map of physical theories, with the constants acting like toggle switches. Classical mechanics sits at one extreme, with all three set to zero: no relativity, no quantum mechanics and no gravity. Switch on c, and you step into special relativity. Turn on *h*, and you're in the quantum realm. Combine both, and you get quantum field theory. Gravity enters the picture when *G* is added, first giving you general relativity, and finally, a hypothetical theory of quantum gravity where all three constants are in play. For Okun, these weren't just numerical conveniences – they were the scaffolding on which all known theories hang.

The banter over constants went on and on. The three physicists would often see each other at conferences and other events, and it became a habit to revisit the question. Okun passed away in 2015, but Duff and Veneziano both remember it as a playful disagreement, at once inconsequential – it wasn't going to change the outcome of any calculations – and strangely deep. Veneziano remembers one time when the three of them ran into each other on a skiing trip. He met Okun just as he was about to step off a chairlift. "And even before saying hello, Okun would point at me," he says, "and ask: 'two or three?'"

In 2001, with the disagreement still not settled, the trio wrote a paper summarising their positions. But what was behind Duff's view that there were no constants at all? He actually had a distinctly different take on the whole problem. For him, the issue wasn't how many constants are needed to describe the universe, but which ones represented something intrinsically real, rather than human convention. Imagine we encountered an alien civilisation with its own language, history, culture and modes of cognition – but an accurate grasp of physics. What numbers would they unavoidably have to use in their equations? That is one way of understanding how Duff approached the question.

To get a better grasp of his answer, we need to know that there is a dividing line between two different types of constants. Some are just ratios of numbers. For example, the ratio of the mass of a proton to the mass of an electron is a constant, but because you are dividing one mass by another, the units drop away, leaving it dimensionless. But *c*, *h* and *G* aren't like that. They come with units attached, and so are called dimensional constants. Take *c*, defined as 299,792,458 metres per second. The trouble with this, says Duff, is that this number gets inked in only because we have already defined what a metre and a second are. If we used some other way to measure distance, it would change. "A committee in Paris decides what we call a metre, but nature doesn't care what that committee is doing," he says.

"Le Grand K" was used to define units of mass until 2019

BIPM (CC BY-SA 3.0)

STEVE TAYLOR ARPS/ALAMY

A clock may be all we need to measure everything

(That committee, incidentally, is the International Bureau of Weights and Measures, which turns 150 this year.)

In fact, it goes further than that. You can deliberately choose your units so the constant becomes 1. This is actually a common practice in some areas of high-energy physics, known as using "natural units". Because anything multiplied or divided by 1 is itself, the result is that the constants effectively vanish from equations. It isn't that physicists think the speed of light or any other constant has literally vanished; it is just that they have redefined their rulers so the constant becomes the baseline.

Not so fundamental

Duff's point is that if a constant can be rescaled out of existence, it was never fundamental to begin with. Much better, he reckons, to stick with dimensionless measures, which remain unchanged. These, he concedes, we may need a few of. But how many depends on your chosen theory, and pinning down the exact number isn't too important. The standard model has up to 25 of these dimensionless parameters, depending on the exact formulation.

The back-and-forth between Duff, Okun and Veneziano and their 2001 paper became physics folklore. But George Matsas at São Paulo State University in Brazil thinks it is time to put this question to bed. "It is a kind of scandal that we know so much about basic physics and are still discussing this controversy," he says.

So, in 2024, he and his colleagues endeavoured to settle the matter, returning to first principles and reframing the question. If a physicist were stranded on a desert island and had to measure everything in the universe, what would be the minimum number of independent yardsticks they would need? That, he says, is what "fundamental" means. To measure the volume of a box, for example, you don't need to invent a new device. A ruler, used in three directions, gets you there. Length is more basic than volume.

The original big three, when taken together, would allow a scientist to define independent measures of length, time and mass – effectively acting as a ruler, a clock and a set of scales. But in their paper, Matsas and his colleagues see redundancies.

Take mass, says Matsas. Because gravity pulls masses together in a predictable way, you would be able to infer the mass of an object just by timing how it falls. Similarly, relativity links time and space so tightly that measuring one gives you the other. A clock can give you a measure of length. At that point, you don't need to ask whether mass or length is "real" in a metaphysical sense. What counts as fundamental is what you can't get rid of. And by the logic of the most brutal minimalism, all you need is a clock. This means you don't need to bother with c, h or G – you can do everything you need just by using a clock and a constant that helps define time, such as the frequency of an atomic clock. Matsas's answer to the question of constants is not three, not two and not zero – just one.

For Matsas, this solution cuts through the decades-old argument. Duff's view that no dimensional constants are fundamental may be logically coherent, but it leaves physicists with little guidance on measuring anything. "By saying that you don't have any fundamental standard, you basically say that space-time doesn't provide you any procedure to measure its structure," says Matsas.

Still, the dust may not have fully settled. Even Matsas admits his team's argument breaks down at the quantum scale. In theory, a single clock might be enough to measure the universe but, in practice, it isn't that simple. You can't build a clock with arbitrarily fine resolution. The Heisenberg uncertainty principle makes sure of that: the more precisely you try to measure time, the more energy your clock must expend. Push too far, and gravity intervenes. Your ultra-precise timepiece might pack so much energy into so small a space that it collapses into a black hole. For that reason, Matsas sees his backing of just one constant as contingent on future developments. "It may be that when we discover quantum gravity, the answer to this question might change, and then it could be zero," he says.

That is precisely the problem with philosophical discussions like these, according to João Magueijo at Imperial College London, who has found himself debating with Duff in the past. "It's just basically your prejudices about theory," he says. "It's so arrogant to say that what we know is going to be the last word forever." He points out that in Galileo's time, Earth's gravity was considered a universal constant, whereas we now know it varies depending on how high up you go.

And perhaps that is what these decades of discussion, which kicked off in the CERN cafeteria all those years ago, have taught us. How many numbers do we need to describe the universe? Well, that depends on what you believe about the foundations of reality. It was so long ago now that Duff and Veneziano don't remember the finer details of what was said during that leisurely summertime lunch – but it was clearly a lot to chew on. ▮

Jacklin Kwan is a features editor at *New Scientist* specialising in physics

The back pages

Debunking gardening myths

Some don't like it hot

Looking for a cheap, easy, safe option to protect your garden from marauding mammals? **James Wong** has the answer

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

IF you've ever stepped outside to find your newly planted flowerbeds dug up or your vegetable patch ravaged, you will know my pain. From curious foxes to marauding squirrels, the destruction wrought by garden mammals on lovingly nurtured plants can be enough to test the patience of even the most mild-mannered gardener.

Hence why garden centres are packed with everything from ultrasonic devices triggered by motion sensors to creepy steel traps and even packets of dried lion droppings, all in an effort to protect your precious plants. But what if there were a cheaper, easier, kinder option that might already be on your spice rack: chilli powder. Is this popular garden remedy too good to be true?

The idea is simple – garden mammals react to capsaicin, the spicy chemical in chillies, in the same way as humans. When it binds to receptors in their mouths and skin, it causes that familiar spicy sensation that encourages them to avoid treated areas.

You might wonder why chilli plants would produce colourful, eye-catching fruit, packed with aroma compounds, only to lace them with this unpalatable molecule. Well, it's because birds don't have these receptors, so they are immune to capsaicin's effects. Researchers believe chilli plants evolved the ability to produce capsaicin as a selective deterrent, discouraging mammals – which destroy chilli seeds during digestion – while having no effect on birds, which spread seeds intact.

SHUTTERSTOCK/CANDICE BELL

Capsaicin is so effective at this task that it has been added to birdseed to prevent it from being eaten by squirrels. It is also used to prevent rats and mice from eating poultry feed and has been effective in preventing rodents eating wildflower seeds and destroying nests of rare ground-nesting birds.

When it comes to larger mammals like deer and badgers, the results are less clear. A 2005 UK field trial found that while European badgers preferred bait without capsaicin, it didn't stop them entirely. Nor did they learn to avoid it over time, unlike other deterrents. That is unsurprising, given badgers are known to dig up and eat wasp and ant nests, so a bit of chilli isn't that off-putting.

Now for the nuance. What makes these trials tricky to compare is that they use different forms of capsaicin: neat chilli powder, chemical coatings or purified extracts. Also, while capsaicin isn't water soluble, meaning it won't be easily washed away by rain, it biodegrades quickly, so multiple applications are necessary, especially as tolerance of its effects can increase through repeated exposure.

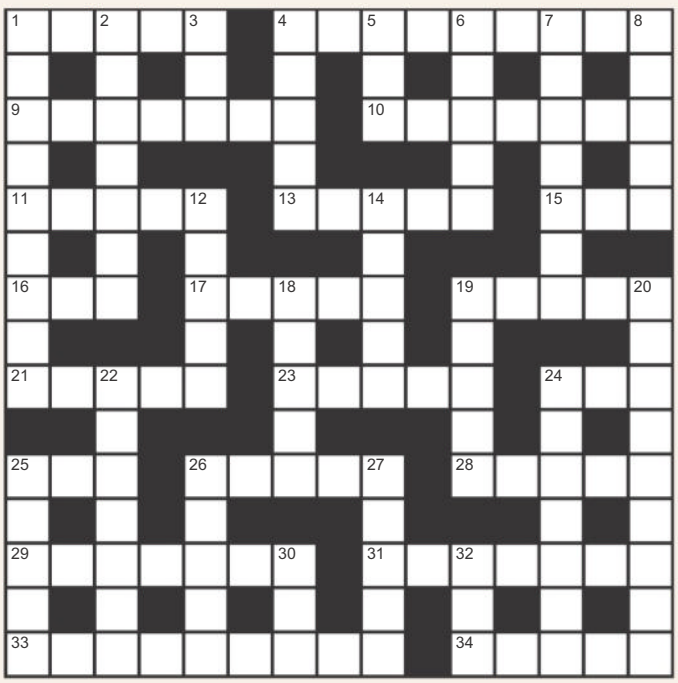
The bottom line? Chilli powder is a safe, natural, affordable way to deter mammals from your garden. Use the hottest type you can find, rotate its use to avoid habituation and apply only where needed. Then keep the rest for your kitchen! ▮

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

Debunking gardening myths appears monthly

Next week
The science of exercise

Quick crossword #194 *Set by Richard Smyth*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Barrier Reef or white shark, perhaps (5)
4 Screw type (9)
9 Small, round drop (7)
10 Zeppelin, say (7)
11 Belly button (5)
13 *Dan Dare* foe (5)
15 Unspecified ordinal number (3)
16 Apple mobile operating system (3)
17 Gordon ___, former Intel CEO (5)
19 Burp (5)
21 Orifice (5)
23 1988 sci-fi anime directed by Katsuhiro Otomo (5)
24 Through, by means of (3)
25 Cube root of 8 (3)
26 Narcotic derived from a poppy (5)
28 ___ throat, term for pharyngitis (5)
29 Br (7)
31 Ca (7)
33 Form of pentyl substituent, $-C_5H_{11}$ (4,5)
34 Key elements in the Monty Hall problem (5)

DOWN

1 Human growth condition (9)
2 Grows or changes adaptively (7)
3 τ (3)
4 Fine-grained sedimentary rock (5)
5 Eggs (3)
6 Klaxon (5)
7 CH_3CH_2OH (7)
8 Type of vertical distance; profundity (5)
12 Bodily fluid (5)
14 Tree of the Philippines, or its resin (5)
18 Forest giraffe (5)
19 Alloy of copper and zinc (5)
20 Devices for transferring thermal energy (4,5)
22 Study of "flying saucers", etc. (7)
24 Dizziness (7)
25 Shinbone (5)
26 Toroid gasket (1-4)
27 Abbreviation for the recording of movement onto a computer (5)
30 Component of the Freudian psyche (3)
32 Lysergic acid diethylamide (3)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #324
set by Tom Leslie

1 What name did Jane Goodall give to a chimpanzee that became the first she saw using a tool?

2 Which condition did researchers treat successfully with gene therapy for the first time in September?

3 Recent analysis of a fossil skull suggests what ancient hominin is a closer relative to *Homo sapiens* than Neanderthals are?

4 Ernest Shackleton's ship Endurance sank in which sea off the coast of Antarctica?

5 Which galaxy did the James Webb Space Telescope's recent picture of a black hole jet originate from?

Answers on page 47

BrainTwister
set by Howard Williams

#95 Coin roll

There is an old fairground game of chance in which you roll a coin onto a board with parallel lines drawn on it. If the coin comes to rest where it isn't touching a line, you win.

The coin has a diameter of 1 centimetre. If the probability of winning is 50 per cent, what is the distance W between the parallel lines?

If instead of parallel lines, the coin has to settle on a grid of squares, how big would the squares have to be to have this same 50 per cent chance of winning?

Another pattern that the coin could rest on is that of identical equilateral triangles. In this case, what would the length of triangle sides need to be to have the same 50 per cent chance of winning?

Answers next week

Sticky end

If I (accidentally) walk through a fresh spider's web, is this a major blow to the survival chances of its occupant?

Jonathan Wallace
Newcastle upon Tyne, UK
An orb-weaver spider's web works by forming a barely visible, sticky net stretched across likely flight paths, such that flying insects accidentally crash into it, allowing the spider to eat them.

The properties that enable the web to catch insects mean there is also a substantial risk that other things may blunder into it too and, if they are large enough, destroy it. A large number of webs must be destroyed every day by mammals (including, but not limited to, humans), birds and even some larger insects.

The spider must expend energy to make its web and is prevented from feeding until the web is replaced, so there is certainly a cost to this. However, since orb-weaver spiders have been around for well over 100 million years and remain abundant and widespread, we may safely assume that, on average, the benefits of ambushing flies in a web

"We may safely assume, on average, the benefits of ambushing flies in a spider's web exceed the costs of webs getting trashed"

significantly exceed the costs of that web getting trashed.

Of course, if the questioner were to systematically and immediately destroy the web each time the spider rebuilt it, that would be very harmful to the spider, but the occasional accident is very unlikely to constitute a major blow to its chances of survival.

Pat French
Longdon upon Tern, Shropshire, UK
The first spider webs may have appeared more than 100 million years ago. At this time, some of the largest land animals ever to have lived on Earth were prolific and were blundering over the planet's surface. It is inevitable that early spider webs were frequently destroyed. Yet they are still here and sauropods aren't. The web catastrophe seems to have been survivable for the spider!

SHUTTERSTOCK/LUCVI

This week's new questions

Route planner **Is it better to walk a mile along a busy main road for exercise, or catch a bus to cut down on the time when you are subject to high pollution?** ***Dudley Miles****, London, UK*

Ghost stories **From an evolutionary perspective, why do we "ghost" people (suddenly cut off all contact) and what effect does it have on them?** ***Caroline Deforche****, Lichtervelde, Belgium*

Is it better to walk along a busy road for exercise or catch a bus to limit exposure to pollution?

Space slam

Could a massive asteroid that hit Mars or the moon affect Earth? How big would it need to be, and what would happen?

Benjamin Fernando
Johns Hopkins University, Maryland, US
Yes, absolutely! When asteroids or comets hit rocky bodies such as the moon or Mars, they form impact craters that displace a large volume of material from the surface. Some of this material can be ejected upwards at speeds exceeding a given object's escape velocity, meaning it is no longer gravitationally bound to the planet or moon and escapes into space. Exactly how big an impactor is needed depends on factors such as what it is made of and the composition of the surface it hits.

Once in space, the ejecta's inertia and gravitational interactions with other bodies can spread the material around the solar system. In the moon scenario, a fraction of this ejecta could end up on a collision course with Earth. Of these, the smallest fragments will burn up in the atmosphere as shooting stars, or meteors. Larger fragments might survive to impact the surface, creating new craters on land or tsunamis in the ocean. Mars is further from Earth, has a higher escape velocity and has an atmosphere that will slow down any escaping material, so any debris ejected from the Red Planet is less of a threat to Earth.

Thankfully, impacts of the size needed to eject substantial volumes of debris into space are rare in the present day, but were probably much more common in the early solar system. In fact, this process is a possible route to achieving "panspermia", the idea that microscopic life can spread around the galaxy carried along with impact ejecta.

John Woodgate
Rayleigh, Essex, UK
If a massive asteroid hit the moon, Earth would certainly be visited by debris, perhaps in large chunks, quite quickly. Our planet's orbital motion and day length might even be affected. If Mars were hit, debris would probably take up to some years to arrive at Earth in force. It would depend on the orbital positions of Mars and Earth at the time of collision. The result might be anything from an interesting display of meteors to a barrage of meteorites for quite a few days, perhaps repeating at varying intervals in years.

Go fetch!

Why do dogs bring back a stick if you throw it? If I were a dog, I would say to my owner: you threw it, you fetch it (continued).

Keith Barrand
Skegness, Lincolnshire, UK
As a veterinary surgeon, I urge readers not to throw sticks for their dog to fetch. When sticks are thrown, especially on rough ground or unmown grass, they can land with one end pointing

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Tom Gauld
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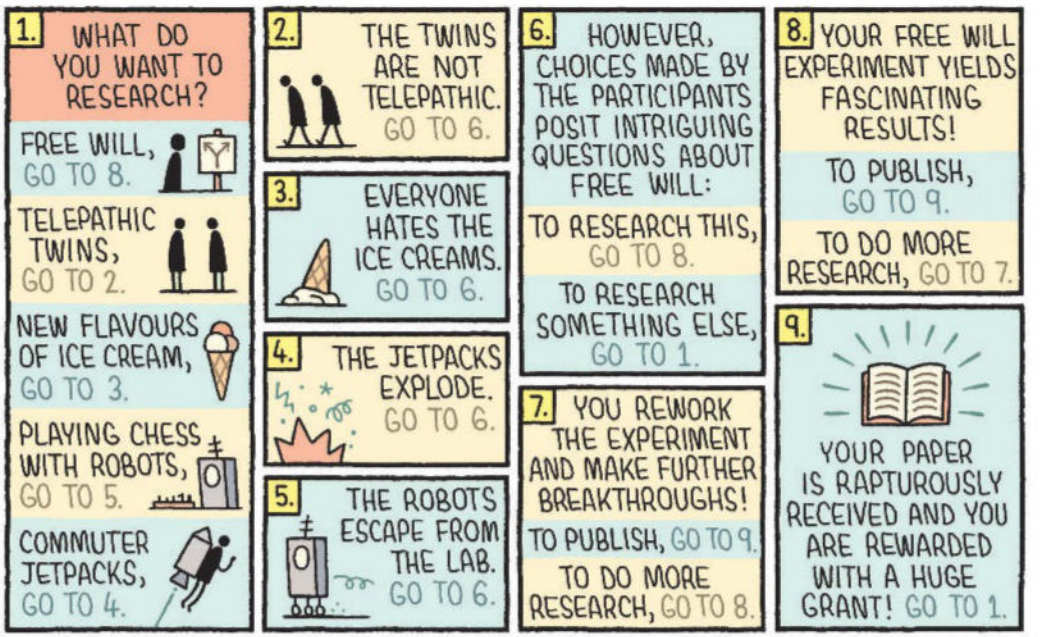


upwards and back towards the dog. A fast-approaching dog can make a grab for the stick and end up with the end impaling the back of the mouth or throat. This is known as oropharyngeal penetrating stick injury.

As well as the immediate problem (which can be life-threatening), even if the stick is apparently removed cleanly, the dog may end up with a chronic, non-healing throat injury due to fragments of stick material becoming embedded in its throat tissue. This can be costly and invasive to fix.

The problem is easily avoided by using an appropriately sized fetch toy instead of a stick. Please don't throw sticks for your dog.

Peter Whittaker
Sheffield, UK
I had a Patterdale terrier that seemed to love retrieving a thrown stick. I felt differently after he invented a new indoor game.

He was whimpering one day as I sat reading, having seemingly lost his ball behind the TV. I retrieved this and returned it to him. Five minutes later, he was whimpering again. I retrieved the ball again. This time, I watched what he would do and saw him deliberately roll the ball under the TV.

"If a massive asteroid hit the moon, Earth would certainly be visited by debris, perhaps in large chunks, quite quickly"

I believe he thought I might be enjoying this game and he was entertaining me. It makes me wonder whether he returned sticks because he thought that I enjoyed throwing them too.

John Worley
Portsmouth, Hampshire, UK
Humans were first domesticated by dogs 40,000 years ago when they discovered our unique ability among animals to throw sticks and stones. Owning a human skilled at throwing stuff was a ticket to successful hunting and therefore food. So dogs have acquired a deep instinct for encouraging their "owners" to practice their throwing skills on every possible occasion.

Keith Brooks
via email
Not all dogs fetch sticks as described in your question, although some breeds exhibit a propensity for this behaviour. It is possible this is a bonding activity and both the thrower and retriever repeat the behaviour to please the other. If you were my dog, I would find another game that provided this type of bonding experience. And if you actually said anything back to me, we could be famous!

Andrew Kadir-Buxton
Hatfield, Hertfordshire, UK
Dogs that are bred for herding will run after a stick, but will then just run round it. Our dog Bella was a Shetland sheepdog and it used to take 2 hours of playing fetch before she ever brought back the thrown stick. So we stopped doing it! ▮

Answers

Quick quiz #324 *Answer*

1 David Greybeard
2 Huntington's disease
3 Denisovans
4 The Weddell Sea
5 M87

Cryptic crossword #172 *Answers*

ACROSS 1 Spambot, **5** Sumac, **8** Precious metal, **9** Psi, **10** Subatomic, **12** Raptor, **13** Scurvy, **15** Sense data, **16** Hog, **18** South-East Asia, **20** Sinew, **21** Asepsis

DOWN 1 Sop up, **2** Adelie penguin, **3** Brimstone, **4** Thumbs, **5** Sum, **6** Metamorphosis, **7** Colicky, **11** Tic-tac-toe, **12** Resists, **14** Sahara, **17** Glass, **19** How

#94 Shape up *Solution*

For a square, $4x = x^2$, so $x = 4$.

For an equilateral triangle, you first need to find the height. Using Pythagoras's theorem, we determine that it is $(\sqrt{3}/2)x$. The area is half the base multiplied by the height, so it can be expressed as $1/2x(\sqrt{3}/2)x = (\sqrt{3}/4)x2$. Setting that equal to the perimeter gives you $3x = (\sqrt{3}/4)x2$, so $x = 4\sqrt{3} \approx 6.93$.

A regular hexagon can be divided into six equilateral triangles, so its area is $6(\sqrt{3}/4)x^2$. Setting that equal to the perimeter gives you $6x = 6(\sqrt{3}/4)x^2$, so $x = 4/\sqrt{3} \approx 2.31$.

Our expiry date

Bad news, everyone: our cards are marked. The human species will go extinct by the year 2339, so we have just a few centuries left (at time of writing).

News editor Jacob Aron shared this shattering revelation with us, which he spotted in a non-peer-reviewed paper on the social sciences preprint server SocArXiv. In it, demographers David Swanson and Jeff Tayman outline how the human population will go from its current 8.1 billion to zero.

Their argument is quite simple. "Given the decline in fertility between 2019 and 2024 and employing a probabilistic forecasting method," they write, "by 2139 the world population will be between 1.55 billion and 1.81 billion… by 2339 there will be no humans."

Swanson and Tayman note that this extinction date is "only 314 years from now". Feedback feels that they could at least acknowledge the inevitable uncertainties in their forecast by rounding it down to 300, but full marks for unearned confidence.

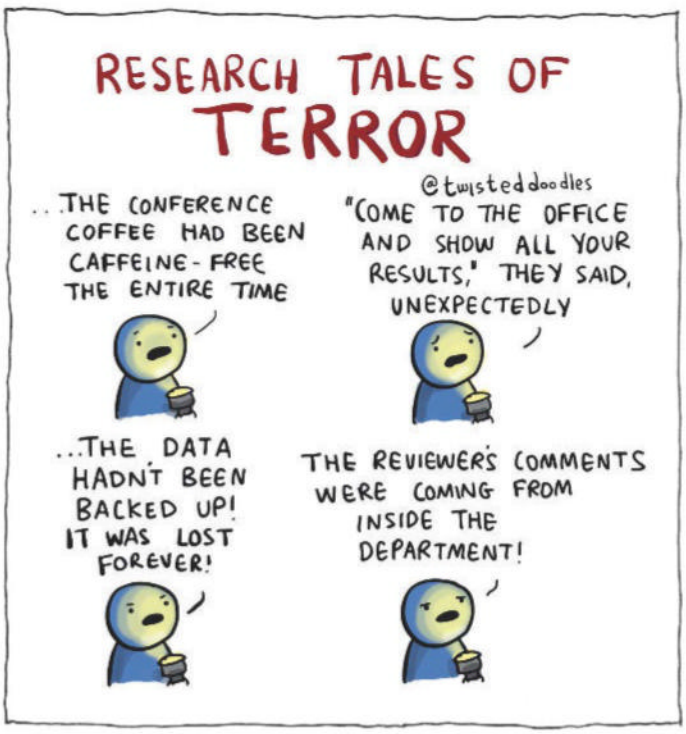
Perhaps this is obvious, but you can't extrapolate from a five-year period to the entirety of the next three-and-a-bit centuries – especially if the five-year period in question is 2019 to 2024, a stretch of time that included one or two major world events that might have affected fertility rates.

And it also doesn't matter that the pair used three distinct approaches called the "Cohort Component Method", the "Hamilton-Perry Method" and even the esteemed and eponymous "Espenshade-Tayman Method". It's still not a valid prediction. But we feel that Feedback's readers might have already worked that out.

We briefly wondered if the paper might be a parody or joke, perhaps intended to bait unwary science journalists into credulous doom-laden coverage. But we don't think so, because Swanson presented it at a conference in September. Apparently his presentation "was followed by a lively discussion". Oh to have been a fly on that wall.

Maybe this is all the prelude to the launch of a new religion, with the apocalypse safely placed three centuries into the future so the founders can't be embarrassed when it fails to occur.

Twisteddoodles *for New Scientist*



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Send it to feedback@newscientist.com
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Consideration of items sent in the post will be delayed

Oh no, not again

Feedback notes with weary bemusement that US President Donald Trump has called climate change a "con job" and claimed that renewable energy sources like wind are "pathetic".

This came after his government issued a report in July, authored by "independent researchers", that was meant to offer a justification for halting efforts to mitigate climate change. The report was checked over by Carbon Brief and was found to contain "at least 100 false or misleading statements". On the other side of the Atlantic, the UK's Conservative party has pledged to repeal the Climate Change Act if they ever get back into power.

Feedback would point out that renewables overtook coal as the world's largest source of electricity in the first half of 2025, which doesn't sound especially pathetic, but we are too busy flashing back to that scene in *Monty Python and the Holy Grail* where the monks rhythmically smack themselves in the face with wooden boards. We can only assume these people read the Swanson/Tayman paper and decided that 2339 was too far off.

A brief thank you

One of the keys to being a great researcher is to think of a question that nobody else has ever considered. Hence the study published in the social science journal *Socius* in September: "'This work would not have been possible without…': The length of acknowledgements in sociology books". Yes, you read that right: it's an entire sociological paper about the acknowledgements sections at the end of sociology books.

The first thing to note, as the authors themselves do, is that they aren't the first to ask this question. Someone called Kenneth Henry Mackintosh did a PhD thesis in 1972 on "Acknowledgment patterns in sociology". Feedback tracked it down online and was dismayed to find it is over 300 pages long and, if the table of contents is to be trusted, doesn't have an acknowledgements section.

What of the new study? The researchers compiled 411 books by 317 sociologists and totted up the words in the acknowledgements (apart from the 7 per cent of books that didn't include any – rude). One of the strongest statistical trends was that female authors wrote longer acknowledgements than male authors.

Likewise, books published by university presses had longer acknowledgements than those from other publishers. In both cases, it's not clear if they were thanking more people or just going about it at greater length.

Naturally, Feedback wondered what the paper's own acknowledgements section was like, so down we scrolled. We were pleased to find that it was a 218-word brick of a paragraph, complete with a mention of "unwavering love and support".

Then we learned that we aren't at all original. Co-author Jeff Lockhart posted about the paper on Bluesky, and another researcher replied that they were "glad that the paper itself has a very long acknowledgment section". To which Lockhart replied: "We felt obligated."

Feedback would like to thank the cats for refraining from stepping on the laptop keyboard during the writing of this piece.

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