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WEEKLY 13 June 2026

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This week's issue

On the cover

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Cover image: Vicki Turner

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MATT CARDY/GETTY IMAGES

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RBC1968

A measured rebel

Controversial ideas in science shouldn't always be dismissed

MAVERICK scientists often get a bad reputation among their more sober peers. Science requires evidence and consensus, and contrarianism is rarely a way forward.

But there is always an exception that proves the rule. Take the idea that the ketogenic diet – a restrictive regime most famous as a way to rapidly lose weight – could be a treatment for anorexia nervosa. Given that this is a psychiatric condition characterised by a compulsion to restrict food, the proposal sounds absurd at best, painfully irresponsible at worst.

We should take this counterintuitive idea seriously, however. As we learn in this week's cover story (see page 28), following the diet does seem to help people with the condition, albeit only in a small study. It is thought to be a result of keto correcting haywire energy release in brain cells, thereby cutting anxiety and, with it, the compulsion to restrict food. If nothing else, this is a sign that keto should be studied as a potential anorexia treatment. At present, one-third of those with the condition don't recover from standard treatment, and anorexia has the highest mortality rate of any psychiatric condition.

> "It is a mistake to think an idea is bad simply because people who have bad ideas support it"

Unfortunately, supporting keto as a treatment for serious mental health conditions aligns one with people such as Robert F. Kennedy Jr, the controversial US health secretary. When it comes to health advice, you can't get much more maverick than a man who claims, without evidence, that vaccines cause autism.

But it is a mistake to think that an idea is bad simply because people who generally have bad ideas support it. Multiple lines of evidence point towards keto's mental health benefits – as we set out in our 2 May cover story, it seems to hold promise for blunting the symptoms of conditions from severe depression to schizophrenia. Given the research is at an early stage, the diet should be used for anorexia only under medical supervision, as much larger trials are needed. But seeking solutions to debilitating conditions via careful science is vital, even if doing so carries the risk of initially being labelled absurd, irresponsible or maverick. ▮

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Environment

‘Cold blob’ may weaken key current

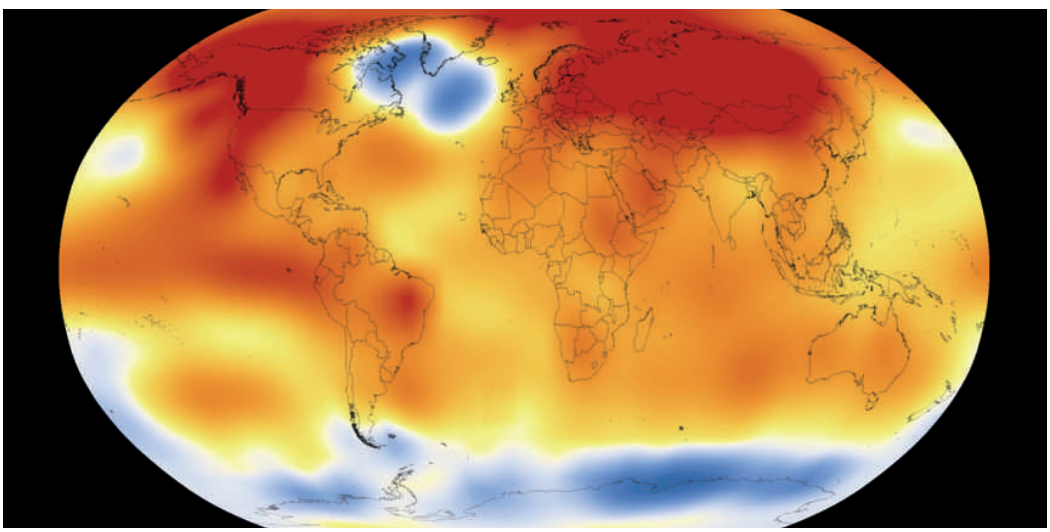
A patch of ocean near Greenland that is bucking the world’s warming trend could be a sign that the Atlantic Meridional Overturning Circulation is slowing down, reports **Alec Luhn**

OVER the past 150 years, Earth’s entire surface has been warming, except for one part of the north Atlantic. Located south-east of Greenland, this area has cooled by as much as 1°C and is known as the “warming hole” or the “cold blob”.

Scientists have been split over why this cold blob exists, but the latest evidence backs up the idea that it is caused by a weakening of the Atlantic Meridional Overturning Circulation (AMOC), the system of currents that transports warmth from the tropics to Europe.

The AMOC carries warm, salty water from the Gulf of Mexico towards the north Atlantic, where it cools and sinks, flowing back south along the ocean floor. Scientists are concerned that the surge of freshwater from Greenland’s melting ice is making this salty water less dense, so it sinks more slowly, weakening the circulation.

Some research suggests the AMOC could cross a tipping point within decades, locking in a future collapse that would freeze Europe and disrupt monsoon rains crucial for agriculture in Africa and Asia. But we only have 22 years of direct observation of AMOC strength, not enough to tease out a clear trend.



NASA/GODDARD SPACE FLIGHT CENTER

The north Atlantic “cold blob” (blue) can be seen in this visualisation from 2015

Climate modelling has suggested that a slowing AMOC is carrying less warm water to the north Atlantic, resulting in the cold blob. However, other modelling has placed most of the blame on the atmosphere.

In a 2022 study, Chengfei He at Northeastern University in Boston and his colleagues found that rapid warming of the Arctic has reduced the temperature difference between the pole and the tropics, shifting the jet stream northwards into the cold blob region. The arrival of these strong westerly winds has forced more evaporation and churned up the water, drawing heat out of the ocean.

Greater evaporation has also led to more clouds, shading the cold blob from the sun’s warmth, a 2020 study suggested.

Stefan Rahmstorf at the Potsdam Institute for Climate Impact Research in Germany and his colleagues have now investigated the cold blob with climate reanalyses, which are based on direct weather observations from satellites, buoys and ships, rather than climate modelling.

They found that heat loss from the ocean surface has decreased in the cold blob since 1955. In addition, the ocean has been cooling not just near the surface, but also a kilometre down (*Geophysical Research Letters*, doi.org/hb6vm2).

That means that the AMOC is transporting less heat, not that winds are taking more heat away, they argue.

“Even if it seems possible the blob is caused by the atmosphere, data shows it is caused by the ocean”

Winds and clouds “only explain a modest fraction of the warming hole”, says Rahmstorf. “Even if, in some modelling approaches, it seems possible that the cold

Cuts to US ocean programme will hurt AMOC monitoring

As the vital AMOC system of currents appears to be weakening (see main story), one tool used to monitor it is to be slimmed down.

Last month, the US National Science Foundation (NSF) announced that most of the five mooring arrays off the US west and east coasts and Greenland, which make up the Ocean Observatories Initiative (OOI), would be removed following cuts by the administration of US President Donald Trump.

Because satellites can’t see beneath the surface of the sea, measurements by the underwater floats, gliders and moorings of the OOI are crucial to understand what’s happening in the 70 per cent of the planet covered by ocean.

The OOI array in the Irminger Sea, east of Greenland, helps to monitor warm, salty water flowing from the tropics to the north Atlantic, where it cools and sinks, driving the AMOC.

Removing the OOI will create a data gap that will limit our understanding of the AMOC, says Hilary Palevsky at Boston College.

In a statement to *New Scientist*, the NSF said the OOI’s removal was to “prioritize support for evolving scientific priorities”.

Without the OOI, fishing fleets in the Pacific won’t know which areas might be less impacted by the coming El Niño (see page 12), says Jack Barth at Oregon State University.

blob is caused by the atmosphere, in fact, the data show it is caused by the ocean."

The finding reveals that Atlantic Ocean circulation has already been changing for decades, he adds, raising concerns about a collapse not only of the AMOC, but also of the subpolar gyre, a massive swirl of currents around the cold blob. The subpolar gyre helps bring in salty surface water to feed the sinking of cold, dense water that drives the AMOC. If it shuts down, it could reduce temperatures in the UK and nearby countries more rapidly than a full AMOC collapse.

"The subpolar gyre passing this tipping point could already lead to serious climate impacts in western Europe as early as in the 2040s," says Rahmstorf.

But the ocean surface heat flux hasn't been directly measured, so the study could only infer it through modelling. A 2021 study based on some of the same reanalyses as the Rahmstorf one found that stronger winds accounted for most of the cold blob.

"It's challenging to try to use reanalysis to infer the energy budget in the cold blob," says He.

The new study is useful, "but it won't be the final word" on what is causing the cold blob, says David Thornalley at University College London.

Because data is limited, alternative explanations for the cold blob still can't entirely be ruled out, according to Neil Fraser at the Scottish Association for Marine Science. For example, a branch of the AMOC known as the Norwegian current may be strengthening, transporting more heat out of this area, he says. "The cold blob is consistent with a weakening AMOC," he says. "But it is not conclusive evidence." ▮

Psychology

Parenthood might make you love your partner less

Carissa Wong

IT MAY feel like the exhaustion of caring for a newborn leaves little room for romance. Now, researchers have found that people really do seem to love their partner less in the first year of parenthood – but there are ways to buffer against this.

Prior studies suggest that relationship satisfaction tends to decline in the two years after having a baby, but these rarely account for the state of things before pregnancy.

"Simply sitting on a couch to Netflix-and-chill with your partner becomes impossible"

When Agnieszka Sorokowska at the University of Wrocław, Poland, started a family, she wanted to know how her relationship was set to change. "I got pregnant, and then I wrote the grant proposal to look at this," she says.

Sorokowska and her colleagues recruited nearly 300 heterosexual couples without children who had been together for at least two years. Every six months, for at least two years, the participants completed surveys – independently of their partner – in which they ranked on a scale from 0 to 6 how much they loved their partner and how committed they were.

The researchers analysed results from 71 of these couples who had a baby during the study and found that pregnancy itself had no impact. But – in line with the prior evidence – the participants reported loving their partners less and being less committed to maintaining the relationship within one year after childbirth.

There was no change in this time among the couples who remained without children.

Sorokowska – who presented the results at the Love, Actually and in Theory meeting in Edinburgh, UK, last month – plans to continue surveying these couples until their children reach adulthood, to determine whether the effects are long-lasting. But prior research suggests that things gradually improve.

"There's a steep decline in [relationship satisfaction] in the first year, only a small decline from year one to two, and then it seems to slowly recover [several years later]," says Valentina Rauch-Anderegg, an independent psychologist in Zurich, Switzerland.

The researchers didn't measure how these initial changes affected the new parents' well-being, but Rauch-Anderegg doubts they cause substantial distress. "It's not that we can say all these couples have relationship distress that means they need to see a therapist, but they certainly can notice something changed in their relationship," she says.

Some of the factors that may be responsible include the residual physical and hormonal turmoil of pregnancy after giving birth, and new parents feeling overwhelmed by childcare duties. "Simply sitting on a couch to Netflix-and-chill with your partner, or going for a walk, [often] becomes impossible," says Rauch-Anderegg.

To prevent this, or bring some of the magic back, she recommends asking loved ones for help and sharing any concerns with your partner.

"You can make sure you're communicating clearly about your vision for having a kid – what is the core of your relationship that you want to maintain even if there is a baby? Whether it's a hike once a year or 20 minutes of partner time a week." ▮

The first year of parenthood can put strain on relationships

DEEPOL BY PLAINPICTURE/KNIEL SYNNATZSCHKE

Health

The genetics behind endometriosis

Endometriosis is thought of as a gynaecological condition, but we now know it has links with cholesterol levels, inflammation and cell movement, finds **Helen Thomson**

A HUGE study into the biology of endometriosis has revealed new mechanisms by which it may cause its severe and wide-ranging effects on health, paving the way for improved treatments. The work, which included data from more than a million women, is also the first to identify specific genes linked to endometriosis in people of African ancestry, a group that has historically been under-represented in research on the condition.

"We were able to pinpoint around 300 genes that are going to be really exciting for the field to focus on," says Shefali Setia-Verma at the University of Pennsylvania.

Endometriosis is a chronic, often debilitating condition in which tissue similar to the lining of the uterus grows elsewhere in the body, forming lesions. It affects around 10 per cent of women of reproductive age and can cause fatigue, severe pain and fertility problems. It has also been linked with cardiovascular disease, but the biological mechanisms behind this association have remained unclear.

To investigate, Setia-Verma and her colleagues took a "multi-omics" approach, combining analyses of genes, proteins, the microbiome and endometriosis symptoms to build a holistic view of the condition. They analysed data from 14 global biobanks, which together hold information about more than a million women.

Their initial analyses identified 58 areas of the genome associated with endometriosis, 27 of which were previously unrecognised. A deeper analysis pinpointed 314 genes linked to its development (medRxiv, doi.org/q9vk).

Endometriosis affects about 10 per cent of women of reproductive age

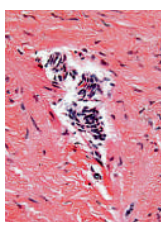
Importantly, the study uncovered three genetic regions associated with endometriosis that were detected only by analysing the genomes of people with African ancestry.

Many of the genes most strongly linked to endometriosis were involved in the immune system, inflammation and cell movement. The last of these is particularly intriguing because endometriosis involves cells growing where they shouldn't. This suggests that the condition

"If inflammation drives symptoms, we might want to target these pathways with existing drugs"

may not simply be about tissue growing in the wrong location, but about the biological process that allows cells to move. "That is really interesting, because we may be able to find treatments that target that movement," says Setia-Verma.

The links with inflammation and the immune system may also explain why endometriosis can have effects beyond the lesions



DR GARY GAUGLER/SPL

Endometriosis can cause cysts to form in ovaries

themselves, such as cardiovascular disease, but also arthritis and depression. In some people, the condition may involve systemic inflammation that goes untreated for years, says Setia-Verma. In the UK, for instance, it takes more than nine years, on average, to receive a diagnosis. "Those years of untreated pain and inflammation can lead to many long-term conditions," she says.

The findings have implications for treatments, too. Endometriosis therapies tend to focus on hormonal pathways, since oestrogen makes lesions grow, bleed and inflame the surrounding tissues. But if inflammation is a driver of symptoms and wider health problems, then we might want to target inflammatory pathways with existing drugs, says Setia-Verma.

The team also identified genes and proteins linked with endometriosis and cardiovascular disease, and the regulation of cholesterol and fats in the blood. "It's essentially saying that endometriosis may be associated with a higher risk for cardiovascular conditions," says Setia-Verma.

Another intriguing finding was that people with endometriosis tend to have lower levels of Bifidobacteriaceae, bacteria involved in maintaining the gut lining and supporting the immune system. "It gives us an understanding of how endometriosis contributes to broader systemic disease risk beyond reproductive health," says Setia-Verma. Microbiologists can now look more closely at the role Bifidobacteriaceae bacteria play in the condition, potentially using this as a target for new treatments, she says.

One strength of the study is that it includes participants from multiple ancestry groups, says Nilufer Rahmioglu at the University of Oxford. This matters because the vast majority of endometriosis research has been conducted in populations of European ancestry, limiting how much the findings can be generalised and contributing to broader disparities in women's health research. "These efforts are an important step towards ensuring that advances in endometriosis research benefit all populations," says Rahmioglu.

However, she adds: "While studies of this type can identify biological pathways and traits that warrant further investigation, they do not by themselves establish that targeting these pathways will improve outcomes for patients."

FINDLAY/ALAMY

De-extinction

A chromosome from a frozen rat has been resurrected inside mice

Michael Le Page

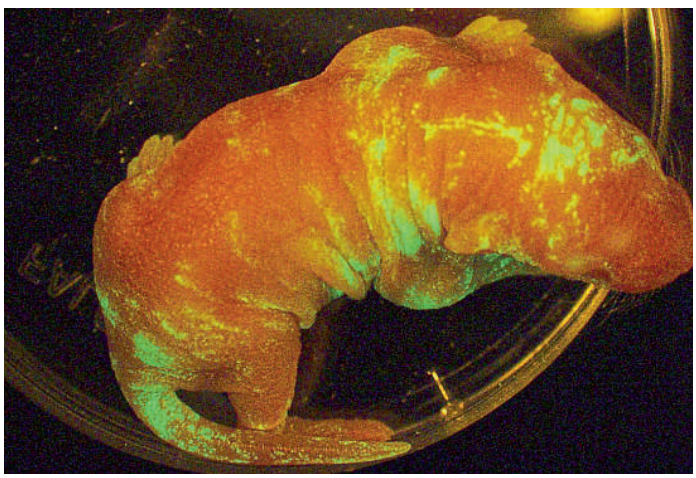
THE de-extinction company Colossal Biosciences could be about to get leapfrogged. It might be possible to resurrect mammoth chromosomes in living cells, after scientists transferred a chromosome from a rat that has been deep-frozen for more than a year into living mouse cells. They then generated entire mice in which some of their cells contain an added rat chromosome.

"Once we have refined the technique, we'll start testing it on elephant cells," says Teruhiko Wakayama at Yamanashi University in Japan. "If we succeed in introducing elephant chromosomes into mouse embryonic stem cells, we definitely want to try it with mammoths."

The team's immediate aim is to study the activity of genes from extinct animals in living ones, which could reveal far more than just analysing genetic sequences. But the work could also help with conservation and de-extinction efforts. For instance, we have frozen tissue from a bird called the Hawaiian po'ouli that went extinct in 2004. A quirk of biology means chromosome transfer would be essential to bring it back to life.

The genomes of animals are divided into pieces known as chromosomes. When cells divide, these long strands of DNA get folded up very tightly and take on the classic cylinder shape pictured in textbooks. These condensed chromosomes, as they are called, can be made visible in living cells without damaging them, for instance, by adding pigments to antibodies that bind to the proteins around which DNA is wrapped.

Wakayama's technique involves extracting the nucleus of a cell and injecting it into an egg to trigger chromosome condensation. This is similar to the nuclear transfer technique used in cloning – Wakayama was the first to clone mice using this technique, soon after the birth of Dolly the sheep.



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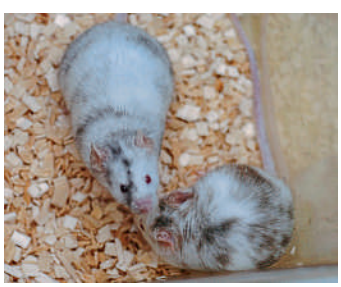

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The cells of mice that contain a chromosome from a rat fluoresce green under UV light (above), but otherwise the animals look normal (left)

The egg with the added nucleus is then injected with enzymes that help separate the chromosomes. Next, a single chromosome is extracted with a microscopic, hollow needle and injected into a second egg. If this egg develops into an embryo, all the cells in the embryo – known as embryonic stem cells – will contain the added chromosome.

"If we succeed with elephant chromosomes, we definitely want to try it with mammoths"

After developing the technique by adding extra mouse chromosomes, Wakayama then tried it with rats genetically modified to fluoresce green. He extracted blood cells from the tail of one of these rats, which had been deep-frozen for more than a year, and successfully generated mouse embryonic stem cells containing an extra chromosome from the genetically modified rat.

These cells were then injected into normal mouse embryos and implanted into female mice, producing chimeric animals in which some of the cells contain the rat chromosome. These animals look like normal mice, but under UV light, some of these cells fluoresce green like those of the original rat (*Scientific Reports*, doi.org/q9md).

The team has attempted to create mice in which all cells contain the extra rat chromosome, but haven't yet been successful. What's more, for now, the technique is working only with rat chromosome 9 – if other chromosomes are added, the eggs don't develop into embryos. "We are currently trying various methods to improve the success rate," says Wakayama.

His team has already obtained samples of frozen elephant tissue from a zoo for testing. Wakayama is also talking to a team that managed to extract and study cell nuclei from a 28,000-year-old mammoth called Yuka about trying this with mammoth chromosomes.

Simply trying to clone mammoths from these cells would never work because there is far too much DNA damage. But Wakayama hopes it might be possible to retrieve individual chromosomes, allowing them to be studied in living cells.

"Even just one successful transfer is a very cool start," says Ben Novak at the non-profit wildlife conservation group Revive & Restore in the US. "In passerine birds, there could be a big value in this work." That's because in passerine birds – a large group that includes more than half of all bird species – the cells that form body tissues, such as skin and muscles, lose a chromosome. This extra chromosome is retained only in the reproductive cells that form the egg and sperm.

Because the Hawaiian po'ouli was a passerine bird and only non-reproductive male tissue was frozen, bringing it back would require adding two chromosomes from closely related species – the chromosome found only in reproductive cells and the W chromosome found only in female birds. "It would produce partial hybrids, but it would allow for the revival of the species," says Novak. ▮

Artificial intelligence

On the edge of burnout

Volunteers that maintain the open-source software the modern world relies on are struggling with the growing burden of fixing AI-written code, reports **Matthew Sparkes**

A VIRAL cartoon about open-source software shows a teetering pile of boxes labelled "all modern digital infrastructure" and one tiny box right at the bottom, propping up the whole lot: "a project some random person in Nebraska has been thanklessly maintaining since 2003".

That's the reality of open source: every website, application and operating system relies on it. Modern society couldn't function without it, yet it's written by volunteers in their spare time.

"AI-written code can look superficially like it's going to work, but the problems are a bit more hidden"

But the growing burden caused by a flood of AI-generated code is causing many to burn out and leave the community altogether, threatening the future of open-source software.

AI models are making it easier and easier to generate code to build new features, fix bugs or create new projects at the click of a button. But that code is often confusing, difficult to integrate into existing projects or simply garbage. While code submissions get ever easier, human contributors responsible for checking, fixing and approving them are getting swamped.

For some workers, the demands have become unbearable. *New Scientist* arranged an interview with Chad Whitacre, who runs the open-source team at Sentry – a company valued at billions of dollars. Days before the interview, Whitacre cancelled and said he was leaving his role. He wrote a blog post explaining that he was stepping away from technology and living a "Neo-Amish" existence. "AI was the last straw," he wrote.

GitHub, the online platform where many open-source projects are hosted and organised, received 1 billion new code submissions in 2025; this year is on track for 14 billion, said its chief operating officer Kyle Daigle in April.

Many projects are blocking new contributors in a bid to stem the flow of what has been labelled "drive-by contributions" generated by AI, often submitted by young developers who want to have an expansive GitHub submission history to boost their appeal to software-company recruiters. Zig Software Foundation, which promotes the Zig programming language, banned AI-assisted contributions because they were "invariably garbage", said its president Andrew Kelley.

"AI-written code can look superficially like it's going to work and not cause any problems, but the problems are a bit more hidden and it takes a lot of effort to comb through and look for the things that might break something," says Miranda Heath at the University of Edinburgh, UK.

Volunteers are having to spend longer checking AI-assisted code submissions

Heath is researching the effects of burnout in the hope of finding ways to mitigate the problem and ensure that open source remains a sustainable field. But she encounters many people who have already had enough.

Increasing demands

Heath believes governments should invest more in open source, rather than awarding contracts to rich technology firms. "Shore up the stuff that's important, that you really need, rather than chucking money towards the [AI] bubble," she says.

Vlad-Stefan Harbuz, also at the University of Edinburgh, works on open source in his spare time and has seen the demands placed on developers by users. "There's this entitlement, like, you've wronged me by not doing free labour for me at the expense of your mental health," he says.

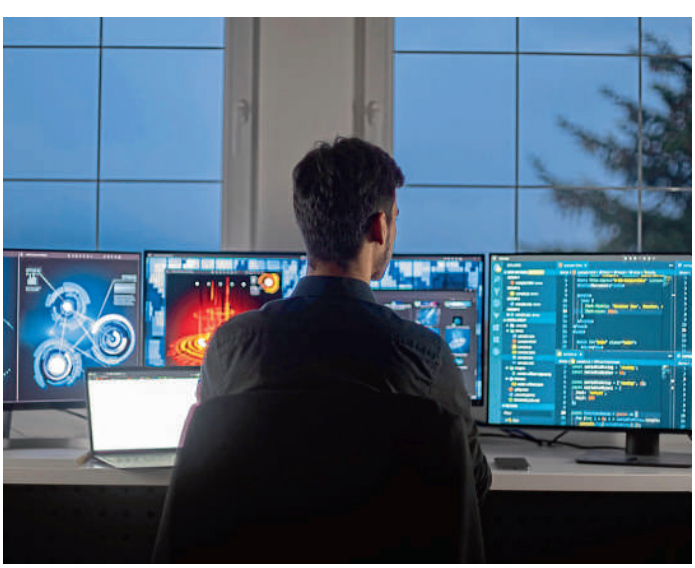
Harbuz says the fault over increasing AI submissions lies with companies that release the models – and that GitHub is one of the main offenders. The Microsoft-owned firm has launched its own AI model, GitHub Copilot, to help people contribute to projects with AI-generated code.

"GitHub will say 'oh, we realise [AI] agents have been such a problem, we're gonna maybe do something to fix it', and it's like, it's you, right? You, GitHub, did this," says Harbuz. GitHub didn't respond to a request for comment.

For Harbuz, the problem with AI-generated code is not just that it might not work, but that people can drop thousands of lines of code without even discussing it with the project's team. It sidesteps planning and can steer them in unwanted directions. Collaboration can be thrown into disarray and the social contract of open source can break, he says.

Developer Mike McQuaid, who works on a project called Homebrew that has an estimated 20 million users, has started an initiative called the Open Source Resistance, which calls on people to work on projects during their day job to make contributing easier. He estimates that as much as 95 per cent of his open-source work is done during office hours.

"We've maybe had this brief golden-age window [where] you can assume if someone writes a two-page document proclaiming a security vulnerability that it's probably legit. My experience in the last year has been the majority of those are nonsense and are just AI-generated stuff that doesn't apply," says McQuaid. "And the skill right now is being able to essentially skim a two-page document and spot that it's nonsense, while investing as little of your own time and energy as you possibly can." ▮



MASTER/GETTY IMAGES

Are we getting to the point where it's safe to gene-edit babies?

A team in the US has reported using an improved form of CRISPR to gene-edit human embryos, but a major issue remains unsolved, discovers **Michael Le Page**

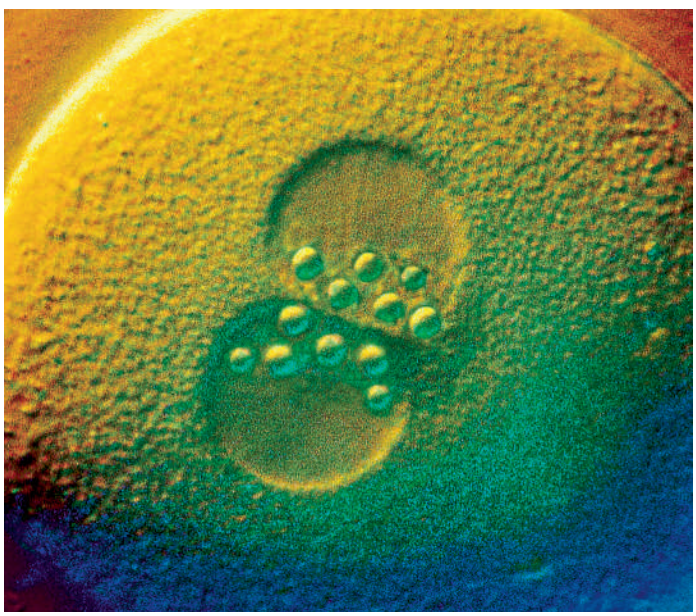
WHEN a rogue researcher in China revealed in 2018 that he had used CRISPR to create three gene-edited children, his actions were almost universally condemned by biologists. The main objection was not that gene-editing babies is wrong in itself, but that the CRISPR technique used wasn't safe and had a very high risk of causing harmful mutations.

Now, a team in the US has used an improved form of CRISPR, known as base editing, to edit healthy embryos and shown that it can be done without introducing unwanted mutations. So, are we now at the point where we could consider allowing the use of the technique? The answer is no, because a major obstacle remains.

Our DNA consists of two strands. The first form of CRISPR to be developed uses a protein called Cas9, which hooks up with a piece of guide RNA that helps it find a specific place in the genome. Once there, Cas9 cuts through both strands. When a cell tries to repair the damage, it often makes mistakes, introducing small mutations that can disable genes.

So CRISPR-Cas9 is a destructive technique even when it works as intended, and it sometimes goes wrong, with the cut ends of DNA being reattached in the wrong places, causing large mutations and chromosomal abnormalities.

But many improved forms of CRISPR have been developed. For instance, CRISPR base editors change a single DNA letter to another, and during the process cut only a single strand of DNA. So base editing can be used to make precise repairs with much less chance of anything going wrong. The technique has already saved lives and a number of trials are under way – for instance, to test it as a treatment for conditions that result in very high cholesterol.



LENNART NILSSON, TT/SCIENCE PHOTO LIBRARY

The male and female nuclei fuse inside a fertilised egg

"This gene editing has to work perfectly, because a human embryo gives rise to every cell in the body"

But editing embryos is very different from treating diseases. In adults, it doesn't matter if gene editing doesn't work perfectly in every cell – often only a fifth of cells in the liver, say, need to be successfully edited to treat a disease. In a human embryo, however, gene editing has to work perfectly, because that embryo will give rise to every cell in the body.

In 2017, a team in China reported promising results in a small study that used human embryos discarded during IVF because of abnormalities. They found base editing made the desired change in almost every embryo, with very few unintended changes.

Now, Dieter Egli at Columbia University in New York and his team have done a larger study using healthy two-cell embryos donated by parents, with broadly similar results (bioRxiv, doi.org/q9t8). The team tried making two changes. One was successfully made in three-quarters of cells, with no unwanted changes. The other change worked only in around half of the cells, and often caused unwanted changes.

The researchers think the reason it worked well in one case and not so well in the other is down to the guide RNAs used – with better design and testing of guide RNAs, it should be possible to avoid off-target effects, they say.

Finding a solution

But the biggest problem is that base editing didn't work in every cell in each embryo, an issue called mosaicism. If a mosaic embryo develops into a child, only some of the cells in their body will have the intended change, which means they could still develop the disease the gene editing was meant to prevent, say. The three gene-edited children growing up in China may all be mosaics.

The trouble with this is that there is currently no way to be sure a gene-edited embryo isn't a mosaic. When there is a risk of children inheriting a serious disease, a single cell can be removed from IVF embryos for genetic testing. This could be done with gene-edited embryos, too, but if the embryos are mosaic, testing a single cell isn't enough.

So while these latest results are promising, the mosaicism problem is going to have to be solved.

How? Well, one way would be to use gene-edited sperm or eggs. If the editing is done before an egg is fertilised and starts to divide, there should be no mosaicism. That has not been done in humans, but a start-up recently claimed it can generate sperm in the lab from sperm stem cells – and if that's true it should be possible to gene-edit those sperm stem cells.

That approach might help us get to the point where we can safely gene-edit children. Whether we should is another question. ▮

Quantum computing

An error-correction milestone

An atom-based quantum computer can correct its own errors during long computations, an important prerequisite for becoming truly useful, reports **Karmela Padavic-Callaghan**

THE race to build the first truly useful quantum computer just got more exciting. A quantum computer made from extremely cold atoms has now passed some of the most important milestones towards usefulness, joining a small group of equally able and promising machines.

Though there is wide agreement that sufficiently powerful quantum computers would transform our ability to discover new materials and drugs, and break the encryption that underpins the internet, there are many competing ideas about how best to build them.

Industry mainstays such as Google and IBM have spent a decade building quantum computers from tiny superconducting circuits, and this approach is currently the front-runner.

But an alternate approach that uses electrically neutral ultracold atoms has recently been gaining traction. Ben Bloom at Atom Computing and his colleagues built a so-called neutral-atom quantum computer that can repeatedly catch and correct its own errors, which is a crucial requirement for it to become useful.

"This is a big check mark for what you can do in a neutral-atom system," he says. "The differences between [experiments] we were doing before were big step changes, but now, it is just about building it better, faster, cheaper."

The researchers focused on error correction, or the quantum computer's ability to recognise it made a computational error and discard and restart the calculation. Quantum computers are notoriously error-prone, so fixing them is one of the biggest obstacles towards usefulness.

Error correction involves spreading information across several quantum computing bits, which are called qubits. Some of these qubits are then used as an alert system for when an error has occurred, so that it can be fixed.

AROM COMPUTING

Atom Computing built its quantum computer using extremely cold atoms

The team at Atom Computing showed that it could increase the size of the qubit groups for error correction, from groups of 16 to groups of 32, without introducing any additional errors. In fact, error rates were lower for the larger qubit grouping. This is important because increasing the number of qubits in a quantum computer is ultimately what makes it more powerful.

In 2023, researchers at Google simultaneously increased the qubit number and decreased the error rate in a superconducting quantum computer, as did a team at the University of Science and Technology of China in 2025. Also in 2025, a team of researchers at Harvard University showed the same for another neutral-atom quantum computer. Bloom says that what sets the new experiment apart is that the team could keep the quantum computer running and checking for errors, looking at those alert-system qubits, up to 90 times in a row. "The goal was always... to run error correction ad infinitum," he says.

> **"The new work sets neutral-atom quantum computers as a formidable competitor to other approaches"**

Solving industrially relevant problems will require both lots of qubits and computations that can reliably keep going, and the team at Atom Computing argues that the new work makes a case for being able to do both.

"This study is the first to bring together all of the capabilities needed to build a real neutral-atom quantum computer in a single experiment," says Jeff Thompson at Princeton University. He says that this required an experimental tour de force, but that there is still room for improvement in the overall error rates and speed of computation.

One step closer

Mark Saffman at the University of Wisconsin-Madison says that this is another step towards building a neutral-atom quantum computer that really could be operated continuously, similar to how conventional computers can just keep working. Yet, Saffman says that as the quantum computer kept working through those 90 rounds of checking for errors, some additional errors did accumulate after all, which detracts from its promise of usefulness.

Bloom says that he and his colleagues are already working on addressing some of the errors, and he is confident in the team's ability to continuously improve the quantum computer's performance. In his view, taken together with the work from other research groups, the new work sets neutral-atom quantum computers as a formidable competitor to other approaches, including superconducting qubits.

"What this work is showcasing is that a lot of the physical mechanisms that stop neutral atoms from being as awesome as superconducting qubits are starting to disappear," says Bloom. Thompson has a similar view. "I expect rapid progress to follow... across the industry," he says. ▮

Artificial intelligence

Ditch the niceties in AI prompts to save energy use

Luke Taylor

UN RESEARCHERS are urging people to be less polite to artificial intelligences, after a report found that cutting words from prompts could reduce ChatGPT's energy consumption by up to 25 per cent.

Removing "please", "thank you" and other unnecessary words from prompts for ChatGPT, for instance, could save 87 to 98 gigawatt-hours of electricity per year, the report from the UN University Institute for Water, Environment and Health (UNU-INWEH) found (*Environmental Cost of AI's Energy Use: Carbon, Water and Land Footprints*, doi.org/q9m2). That is the equivalent of the annual residential electricity use of up to 760,000 people in sub-Saharan Africa.

To reduce their energy consumption and carbon footprint, people should write concise prompts, avoid getting sucked into conversation loops and refrain from starting relationships with AI, the researchers said. "We are not saying be rude to your AI. But don't fall into the interaction trap and don't go falling in love with it either," says Kaveh Madani at UNU-INWEH.

The large language models behind AI chatbots process text in small units known as tokens. Madani says concise prompts can save energy because they can reduce both the number of tokens the model has to process and the number it generates in response. In some cases, shorter prompts may also simplify the task, further reducing the power required.

People should be encouraged to avoid using AI unnecessarily and, when they do use it, to cut words and use less powerful models, says Madani.

"We are not saying AI is bad," he says. "We are just saying let's use it in a proper way. It's like a knife: you can save a patient's life in the operating theatre, but you can also kill someone with it." ▮

Environment

Mysterious triple symmetry could influence Earth's climate

James Woodford

A LINE that runs through Africa, Europe, Alaska and both poles divides Earth into two halves that reflect the same amount of light – and this may have implications for solar geoengineering schemes.

It was previously known that the northern and southern hemispheres have almost equal reflectivity, or albedo, but Jianhao Zhang at the National Oceanic and Atmospheric Administration in the US and his colleagues have now uncovered a second line of symmetry along the 27° east and 153° west meridians.

The hemispheres separated by this line are nearly equal in three respects: their albedo in clear skies, the reflectivity of clouds and the fractions covered by ice-free oceans. This symmetry has persisted over 25 years of satellite observations analysed by Zhang and his team (*Nature*, doi.org/q9gf).

At first, Zhang thought it must be a coincidence. "What convinced me that the east-west symmetry is not trivial are three features: its uniqueness, its persistence and what we call the triple symmetry feature," he says. "Finding one division with equal total reflection might be expected. But finding a persistent, unique east-west division that also balances land-ocean distribution, clear-sky reflection and cloudy-sky reflection is much less trivial – especially given how variable and dynamic clouds are."

"This may be connected to one of the most important modes of climate variability on Earth"

While the east-west symmetry is centred near 27° east when averaged over the 25-year satellite record, in any individual year, the exact line of symmetry shifts slightly. The team found that these small year-to-year shifts are strongly related to the phase of the El Niño-Southern Oscillation (ENSO), a global climate phenomenon related to fluctuations in sea-surface temperatures in the Pacific.

"In other words, the symmetry may not simply be a geometric accident," says Zhang. "It may be connected to one of the most important modes of climate variability on Earth."

Øivind Hodnebrog at the Centre for International Climate Research in Oslo, Norway, says he doubted the discovery at first. "I was a bit sceptical of an east-west symmetry separated at around 27° east, which intuitively seems much less obvious than a separation at the equator." However, he says he now thinks it is likely a "robust feature, and potentially another fascinating property of Earth".

The connection to ENSO may also be significant, says Hodnebrog. Unlike the north-south symmetry, which appears to be weakening due to the effects of climate change on sea ice and clouds, the east-west symmetry is currently stable, though models suggest it could weaken in future. "A potential future asymmetry could be an indication of changes in the atmospheric circulation," he says.

Martin Jucker at the University of New South Wales Sydney says there is a high chance the symmetry is a coincidence. "Earth's weather and climate communicate easily across longitudes," says Jucker. "This is due to Earth's rotation, which creates bands of circum-global easterly and westerly winds, and atmospheric perturbations preferentially propagating in the east-west direction as well."

If there are mechanisms that maintain the east-west symmetry, they could have implications for geoengineering schemes, says Zhang. For example, attempts to increase the albedo of one hemisphere might be negated by a global-scale feedback loop. ▮

A line through Europe and Africa splits Earth into two equally reflective halves

PLANETARY VISIONS LTD/SCIENCE PHOTO LIBRARY

Analysis Climate change

The looming El Niño could be bad – but worse is to come

Global warming will amplify the impacts of El Niño events, and could also make them much stronger, finds **Michael Le Page**

A "GODZILLA El Niño" is coming, according to some newspapers. The actual story is that there is an 80 per cent chance of an El Niño developing by September. Most models forecast a moderate event – but some suggest it could be very strong, perhaps even a so-called super El Niño.

That said, the bigger picture isn't reassuring. However strong this El Niño turns out to be, we can be sure that even more damaging El Niños will occur in the coming decades.

"Even a standard El Niño event in future will cause larger regional and global impacts," says Axel Timmermann at Pusan National University in South Korea.

What's even more alarming is that studies by Timmermann and others suggest that El Niños and La Niñas, known as El Niño-Southern Oscillation (ENSO) events, will start to drive weather in the Atlantic in addition to the Pacific region, amplifying their impacts.

"Our latest computer model simulations predict a shift to more regular and much stronger El Niño-La Niña extremes, as well as an intensification of ENSO impacts on remote regions, in particular Europe," says Timmermann.

The El Niño phenomenon is all about water and winds in the Pacific. During so-called neutral conditions, trade winds blow westwards along the equator, pushing the surface water westwards and piling warm water up along the western Pacific. Cold water wells up next to South America to replace the surface waters being pushed westwards, while warm, moist air rises above the warm waters piled up in the west, producing a lot of rain.

But sometimes the trade winds weaken and even reverse, allowing some of that warm water to spill eastwards. The area of rainfall shifts eastwards, too, which can strengthen the easterly winds – one of the positive feedback loops that cause El Niños to develop.

"Even a standard El Niño event in future will cause larger regional and global impacts"

This eastward shift also causes droughts in places such as Australia and Indonesia, and floods in South America.

It is also why El Niños lead to rapid warming of Earth's surface. A larger area of warm water leads to more evaporation, and energy from the water is released as latent heat when clouds form, transferring vast amounts of heat from the Pacific into the atmosphere.

The strength of El Niños is determined by just how much and how far warm water moves eastwards towards South America. This is measured in terms of how much warmer than usual the central and eastern Pacific becomes. Definitions vary, but an El Niño is said to be happening when the sea-surface temperature anomaly exceeds 0.5°C. A super El Niño isn't a scientific term, but it could be used for those above 2°C, suggests Adam Scaife at the Met Office Hadley Centre in the UK.

As El Niños develop, there are negative feedback loops that also kick in. In particular, more clouds over the central Pacific have a cooling effect, leading to a return to neutral conditions or a shift to La Niña, where the westerly trade winds strengthen and push cooler upwelling water further west than usual.

The three strongest El Niños since records began were in 1982-83, 1997-98 and 2015-16. All three were super El Niños that caused immense harm to people and wildlife. Each also caused trillions of dollars in damages, according to a 2023 study by Christopher Callahan at Indiana University.

As the world warms, future El Niños – and super El Niños – will do even more damage. ENSO-related floods will become more intense because there will be more moisture in the atmosphere, says Richard Allan at the University of Reading, UK. This means more rain will fall when it rains. And the droughts will be longer and more intense, too, because soils dry out faster when it is hotter.

Big swings ahead

Some climate models also suggest warming will amplify the feedback loops that drive ENSO events. That could lead to stronger El Niños and La Niñas, with faster transitions between them.

Worse still, Timmermann's team's study suggests these stronger swings would lead to ENSO events starting to drive and synchronise with a climate phenomenon known as the North Atlantic oscillation. This would lead to big swings between floods and droughts in Europe, too.

While there's high certainty that El Niños of the same magnitude will be more damaging, there's much less certainty about El Niño becoming more intense. "There is quite a bit of disagreement about the future behaviour of El Niño and La Niña," says Scaife.

Even if ENSO events do become more intense, they won't continue to intensify indefinitely, says Timmermann. The intensification is driven in part by the rapid warming of the top 100 metres of water in much of the Pacific. Once the underlying waters start to catch up and the temperature difference falls, ENSO events are likely to weaken, he says. The catch? This might not start to happen until after 2150. Buckle your seatbelt.

Future El Niños could be even more damaging than they are now

REBECCA BLACKWELL/AP PHOTO/ALAMY

Archaeology

Stonehenge's altar stone probably wasn't transported by a glacier

James Woodford

RESEARCHERS investigating Stonehenge's enigmatic altar stone say it is possible the 6-tonne rock was carried southwards from Scotland by ice flows – but this hypothesis relies on an unlikely series of events, making it more likely that humans transported it.

The 5-metre-long monolith, which is partially buried and overlain by two other stones, has been at the centre of Stonehenge's ring of worked boulders for around 4500 years.

In 2024, researchers including Anthony Clarke at Curtin University in Perth, Australia, determined that the altar stone came from north-east Scotland, based on the rock's chemistry.

"The altar stone is a sandstone – you can imagine grains of sand at the beach that have been squished together," says Clarke. "We can get an age and the chemical composition for each of those grains and build up a fingerprint, which we can then forensically compare to other rocks."

The altar stone's chemical fingerprint matched outcrops in the Orcadian basin, a geological feature that overlays parts of north-east Scotland. This meant the stone must have been transported 750 kilometres southwards to Stonehenge, in southern England.

Clarke and his colleagues originally thought it was most likely that the stone had been transported by boat. But they also wondered whether it could have been moved by ice during the last glacial period, potentially reducing the distance humans would have had to carry it.

There are many mysteries surrounding the construction of Stonehenge

In the new study, Clarke and his team used geological analysis and ice-flow modelling to reconstruct ancient glacial movements.

They found that most ice flows from north-east Scotland went to the north, but some did head south and would have dumped their cargo of rock at Dogger Bank (*Journal of Quaternary Science*, doi.org/q9f6). During the last glacial period, Dogger Bank was part of a land bridge connecting Britain with mainland Europe, but it now lies under the North Sea, off England's east coast.

KARL HENDON/GETTY IMAGES

If ice had transported the altar stone to Dogger Bank, it would have shortened the distance humans would have needed to move the stone by several hundred kilometres.

But Dogger Bank was inundated around 8000 years ago, and the construction of Stonehenge didn't commence until around 5000 years ago. This means it requires an "increasingly elaborate set of circumstances" to envisage how glaciation could have moved the altar stone, says Clarke.

Some of the other stones that make up Stonehenge, weighing 25 to 30 tonnes, were transported tens of kilometres by humans. This means that, with enough time, they would have had the technology to move the altar stone even further, says Clarke.

"These people... weren't in any rush. This could have been much like the pyramids, a multi-year endeavour, so it doesn't need to happen on our modern timescales of months," he says. ▮

Health

Pancreatic cancer drug doubles survival time

PEOPLE with advanced pancreatic cancer taking an experimental pill lived nearly twice as long as those receiving chemotherapy infusions.

"It's a transformative treatment," says Pilar Acedo at University College London, who wasn't involved in the research. "[The new treatment] gives you double the amount of time to enjoy your life."

About 70 per cent of people with pancreatic cancer are diagnosed at an advanced stage. A combination of no routine screening and vague symptoms means the condition is usually spotted when it has spread elsewhere. Standard treatment involves chemotherapy, but most people survive for only about three to six months, on average.

More than 90 per cent of pancreatic cancers are driven by mutations in the *KRAS* gene, which encodes for a protein known as K-Ras. When the gene is mutated, K-Ras gets stuck in a state that drives cancer cells to divide uncontrollably.

Eileen O'Reilly at Memorial Sloan Kettering Cancer Center in New York and her team wondered if a drug called daraxonrasib, which binds to the protein, could dampen its signals and slow the growth of cancer cells.

So they recruited 500 people with metastatic pancreatic cancer from the US, Europe and Asia, all of whom had stopped responding to an initial round of chemotherapy. They were split into two groups: the first took daraxonrasib every day, and the second continued to receive standard chemotherapy infusions.

"This is a transformative treatment. It gives you double the amount of time to enjoy your life"

The team – who presented the results at the American Society of Clinical Oncology meeting in Chicago on 31 May – found that those in the daraxonrasib group went on to survive for 13.2 months, on average, compared with 6.7 months in the chemotherapy group.

The team has submitted the findings to the US Food and Drug Administration, and hopes to get the drug approved for use in people with metastatic pancreatic cancer who have had chemotherapy in the coming months, says O'Reilly. ▮

Carissa Wong

Archaeology

Ötzi's microbiome may be active

We have identified bacteria that lived in the gut of Ötzi, a 5300-year-old mummy, as well as cold-tolerant fungi that colonised his body after death, finds **Chris Simms**

SOME of the microbes lingering on the 5300-year-old remains of "Ötzi the Iceman" may still be metabolically active, despite being kept in icy conservation conditions.

Ötzi's mummified body was discovered in 1991, thawing out of an Alpine glacier close to the border of Austria and Italy. He is estimated to have lived at some point between 3350 and 3120 BC, and in the 35 years since he was found, studies of his remains have revealed a treasure trove of information, including that he was probably dark-skinned and balding, and had a wound in his shoulder from an arrow, suggesting he was murdered.

"This study shows that Ötzi isn't a biologically frozen time capsule, but a complex ecosystem"

Ötzi is now kept at the South Tyrol Museum of Archaeology in Bolzano, Italy, in conditions designed to mimic those inside the glacier where he was found: a temperature of -6°C (21°F) and a relative humidity of 99 per cent.

Frank Maixner at Eurac Research's Institute for Mummy Studies in Bolzano and his colleagues have analysed the bacteria and fungi found in skin swabs, tissue fragments and internal thawed water samples from the mummified remains taken in 1992, 2010 and 2019 and compared them with soil and ice samples collected from the discovery site in the 1990s.

On Ötzi, they found both ancient and modern-day microbes, some of which may be metabolically active (*Microbiome*, doi.org/hb6dd7). "We can really distinguish between the Iceman's endogenous gut bacteria and microbes that joined from the environment as soon as he died," says Maixner.

The team's metagenomic analysis of internal tissues revealed specialist bacteria that thrive without oxygen inside the mammalian gut, including species of *Treponema* and *Kineothrix*. Based on the level of damage to the DNA of these bacteria, which accumulates over time, the bacteria probably lived inside Ötzi when he was alive.

There was a wide variety of microbes present, as seen in other prehistoric gut-microbial communities, which may reflect the more varied diet of Copper Age humans compared with modern Western societies, says Maixner.

They also found *Pseudomonas* bacteria – commonly seen in soil and water – in all samples. The DNA damage of these bacteria indicates that they probably belong to an ancient community from the discovery site, says Maixner.

On the external Ötzi samples, the team uncovered cold-loving, or psychrophilic, yeasts, including *Phenoliferia*, *Glaciozyma*, *Goffeauzyma* and *Mrakia*.

A reconstruction of what Ötzi may have looked like, according to researchers

DNA damage indicated that these were also ancient microbes, but the abundance of *Glaciozyma* increased between 2010 and 2019, and it became the dominant strain, while the level of DNA damage dropped. This suggests it may be metabolically active, or able to replicate under the conservation conditions.

"I think it's good evidence that *Glaciozyma* colonised the mummy post mortem. They seem to be growing for some reason," says Nikolay Oskolkov at Lund University in Sweden, but he would like to see more data points to show that the results aren't a result of experimental procedure.

The growing abundance of this yeast is potentially very interesting, says Damla Kaptan at the University of Stavanger in Norway. But we can't be sure it is active until we also look for RNA that would be produced from the yeast DNA, which would indicate that its genes are turned on. "There is still the possibility that the yeast remained dormant or became active to some extent during thawing," she says.

Some of these yeasts encode enzymes for breaking down protein and collagen, so they could harm the mummy, but the team saw no evidence of damage.

The team also found that some of the microbes contain genes required for degrading the toxic compound phenol. Maixner suggests this may be a side effect of researchers in the 1990s treating the mummy to kill off fungi.

Maixner says the study shows that Ötzi isn't a biologically frozen time capsule, but a complex ecosystem shaped by the succession of his gut microbes after he died, the infiltration of organisms from the glacier over thousands of years and then three decades of conservation.

He recommends regular genomic surveillance, including looking for other signs of activity, like RNA and metabolites produced by microbes, to check whether the microbial communities have really awoken from dormancy and are degrading the mummy's tissues. If so, scientists might need to consider whether conservation conditions should be changed. ▮

Ötzi the Iceman's remains are kept at a temperature of -6°C

AUGUSTIN OCHSENREITER, MARION LAFOGLER/EURAC RESEARCH/SOUTH TYROL MUSEUM OF ARCHAEOLOGY

Geology

Mysterious metal may have helped bring us oxygen

Karmela Padavic-Callaghan

DEEP below our feet, manganese may exist in a form we have never seen before, and this underground source of the metal could have played a role in how Earth got its oxygen.

Until about 2 billion years ago, Earth's atmosphere barely contained any oxygen. Then came the Great Oxygenation Event (GOE), when oxygen produced by photosynthesising microbes started to accumulate, spurring the development of more diverse forms of life and changing the planet.

Manganese is thought to have been a crucial component in an early version of photosynthesis, before the evolution of the oxygen-producing pathway that is widespread today. In Earth's crust, manganese is commonly found in oxygen-containing ores, which started to accumulate at around the same time as the GOE.

According to Jingming Shi at Jiangsu Normal University in China, some of this ore could have come from a hitherto unknown manganese compound deep underground, hiding in Earth's mantle.

> "We did not expect such a manganese-rich oxide to be stable over such a wide pressure range"

Many manganese oxides are known to exist at standard pressure, but Shi and his team set out to explore which of them may be stable at extreme pressures and temperatures deep inside our planet. They used a computer simulation to explore how thousands of different arrangements of manganese and oxygen atoms would behave at pressures up to 1.5 million times atmospheric pressure, comparable to conditions 2900 kilometres under Earth's surface.

This led them to several new compounds, including one that has four manganese atoms for every oxygen atom, which is unusually rich in the metal (*Physical Review B*, doi.org/hb6ggb). "We did not necessarily expect such a manganese-rich oxide to be stable over such a wide pressure range. That was the most interesting and unexpected finding," says Shi.

While the team doesn't have direct evidence that the new compound exists within Earth's mantle, its properties could partly explain why seismic waves travel unusually slowly through some regions where our planet's mantle and core meet. This raises the possibility that some very manganese-rich patches in Earth's interior have gone unrecognised in studies of how manganese moved through it in the past, says Shi.

The new manganese compound could have plausibly moved from Earth's interior to the floor of ancient oceans, partly explaining why so much manganese ore appeared during the GOE, says Timothy Lyons at the University of California, Riverside.

"One reason this work is interesting is that high pressure can stabilise compounds that would not normally exist near Earth's surface. Under extreme compression, atoms bond differently and materials can adopt unusual crystal structures and oxidation states," says Caroline Peacock at the University of Leeds in the UK.

But a lot more evidence is needed to make any firm conclusions, in her view. ▮

How to tell if memory slowdown is 'normal' Memory lapses are common, but can also be signs of dementia. **Daniel Cossins** learns how to separate typical brain ageing from cognitive decline

Daniel Cossins is a freelance journalist who was on staff at *New Scientist* for nine years, latterly as head of features

Daniel's week

What I'm reading
The Life You Want *by Adam Phillips, on what psychoanalysis and philosophy have to say about what we want from life*

What I'm watching
Big Cats 24/7, *about the scrap for survival among lions, leopards and cheetahs in Botswana's Okavango Delta*

What I'm working on
A feature about world models in AI

WE'VE all been there. You walk upstairs only to find yourself wondering why you bothered. You blank on an acquaintance's name, just as you're introducing them. Or maybe, after a frantic search, you find your car keys in the fridge of all places.

Such momentary lapses of memory can be disconcerting, but they are part of getting older. "Decline in what researchers call episodic memory – what happened, where and when – is a normal part of human cognitive ageing," says Ulman Lindenberger, a cognitive neuroscientist and director of the Max Planck Institute for Human Development in Berlin.

This is largely explained by structural and functional changes to the brain that begin in middle age and accelerate from there. In a 2025 paper analysing more than 3700 "cognitively healthy" adults, Lindenberger and his colleagues found age-related memory decline tracks closely with the deterioration of connections between brain regions, itself the result of the gradual degradation of the fatty coating that insulates neurons, and shrinkage of the hippocampus – a brain region crucial in forming new memories.

> **"In many cases, everyday memory failures are actually just failures of attention"**

This is nothing to worry about, says Lindenberger. "Learning and episodic memory are all about forming new, and remembering previously formed, associations – and the corresponding machinery of our brains becomes less reliable with advancing adult age."

In many cases, everyday memory failures are actually just failures of attention: if your brain never properly encoded where you put your keys because you were distracted or stressed in the moment, there isn't much in the way of memory to retrieve later.

RENE SCHMIDT/ALAMY

Forgetting where you put your keys is a common example of a memory lapse

Broadly speaking, neurologists themselves take notice when incidental forgetfulness becomes a pattern that interferes with daily functioning, and when memory loss accelerates in such a way that others notice. "When it starts to become a pattern and those around you notice these episodes, it might be time to seek attention," says Ronald Petersen, a neurologist at the Mayo Clinic in Minnesota.

Petersen says one way to think about what constitutes a pattern might be to think about whether you, or someone you're concerned about, repeats themselves.

The reason conversational repetition is a good indicator has to do with what happens in the brain in mild cognitive impairment, the transitional stage between typical ageing and dementia, and early-stage dementia. In Alzheimer's disease, by far the most common form of dementia, some of the earliest changes occur in the hippocampus and entorhinal cortex, which are crucial for encoding and consolidating new episodic memories. This means that people affected struggle disproportionately with forming new memories – of a recent conversation, for instance – rather than with recalling established memories. If someone asks the same question several times in the space of an afternoon, it may be because the memory of asking the question never properly formed in the first place.

However, there is no hard-and-fast rule when it comes to what kinds of forgetfulness indicate something more serious than typical age-related memory loss. "In advanced old age, the line between the lower range of normal [age-related memory decline] and dementia is difficult to draw," says Lindenberger. Put simply, the problem is that there isn't a sharp distinction, in terms of behaviour, or even biology, between the two.

Everything from anxiety, stress and depression to menopause and medications have been shown to temporarily impair attention and episodic memory. So, it is always worth considering what else might lie behind signs of cognitive impairment. We should also be wary of over-interpretation. A 2025 study showed that older adults with high levels of what researchers call "dementia worry" are more likely to interpret everyday memory lapses as signs of impending cognitive decline than those in a control group, which is itself associated with negative health outcomes.

The truth is that knowing what is "normal" and when to worry about memory loss in old age is difficult even for neurologists – never mind for the rest of us. Ultimately, then, perhaps the best rule of thumb is, as Lindenberger says, that "there is reason to be concerned when [memory] decline is fast and starts to interfere with daily routines".

Does turmeric have any actual health benefits? The spice is heralded for its anti-cancer and anti-inflammatory properties, but **Alice Klein** finds that the evidence for this is shaky

AS THE temperature drops in Australia, I've been seeing recipes on social media for "golden milk", a mix of turmeric, other spices and honey in warm milk. In addition to being delicious, it is meant to have medicinal qualities, thanks to a compound in turmeric called curcumin, which gives it its distinct yellow colour. Curcumin is said to have anti-inflammatory properties that are protective against cancer, arthritis, hay fever, Alzheimer's disease and many other ailments. But is this based on solid evidence?

Turmeric has been used in South Asian cooking and medicine for thousands of years, but has been exalted as a "superfood" in the West over the past couple of decades. This is largely thanks to the research of Bharat Aggarwal, a biochemist formerly at the University of Texas MD Anderson Cancer Center. Starting in the early 2000s, he published over 100 papers showing that curcumin reduces inflammation and kills "almost all types" of tumour cells.

Turmeric has been used in South Asian cooking for thousands of years

But a large question mark now hangs over the validity of Aggarwal's research findings. In 2012, the Office of Research Integrity at the US Department of Health and Human Services notified the MD Anderson Cancer Center about allegations by academic whistleblowers of potentially fraudulent results in at least 65 of Aggarwal's papers (although that doesn't mean that the results are, in fact, fraudulent). Aggarwal left the cancer centre after an internal investigation, and 30 of his papers have now been retracted from scientific journals based on concerns about the authenticity of the results. Aggarwal's papers, of which there are several hundred, are still regularly cited. *New Scientist* was unable to reach him for comment.

Personally, I find it surprising curcumin has managed to attract so much attention because a quick look at its chemistry tells you it is unlikely to be much good as a drug. Years ago, when I did a PhD in cancer drug development, one of my lab colleagues experimented with curcumin, but found it almost impossible to work with because of its poor solubility and tendency to degrade.

Because very little curcumin dissolves in water, it isn't easily absorbed into the blood following ingestion. Instead, most of it stays in the gut and is excreted in faeces. A study published by Dutch researchers last year found that curcumin was barely detectable in the bloodstreams of men who took curcumin supplements, even high doses of "enhanced" formulations meant to boost absorption with piperidine from black pepper or nanoparticle delivery systems. The concentrations detected in the volunteers' blood were more than 100 times lower than those that have shown activity against cancer cells in a dish.

This probably explains why curcumin has failed to show convincing benefits in any rigorous clinical trials of people with cancer, arthritis or other conditions.

Another concern is that turmeric products are sometimes adulterated with harmful substances. In the US, for instance, more than a dozen brands of ground turmeric spice were voluntarily recalled between 2011 and 2016 after they were found to contain lead chromate, which was added to enhance the spice's yellow colour.

I had a go at brewing up some golden milk, hoping the turmeric in my cupboard was lead-free, and can confirm it is deeply comforting to the soul, if nothing else. I think I will make it a winter staple, but with the recognition that its magic lies in turmeric's unique flavour, rather than in any miracle health benefits. Aggarwal and his colleagues once wrote in the journal of the American Association of Pharmaceutical Scientists that curcumin's efficacy may seem "too good to be true". He was certainly right about that.

ARUN SANKAR/AFP VIA GETTY IMAGES

Alice Klein is a reporter at *New Scientist* based in New South Wales, Australia, who mainly writes about health and medicine

Alice's week

What I'm reading
The Last Human Job *by Allison Pugh, about automation eating into jobs that require human connection*

What I'm watching
Don't Die*, the unsettling but captivating documentary about Bryan Johnson's longevity quest*

What I'm working on
A feature on precision oncology

The meme that has been amusing mathematicians for a century

The Collatz conjecture is addictive, deceptively simple and could eventually be solved by AI. **Jacob Aron** explores the puzzle's origins

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

Jacob's week

What I'm reading
We previously ran a cover story on it, but now I'm catching up with the full book of The Lost Girls of Autism *by Gina Rippon*

What I'm playing
Stellaris*, which lets you conquer the galaxy one star system at a time*

What I'm working on
A review of Biological War *by Annie Jacobsen*

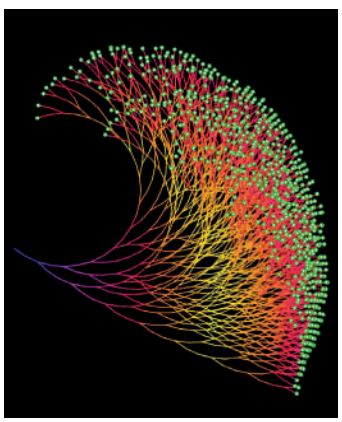
IN THE 1930s, a mathematician came up with a puzzle that was so seemingly simple and yet so fiendishly difficult that it has been distracting other mathematicians ever since. It has become a meme that jumps from brain to brain, with many people claiming to have solved it, only to have their hopes dashed as the proof unravels. And be warned – once I explain the rules, you will immediately want to start playing around with it yourself, and I take no responsibility for how much of your time you waste.

It starts a bit like a magic trick. Pick a number, any number – well, at least any positive whole number; don't try to get clever with something like pi. If it is an even number, divide it by 2. If it is an odd number, multiply it by 3 and add 1. Next, apply the same rules to the resulting number. Do this long enough, and you will always end up at 1.

Or at least, mathematicians think you will. Whether this is true for every possible positive whole number is an open question called the Collatz conjecture, named after Lothar Collatz.

So why is the Collatz conjecture so difficult to prove? If you are anything like me, when you first hear about the problem, you will immediately reach for your calculator and start crunching numbers to see if you end up at 1. Indeed, mathematicians have used computers to check every number up to 2^{71}. Unfortunately, this leaves an infinitely large amount of numbers left to check, so it doesn't really help us in the quest to find a proof.

"Pinning down the origin of the Collatz conjecture is difficult, though not as difficult as finding a proof"



MARZIO DE BIASI – ALGORITMARTE

The numerical connections produced by the Collatz conjecture create a tree-like structure

One problem is that numbers don't behave in an orderly way. If we start with 1, we're done. For 2, we halve it and we're done. But for 3, the chain of numbers goes: 10, 5, 16, 8, 4, 2, 1. For 7, it goes: 22, 11, 34, 17, 52, 26, 13, 40, 20, 10, 5, 16, 8, 4, 2, 1. You might notice that the chain for 7 contains the chain for 3, and that's an interesting aspect of Collatz – once you land on a number that has previously been checked, you don't need to check it again, because you already know where the chain ends up.

Pinning down the origin of the Collatz conjecture is surprisingly difficult, though not as difficult as finding a proof. In a 1980 letter, Collatz wrote that he began investigating it "almost 50 years ago". It seems he kept the conjecture to himself for many years, presumably seeing it as nothing more than an idle curiosity. It didn't begin spreading more widely until 1950, when Collatz went to the International Congress of Mathematicians – the largest meeting in the field – and informally chatted about the problem with other attendees.

One of the first big results came in 1976, when Riho Terras proved an important result. You'll notice that if you start with an even number, your Collatz chain always drops below this starting number because your first step is to halve it. If you start with an odd number, however, your first stop goes above your starting number – so the question becomes, how long until you come back down again below your starting point, hopefully on your way to 1? Terras called this the "stopping time" for a number, and proved that in almost all cases, the stopping time is finite – meaning that the numbers do eventually go down, rather than blowing up forever.

This isn't enough to prove the Collatz conjecture, as just one counterexample of an unimaginably large number that never reaches 1 would be enough to disprove it.

The biggest breakthrough came in 2019, when Terrence Tao, arguably the world's greatest living mathematician, decided to have a crack at this notorious problem. He proved a much stronger version of Terras's result, showing that not only do "almost all" numbers eventually go below their starting point, but that, effectively, you could get them as low as you want. This feels pretty close to a proof of the Collatz conjecture – except that, in a sense, it isn't any closer, because there is always the possibility of a counterexample lurking in the far reaches of the number line.

So, what comes next? As I was writing this column, the news broke that OpenAI had used a large language model to solve a major problem that had stumped mathematicians for 80 years. It did this not by proving it correct, but by finding an unexpected counterexample. Could the same thing happen for Collatz? I wouldn't dare to predict, but it would certainly be ironic if a problem that has infected so many human minds ended up being solved by an AI. ▮

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Break the cycle of energy crises. Build a more resilient energy system.

Britain can build a stronger, cleaner and more secure energy system by making use of the heat we already produce. Large-scale heat networks can capture wasted heat from industry, data centres and other local and ambient sources, alongside heat from excess renewable electricity, and deliver it to homes, businesses and public buildings.

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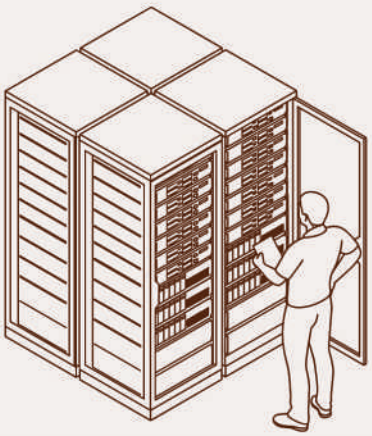
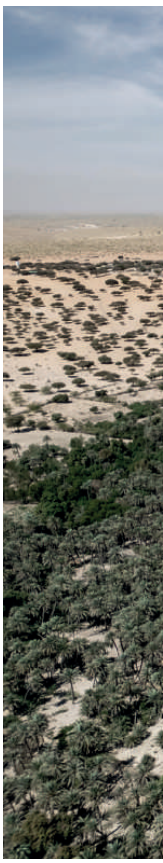
These shocks will keep coming for as long as Britain remains reliant on gas and on prices it cannot control.



By 2035, waste heat from data centres could heat 3.5 to 6.3 million homes - but only if we build the networks to capture and move it to where it is needed.

EnergiRaven



Desert waters

Tommy Trenchard
Panos Pictures

THIS oasis (upper near left) next to the town of Mao, Chad, allows farmers to grow date palms and cultivate a few crops in the small fields around it. But rising temperatures due to climate change are a growing threat to oases such as this, and to the people and wildlife that depend on them.

The image is part of a series shot by photographer Tommy Trenchard for the photo essay "Saving the Sahara's oases", which explores how these fragile ecosystems are disappearing. As temperatures rise, vegetation is retreating around oases and sand dunes are encroaching upon them. To try to hold back the sands, farmers in villages such as Kaou, also in Chad, are building barriers from palm fronds (top far left and bottom near left).

Mao and Kaou are located in the Sahel region, the semi-arid belt south of the Sahara desert that stretches right across Africa, from Mauritania to Eritrea. In 2007, the African Union launched the Great Green Wall initiative to try to prevent the desertification of the Sahel.

As part of this initiative, solar-powered water pumps have been installed in places such as Barkadroussou (bottom far left), not far from Mao in Chad, to help farmers irrigate crops. But the Great Green Wall initiative is controversial, with many questioning whether it will work.

Even where measures such as building barriers or installing boreholes do make a difference, with temperatures set to rise higher still, it is far from clear that oases like these will remain oases for much longer.

Michael Le Page

The dinosaurs among us

Palaeontologist Steve Brusatte turns his attention to the evolution of birds in an excellent and sometimes startling account, finds **Michael Marshall**

Book

The Story of Birds

Steve Brusatte

Picador (UK); Mariner Books (US)

STEVE BRUSATTE is three for three. His debut book for general audiences, *The Rise and Fall of the Dinosaurs*, was a big hit, and he followed it with *The Rise and Reign of the Mammals*, which I enjoyed very much. Now comes his third palaeontological tale, *The Story of Birds* and, once again, he manages to combine a rigorous account of the science with a readable narrative.

Brusatte is a palaeontologist at the University of Edinburgh, UK, who has worked extensively on the fossils of dinosaurs, birds and mammals. He has excavated on the Isle of Skye, off the west coast of Scotland, where the bones and footprints of Jurassic-era animals are beautifully preserved. Alongside this, he has built up a career as a science communicator: partly by acting as palaeontology consultant to the *Jurassic World* films, and partly through his books.

The Story of Birds, subtitled *An evolutionary history of the dinosaurs that live among us*, does exactly what it says on the tin. Brusatte recounts the evolution of birds from their origins deep in the dinosaur era, through their diversification, to their position today as one of the most successful animal groups.

He begins in 1868, when the idea that birds evolved from dinosaurs was first publicly proposed by Thomas Henry Huxley, partly to shore up the then-nascent theory of evolution by natural selection. Charles Darwin's *On the Origin of Species* had come out almost a decade before and contained strong evidence that populations can be gradually changed by all kinds of pressures, driving the emergence of new body types and, ultimately, the great diversity of the natural world. Darwin had done great work, but the idea still had some issues.

"The dramatic discovery of *Archaeopteryx* bolstered Huxley's case that birds evolved from dinosaurs"

Birds were a particular problem, as they are so unlike other animals. For one thing, they have feathers: "by far the most complex things that grow from the skin of any animal", as Brusatte puts it. They have wings, supported by "outlandishly long arms", and beaks. What's more, "they stand only on their hind legs, a most unusual posture that we take for granted as humans, but which is exceedingly rare in the animal kingdom".

Huxley solved this problem, and put birds in their correct place, by linking them to another newly identified group: dinosaurs. Their skeletons had many bird-like characteristics, to the point that the hind legs of the diminutive *Compsognathus* were almost indistinguishable from those of an embryonic chicken.

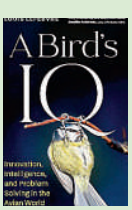
The dramatic discovery of *Archaeopteryx*, a fossil bird with feathers and wings, but also teeth, and claws on its wings, bolstered Huxley's case. Birds evolved from dinosaurs. In fact, as Brusatte makes clear, they are a kind of dinosaur. The asteroid that struck Earth 66 million years ago didn't wipe out the dinosaurs completely, because some of the birds survived, and birds are dinosaurs.

JA CHIRINOS/SPL; MARK P. WITTON/SPL; FLORILEGIUS/ALAMY

From *Archaeopteryx*, Brusatte proceeds through the fossil record of birds during the dinosaur era. He explores how and why they evolved feathers and powered flight.

He paints a vivid picture of Mesozoic bird diversity, when groups like the enantiornithines – so-called opposite birds that split from modern birds between 150 million and 130 million years ago – spread around the world. Then comes the big rock from space, which wipes out almost all of them: Brusatte is in his element discussing which groups of birds survived the calamity and why,

Three more great reads about the evolution of life

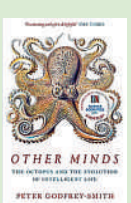


A Bird's IQ: Innovation, intelligence, and problem solving in the avian world by Louis Lefebvre

Biologist Louis Lefebvre (in this translation by Pablo Strauss) explores the evidence for innovation and culture in bird societies, in a book rich with intriguing findings but sadly scattershot in its storytelling.

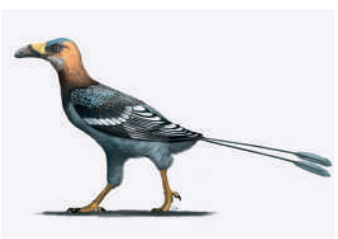
How Flowers Made Our World: The story of nature's revolutionaries by David George Haskell

The tale of flowering plants (angiosperms) runs in parallel to that of birds, with each group having profound influences over the other, so this makes an ideal companion to *The Story of Birds*.



Other Minds: The octopus and the evolution of intelligent life by Peter Godfrey-Smith

In this modern classic, philosopher of science Peter Godfrey-Smith explores the origins of consciousness and intelligence in animals that are very different from humans.



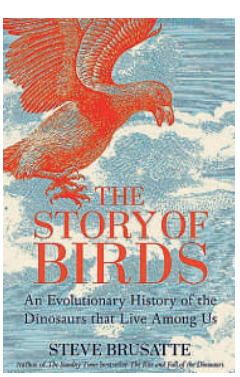
Artist's impressions (clockwise from left) of *Archaeopteryx*, *Compsognathus* and *Falcatakely*, an enantiornithine

when so many others (including all the enantiornithines) were destroyed.

In the second half of the book, Brusatte brings the story up to the present. Post-impact, birds diversified enormously to fill many of the niches left behind by the lost species – even as mammals did the same. He gives equal attention to present-day bird groups like penguins and songbirds, and to extinct marvels like terror birds and (evidently a particular favourite) demon ducks.

As someone who writes a fair bit about palaeontology, it is difficult for a book like this to really surprise me. Much of the material is at least somewhat familiar, and there are some species, like *Archaeopteryx*, that simply must be re-described because they are so central to the story.

Yet, Brusatte managed to startle me with the opening of chapter seven. There he discusses Zealandia: the relatively recently discovered eighth continent, mostly submerged by rising seas, of which New Zealand is part. Zealandia, Brusatte says, is the one place where the age of dinosaurs continued until almost the present day. No large mammals reached Zealandia, so the ecosystems were dominated by large birds like moas and Haast's eagles.



"Zealandia was brimming with dinosaurs," writes Brusatte, only slightly facetiously. This changed only when the first Māori settlers arrived, probably in the 1300s. If it hadn't been for the arrival of humans, dinosaurs would still dominate Zealandia today.

To close the book, Brusatte steps away from palaeontology to describe his work with Pavel Němec and Kristina Kverková: neuroscientists who study the brains of present-day birds. They have tried to explain how birds can display such prodigious intelligence, from recognising themselves in mirrors to making tools and solving puzzles, when they have such small brains – necessarily so because, in order to fly, they have reduced their weight. Their brains are proportionally large, compared with their bodies, but smart birds like crows "have brains that are merely the weight of a walnut".

The solution the team has alighted on is that bird brains, though small, are absolutely stuffed with neurons: "a given bird has about twenty-one times more neurons in its brain than a reptile of similar body mass", writes Brusatte. I suspect there will be more to it than that – what are all those neurons doing? – but this does seem like a key finding.

The Story of Birds, then, is pretty much an unqualified success from beginning to end – and I'm already looking forward to (I'm guessing here, but I would definitely read it) *The History of Reptiles* in a few years' time. ▮

Michael Marshall is a science writer based in Devon, UK

New Scientist *recommends*

Eleanor Parsons
Magazine editor
London

As I walked around the large green form, watching how the shadows and light changed, I felt my stress levels drop. *Reclining Mother and Child* by Henry Moore has a peaceful feel about it. I could imagine the mother and child enjoying the lush gardens they were sitting in, just as I was.

The sculpture is one of 30 of Moore's at Kew Gardens in London as part of the exhibition **Henry Moore: Monumental Nature**, which runs until 31 January 2027. Looking at the smooth curves, sharp edges and greens and golds of these bronzes, I really got a sense of Moore's inspiration from the natural world. Some,

like *Large Spindle Piece*, pictured, reminded me of seeds. *Sheep Piece*, as its name suggests, echoes a lamb with its mother.

An exhibition in the Shirley Sherwood Gallery of Botanical Art gave an insight into Moore's process. Don't miss his etchings of an elephant skull, and his striking drawings of trees, as they really helped me see the inspiration for some of his more abstract shapes.

INES STUART-DAVIDSON/ROYAL BOTANIC GARDENS, KEW

Into the backrooms

A sci-fi horror film with its origins in a creepy image posted on 4chan is a triumph for its 20-year-old director, says **Davide Abbatescianni**

Film

Backrooms

Kane Parsons

In cinemas now

A24

Clark (Chiwetel Ejiofor) discovers an unsettling series of rooms in a furniture store

There is something uniquely disturbing about a room that seems to have no reason to exist. A corridor without destination. A chair half planted into the floor. A couch positioned just wrongly enough to become a threat. In *Backrooms*, the feature debut of 20-year-old Kane Parsons, ordinary objects are stripped of their everyday usefulness and made alien. A shadow, a carpeted hallway, a buzzing fluorescent light: all become evidence that reality has lost its bearings.

Parsons, better known online as Kane Pixels, first developed *Backrooms* as a YouTube phenomenon inspired by a photo of a yellow-wallpapered, fluorescently lit room posted online by an anonymous 4chan user in 2019. The poster asked for other "disquieting images that just feel 'off' "; another user responded with the concept of "the Backrooms, where it's nothing but the stink of old moist carpet, the madness of mono-yellow... and approximately six hundred million square miles of randomly segmented empty rooms to be trapped in". An internet horror phenomenon was born.

Parsons's film, written by Will Soodik, is set in June 1990. It follows Clark (Chiwetel Ejiofor), a failed architect now running a large furniture store, and Dr Mary Kline (Renate Reinsve), his psychotherapist. Clark, a bruised, ordinary man, discovers a strange door in the store's basement, leading to a seemingly infinite series of rooms. He can't find his way out – and Mary goes in looking for him.

The leap from short-form web horror to feature film could easily have diluted the concept. Instead, this film keeps the unsettling atmosphere of the original shorts intact, then expands it through disquieting production design, patient cinematography and a soundscape that may be its most terrifying feature. A constant electrical buzz becomes almost ingrained in the skull, producing a low-grade discomfort that never quite fades.

The early-1990s setting does more than provide a period aesthetic. The VHS textures, analogue recordings and institutional blandness place the film in a technological limbo, just before the digital world made surveillance, mapping and simulation feel ordinary. That matters, because *Backrooms* is, at heart, a horror film about space as an unstable system.

The "backrooms" aren't simply a maze or another dimension waiting to be explained. The film suggests that spending time inside them can affect the psyche, and that the psyche may, in turn, distort the place itself. Perception becomes a building material. Fear, memory and obsession may have spatial consequences. That idea gives *Backrooms* a richer texture than a straightforward monster-in-the-dark story, even if the lore remains deliberately incomplete.

It also places the film within the current wave of liminal-space horror, alongside *Exit 8*, Genki Kawamura's adaptation of the Japanese video game about a man trapped in a looping metro passageway. Both films understand that repetition and slight wrongness can be scarier than gore. Both are rooted in viral digital culture. Both turn spaces we normally pass through without thinking into psychological traps. Yet, *Backrooms* is less about spotting anomalies within a rule-bound loop than about surrendering to a world whose laws may be forming around its victims in real time. Where *Exit 8* is precise, minimal and almost gamified, *Backrooms* is more sprawling, contaminated and cosmological.

> **"*Backrooms* has a richer texture than a straightforward monster-in-the-dark story"**

The film is also smart about the horror of utility. Everything in the backrooms could, theoretically, be useful. Endless empty space could solve problems of storage, housing, logistics, even urban overcrowding. One can see why a corporation or research body might consider it a treasure. But Parsons twists that possibility into dread. What looks like opportunity is also unknowability. A limitless warehouse is a nightmare if you cannot find the way out.

The performances help ground this abstraction. Reinsve is excellent as Mary, bringing a warmth and eerie certainty to her character. Meanwhile, Ejiofor gives Clark the weary confusion of a man who has already failed in one world and is now being invited, or condemned, to enter another.

The ending is abrupt, clearly designed with further instalments in mind. Many questions remain unanswered, perhaps violently so. Yet, that frustration is partly the point. By the end, we share Clark's compulsion to understand what the backrooms are. Few recent horror films have made shadows, wallpaper and cheap furniture feel so hostile. What began as an image posted on a 4chan thread has become an unusually potent big-screen experiment in fear, space and perception. ▮

Davide Abbatescianni is a film critic based in Rome, Italy

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Editor's pick

How to slow down ageing on Earth and in space

30 May, p 18

From Stephanie Trotter, Isle of Wight, UK

Graham Lawton pointed out many of the similarities between the lifestyles of astronauts and older people, and how research into preventing ageing in astronauts could help us all. For example, both microgravity and sitting on the sofa too much cause muscle wasting, and both can be prevented by exercise.

However, perhaps astronauts would also benefit from breathing fresh air, feeling the wind in their hair, seeing plants grow, putting their bare hands into the earth, smelling botanicals, hearing birdsong and watching waves breaking on a beach while walking barefoot on the sand. Maybe one day, in very large space stations, all these will be possible.

Meanwhile, let's make sure our older people, and those who are in care homes or hospitals, are not deprived of these joys.

Alternative views on the meaning of love

23 May, p 10

From Barry Leggett, Tonbridge, Kent, UK

I read with interest the article "Trying to solve the mystery of love". However, I believe the idea that love has (only) three core pillars (intimacy, passion and commitment) misses what should be a key factor in human pair bonding. The ancient Greeks used several words for love. One of them, agape, might be described as selflessness. While intimacy might grow stale as passion – often linked to sexual attraction – becomes less relevant, and commitment might lead to possessiveness, selfless care for a partner has no such downside. As partners grow more frail, selfless care becomes more important, and this love doesn't fade.

From Jim McHardy, Clydebank, West Dunbartonshire, UK

After the big bang, electrons created from gamma rays would be entangled. According to a previous *New Scientist* article, electrons in the human gut are entangled. Falling in love could involve two peoples' electrons somehow becoming entangled, or previously entangled electrons from the big bang meeting each other, again leading to love.

Considering *The Selfish Gene* 50 years on

23 May, p 32

From Jon Arch, Welwyn Garden City, Hertfordshire, UK

I remember seeing Richard Dawkins and Desmond Morris chatting during drinks breaks in the Oxford zoology department in the early 1970s. I was a graduate student. I accepted the premise of *The Selfish Gene* when it was published in 1976, but as I learned more, I became increasingly sceptical. Where in our DNA does a gene begin and end? How can cooperative behaviour between genes or species be explained by selfish genes? I even had a letter published in *New Scientist* on the latter subject. Fifty years on, I am grateful to Rowan Hooper's article, which explains how Dawkins has addressed these doubts, though not all are convinced.

From Wai Wong, Melbourne, Victoria, Australia

I find the argument against Dawkins's memes – neither passed on, nor immortal – unconvincing. Genes are not immutable; mutation of genes is a tenet of evolution. The only significant difference between genes and memes is in the timescale: it usually takes many generations for a successful gene to emerge or a bad gene to be eliminated, but a popular meme can come and go in a fraction of a species' lifetime.

However, that is not to say a gene necessarily outlives a meme. The seasonal flu is an example of genes that come and go, but memes like hunting techniques and songs of many intelligent species can be passed down for generations, and they can even perpetuate themselves by promoting genes that favour those memes. Other examples of long-lived memes include stories, games, words, gestures, recipes, conspiracy theories, use of tokens and phrases like "selfish gene".

From John Woodgate, Rayleigh, Essex, UK

It has been pointed out that *The Descent of Man* would have been more welcome as *The Ascent of Man*. Similarly, I think that *The Selfish Gene* (which implies an immoral motivation) might have been better received, and even understood, as *The Single-Minded Gene*.

More on consciousness and the wave function

Letters, 30 May

From Britt Chappell, Lebanon, Tennessee, US

Regarding the debate on wave function collapse and human consciousness, Andrew Smyth suggests a universe where reality depends on human awareness, while Nick Canning's correction – declaring the mechanism "entirely mechanical" – reduces quantum physics to a 19th-century grandfather clock.

Both are incorrect. Apparent collapse is caused by the omnipresent interaction of quantum fields, a universal process independent of human observation or mechanical gears. "Observation" is simply a specific physical interaction where fields collide. There are no gears turning and no minds wishing; there are only field couplings, entanglement and decoherence.

The human-imposed guard rails of AI

Letters, 23 May

From Colin Nicholson, Stockport, Cheshire, UK

In her letter, Jacqueline Christmas misses the point that it was exactly such human-imposed guard rails that I was looking for in my correspondence with AI concerning nuclear weapons. Another insight into the nature of AI came when I asked ChatGPT if Eric was a suitable name for a pet caterpillar, and if it would be OK to take it for walks on a lead. The large language model (LLM) replied that Eric was a perfectly suitable name, but advised against taking my caterpillar for walks on a lead, as it might pull on the lead and hurt itself. In such ways, LLMs reveal their true nature.

How to remove all the emissions from shipping

30 May, p 9

From Gethin Bermingham, Warton, Lancashire, UK

The article that considers the possibility of using wind and route planning to reduce the fuel consumption of cargo ships suggests some interesting techniques to achieve future energy savings. It's rather unfortunate the researchers don't seem aware that many cargo ships in the past were achieving a 100 per cent energy saving. These vessels were of course called sailing ships! ▮

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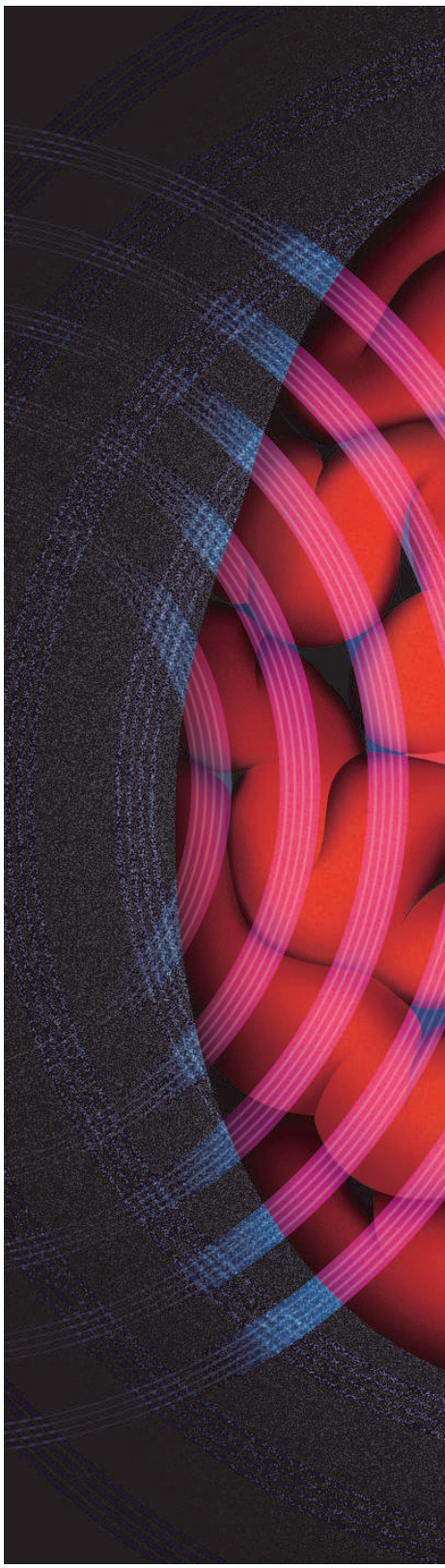
For the record

▮ **Pancreatic cancer tumours have tough, fibrous exteriors (6 June, p 7)**

Breaking anorexia's control

One-third of people with anorexia don't recover, but pinning down what's happening in the brain is bringing new treatments, discovers **Grace Wade**



VICKI TURNER

THIRTEEN years ago, I was on the brink of death. My nearly year-long battle with anorexia nervosa had reached a tipping point: tests showed my heart could give out at any moment, and I was rushed to the emergency room.

But I didn't care. I only wanted to go home and celebrate my 15th birthday with the two chocolate-covered strawberries I had allotted in my self-imposed calorie restrictions.

It wasn't that I wanted to die. The fear of eating more and gaining weight simply felt more immediate than the reality of my heart failing. That paradox – continuing to starve yourself despite the consequences – is why anorexia nervosa remains one of the deadliest and most challenging mental health conditions to treat. Roughly a third of those affected don't recover, even with treatment.

"We could do much, much better. That is clear," says Ulrike Schmidt at King's College London.

Shmidt is part of a growing group of researchers who, in recent years, have turned to the brain for answers, and these efforts are finally bearing fruit. A wave of studies now suggests that anorexia nervosa alters circuits governing reward, habit and emotion – changes that may explain why eating can become so aversive, even for people who want to recover.

While it is still early days, these insights are already reshaping how we think about anorexia nervosa and inspiring potential new therapies, from brain stimulation to experimental medications, that could one day shift treatment outcomes.

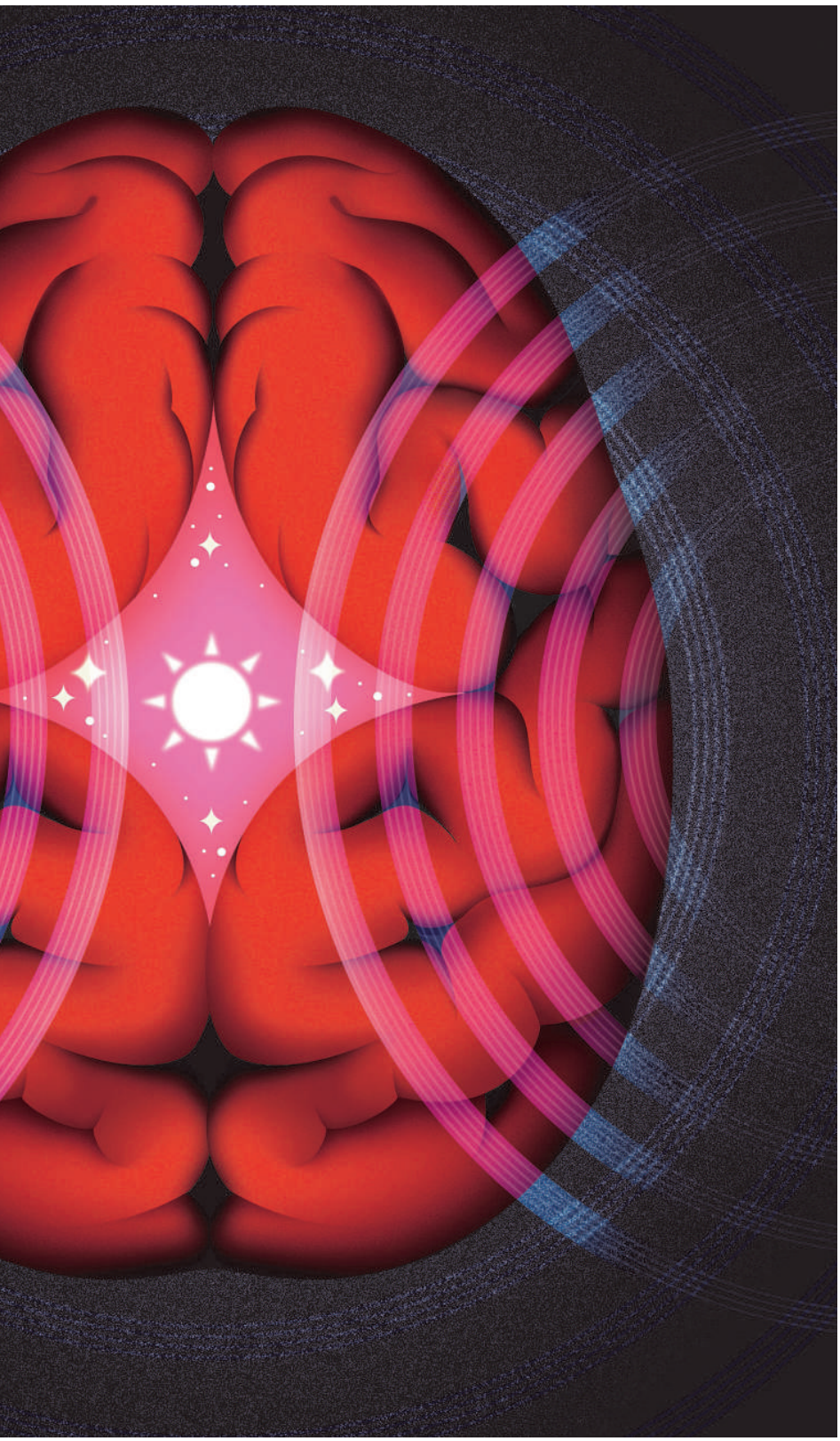
Anorexia nervosa is an eating disorder characterised by severe calorie restriction and an intense fear of gaining weight, typically leading to dangerously low body weight. Estimates suggest it affects up to 4 per cent of women and 0.3 per cent of men during their lifetime, though some studies indicate incidences are rising. Research suggests shifting beauty standards, social media and the stress of covid-19 lockdowns may be driving the trend.

Yet anorexia predates these modern pressures, with the first cases described in the early 1870s. Until the 1980s, most treatment approaches focused on identifying the external motivators driving the condition: "To be fit, to be thin, to get over some problem, to react to some insult," says Timothy Walsh at Columbia University in New York.

"The thinking was, once we have worked out what is driving this, they will start eating," he says. "Wrong." It turns out that many of the condition's symptoms are exacerbated, if not caused, by starvation.

That revelation came from an ethically dubious experiment. In the 1940s, researchers at the University of Minnesota halved the calorie intake of 36 young, healthy men with the aim of better understanding starvation.

After six months, the men had lost around 25 per cent of their body weight and experienced profound psychological changes. They became argumentative, obsessed with food and socially withdrawn, developing



symptoms of anxiety and depression. What's more, their eating habits changed. They began toying with their food, cutting it into small pieces or diluting it with water – behaviours also seen in anorexia.

Decades later, researchers connected these findings to anorexia, transforming our understanding of the condition. "Even in people who have no genetic, personality or psychological predisposition to an eating disorder, there was this lasting effect from the period of starvation," says Schmidt.

Doctors realised that treating starvation, not necessarily the underlying psychology, was a crucial first step in helping those with the condition. "After eating and getting renourished, people are less anxious. They are less depressed. They are less obsessional," says Joanna Steinglass, also at Columbia University.

The treatment gap

Supervised weight restoration, in which doctors and dietitians monitor weight and food intake, now forms the backbone of anorexia treatment, alongside talk therapies centred on reshaping thoughts, emotions and behaviours. While this helps roughly two-thirds of people to recover – including me – it isn't enough for the rest.

"We have a reasonable set of first-line treatments," says Schmidt. "But what do you do if those don't work? We haven't really got a clear answer for what should be next."

To address this urgent treatment gap, researchers are probing the brain for clues. Neural mechanisms underlying the condition have largely remained a mystery – but that is beginning to change.

We now know that anorexia is associated with profound brain alterations. A 2022 study of 685 women with the condition and 963 women without an eating disorder found that the brain's outer layer, the cerebral cortex – which plays a crucial role in thinking, reasoning and emotion – was significantly thinner in those with anorexia, for instance. The reduction was two to four times greater than that seen in other mental health conditions, such as depression and obsessive-compulsive disorder (OCD).

Thinning was less pronounced, however, in the 251 participants with anorexia who had begun regaining weight, not only suggesting that the changes are reversible, but also that they may result from starvation rather than some pre-existing difference in the anorexic brain. "The brain is strongly ›

An unexpected therapy

While researchers start to home in on the neural underpinnings of anorexia (see main story), shifting someone's metabolism via the ketogenic diet may hold promise for treating the condition.

Our metabolism runs mostly on carbohydrates, which are broken down into glucose to be burned in the energy-releasing mitochondria in cells. Problems with this energy release in brain cells have been linked to mental health conditions, including anorexia.

When carbs are unavailable, the body adapts to burn fat, releasing it from storage and converting it in the liver to molecules called ketone bodies that can be burned in place of glucose. The ketogenic diet can prompt this metabolic shift, as it involves eating high amounts of fat, moderate amounts of protein and very few carbs.

Guido Frank at the University of California, San Diego, and his team asked 22 women with anorexia, whose body mass index had risen enough to sit in the healthy to slightly underweight range, to follow a ketogenic diet for 14 weeks, supervised by a dietician, psychiatrist and a peer support counsellor who had experienced anorexia. Their weight, mood and anorexia symptoms were monitored weekly, using questionnaires to track any changes in body image, depression, food-related anxiety and fear of weight gain.

The 18 women who stuck to the diet for the full 14 weeks showed a significant improvement in anorexia symptoms and scores of depression. Thirteen even improved enough to drop below the threshold for clinical diagnosis for both anorexia and depression. "The level of recovery was far better than what we see in other anorexia treatments," says Frank.

But Sahib Khalsa at the University of California, Los Angeles, who researches and treats eating disorders, says without more data from large trials, it is too soon to change how we treat anorexia. Caroline Williams

affected by food restriction because the brain is mainly based on fat," says Clara Moreau at the University of Montreal.

To disentangle the effects of starvation, last year she and her colleagues analysed brain scans from 290 children, 124 of whom had anorexia and 50 of whom had another eating disorder called avoidant/restrictive food intake disorder (ARFID). This condition also causes severe food restriction and weight loss, yet, unlike anorexia, it is driven by sensory sensitivities, a disinterest in food or an intense fear of choking or vomiting.

Compared with children without an eating disorder, those with anorexia showed significant thinning in 32 brain regions, even after accounting for body mass index. A similar pattern emerged in comparisons with children who had ARFID, indicating that at least some brain differences in anorexia are distinct from those caused by starvation.

The superior parietal lobule and the thalamus, both of which process sensory information, were most affected. This may explain one hallmark of anorexia: that those affected have a disturbed perception of their own body, says Anael Ayrolles at the Robert Debré Hospital in Paris. Many, including myself, tend to overestimate their body size. No matter how much weight I lost, my body appeared the same to me. Only years later, when looking at an old photo, did I grasp how underweight I had been. Ayrolles says this could have been due to altered brain pathways involved in evaluating my body.

Comparisons of these results with brain-imaging studies of other mental health conditions showed that anorexia overlapped most with OCD, hinting at a shared mechanism between the two, says Moreau.

"MANY OF THE CONDITION'S SYMPTOMS ARE EXACERBATED, IF NOT CAUSED, BY STARVATION"

This isn't the first time the conditions have been linked. More than a third of people with anorexia also have OCD, and anorexic behaviours, like calorie restriction or excessive exercise, may serve a similar function to OCD compulsions in temporarily relieving the anxiety caused by intrusive thoughts.

While intriguing, these results are far from conclusive. "It is difficult to associate one altered [brain] region to a specific function," says Ayrolles. Both he and Moreau are part of a consortium working towards that goal. Over the next year, they will collect functional magnetic resonance imaging (fMRI) scans from nearly 1000 people with anorexia worldwide. Unlike structural brain scans, fMRI measures brain activity over time, offering greater insight into how these brain changes may influence behaviour.

Harmful habits

Other research groups are taking a different approach, zeroing in on specific circuits they suspect play a role in anorexia, such as those regulating interoception, the ability to detect bodily sensations. Two brain regions, the thalamus and insula, help process these signals and relay them to other areas, ultimately shaping behaviour, emotions and body image. Emerging evidence indicates these circuits are disrupted in anorexia, which may explain why many people with the condition feel disconnected from their body and emotions.

Brain circuits governing reward and habit have also been implicated in the condition. "People aren't born with anorexia nervosa. It doesn't just hit them like lightning," says Walsh. "They learn to do it somehow."

This led him to propose a hypothesis called the habit-formation model of anorexia in 2013, which he and others have since been investigating. It posits that people with the condition avoid certain foods – particularly those high in fat – because they initially find it rewarding. Over time, however, restrictive eating becomes a habit, and habits are notoriously difficult to break, especially the longer they are practised.

The brain reinforces gratifying behaviours through dopamine, a feel-good chemical that activates pathways in the ventral striatum, the brain's so-called reward centre. Two types of activity engage this system: those resulting in positive outcomes, such as reward or praise, and those preventing negative outcomes, such as threats or harm.

Both probably have a hand in anorexia, says Walsh. Some people receive compliments as they lose weight. Others avoid high-calorie foods out of genuine fear or disgust: brain scans in people with anorexia show that such foods can activate the threat-detecting amygdala. "You can make an argument that starvation becomes rewarding," says Walsh.

When a behaviour is consistently rewarding, the neural pathways governing it shift from the ventral striatum to a more efficient circuit involving the dorsal striatum, nicknamed the habit hub. "It doesn't matter any more what the original reward was," says Steinglass. "Now, you are just going to do that thing over and over and over again." So, even if someone with anorexia wants to get better, it isn't as simple as eating more, she says. The decision to avoid certain foods has become automatic.

Listening to the two researchers, it feels as though they are describing my own experience with anorexia. At first, hitting my daily calorie count and watching my weight fall brought me an intense sense of accomplishment – almost a high. But at some point, the behaviour spiralled out of control. I couldn't hit the brakes, even as I careened towards an ever-darker place.

Though not definitive, mounting evidence supports this habit hypothesis. In a seminal 2015 study, Steinglass, Walsh and their colleagues instructed 42 participants – half of whom were hospitalised with anorexia – to choose between various foods. As expected, people with anorexia were significantly less likely to choose high-fat foods than those without the condition. Brain scans capturing these decisions revealed greater activation in the dorsal striatum – the brain's habit hub – compared with controls.

Another study in 2020 showed that people with anorexia have more white matter, which transmits brain signals, in this region than those without an eating disorder, further implicating it in the condition.

Many unknowns remain. For instance, why do people with anorexia find restrictive eating rewarding in the first place? "I think for some folks, one of the drivers is, 'I feel less anxious. I feel less bad. I feel less depressed. I am more certain of who I am,' " says Walsh. But why, then, don't most people who diet develop anorexia? After all, many of them probably find some aspect of it rewarding.

One possibility is that people with anorexia are more sensitive to rewards. Studies have found that their dopamine-related pathways are hyperresponsive. But it isn't clear ›

WALLACE KIRKLAND/THE LIFE PICTURE COLLECTION/SHUTTERSTOCK

Insights from the Minnesota starvation experiment changed the treatment of anorexia

whether this precedes anorexia's onset or is simply the result of starvation, which is known to sensitise dopamine receptors.

Genetics probably forms some part of the equation as well, says Walsh. Twin studies suggest this accounts for up to 60 per cent of the risk of developing anorexia. "There might be a genetic predisposition to altered reward or habit-learning pathways," he says. "There could be some other biological factor that allows them to withstand the pressure to eat. I don't think we know yet."

Untrain your brain

Several studies have found that genes linked with the condition are also associated with a lower body mass index and a reduced risk of obesity and type 2 diabetes. It may be, then, that anorexia is also a metabolic condition, in addition to a mental health one. Processes regulating weight and metabolism might differ in those with the condition, making it harder for them to maintain a healthy weight. This may also explain why early evidence indicates the ketogenic diet – which can impact brain metabolism – may help treat anorexia (see "An unexpected therapy", page 30).

These findings are a toehold on the neural mechanisms behind anorexia, says Steinglass, which could pave the way for new treatments.

One of the most promising involves using electromagnetic pulses to modulate brain activity, a technique called repetitive transcranial magnetic stimulation (rTMS). In 2021, Steinglass and her colleagues administered it to 10 women hospitalised with anorexia as they made decisions about various foods. They specifically targeted the right dorsolateral prefrontal cortex, which helps inhibit automatic and habitual behaviours. When receiving stimulation, the participants were more likely to choose high-fat foods while determining what they would rather eat, compared with when they received a mock stimulation.

Schmidt and her colleagues have tested a similar treatment in 34 women with anorexia. Half underwent 20 rTMS sessions targeted at their left dorsolateral prefrontal cortex – a region implicated in depression and substance use disorders – alongside usual treatment. Four months later, their mood had significantly improved compared with those who received a mock stimulation. "They were more relaxed around eating, more able to put people and social connections ahead of their eating disorder," says Schmidt.

The treatment's impact on the participants' weight was slower to kick in, but an 18-month follow-up with 24 of the participants revealed promising results. A quarter of those who had received targeted rTMS had reached a normal body mass index, with another quarter showing partial weight recovery.

The researchers are now repeating the study in 66 young women whose anorexia hadn't responded to standard treatment. This time, however, they are using intermittent theta-burst stimulation, which delivers pulses in a different pattern, potentially producing more durable effects. Schmidt expects the trial to wrap up in the next couple of months. If positive, the results could "really transform the therapy landscape", she says. "It could be a big step forward."

Other researchers are turning to experimental drugs, including psychedelics. A 2023 study found that a single dose of psilocybin improved body image, reduced anxiety and lessened preoccupations about eating and food in 10 women with anorexia. Yet, without a control group, the results could be explained by the placebo effect. More robust trials are now under way.

All these approaches are still in the early stages of testing, and most include just a handful of participants, the vast majority of whom are young women. So, it would be unwise to raise hopes too high. Still, Walsh says he is more hopeful now than at any other point in his nearly 50-year career: "I think we understand the enemy better."

I used to doubt whether I could ever vanquish this enemy. A month after being hospitalised, I wrote in my journal that "my eating disorder is as strong as ever... will these thoughts ever leave me alone?"

I am grateful to say they have. I no longer obsess over calories or weight loss. In fact, I rarely think about them at all. Foods that 15-year-old me could have never fathomed eating without fear now only bring me joy.

I am hopeful that one day, we will find a way to quiet these thoughts in anyone plagued by them. While we aren't there yet, I believe we are getting closer. ▮

Grace Wade is a features editor at *New Scientist*

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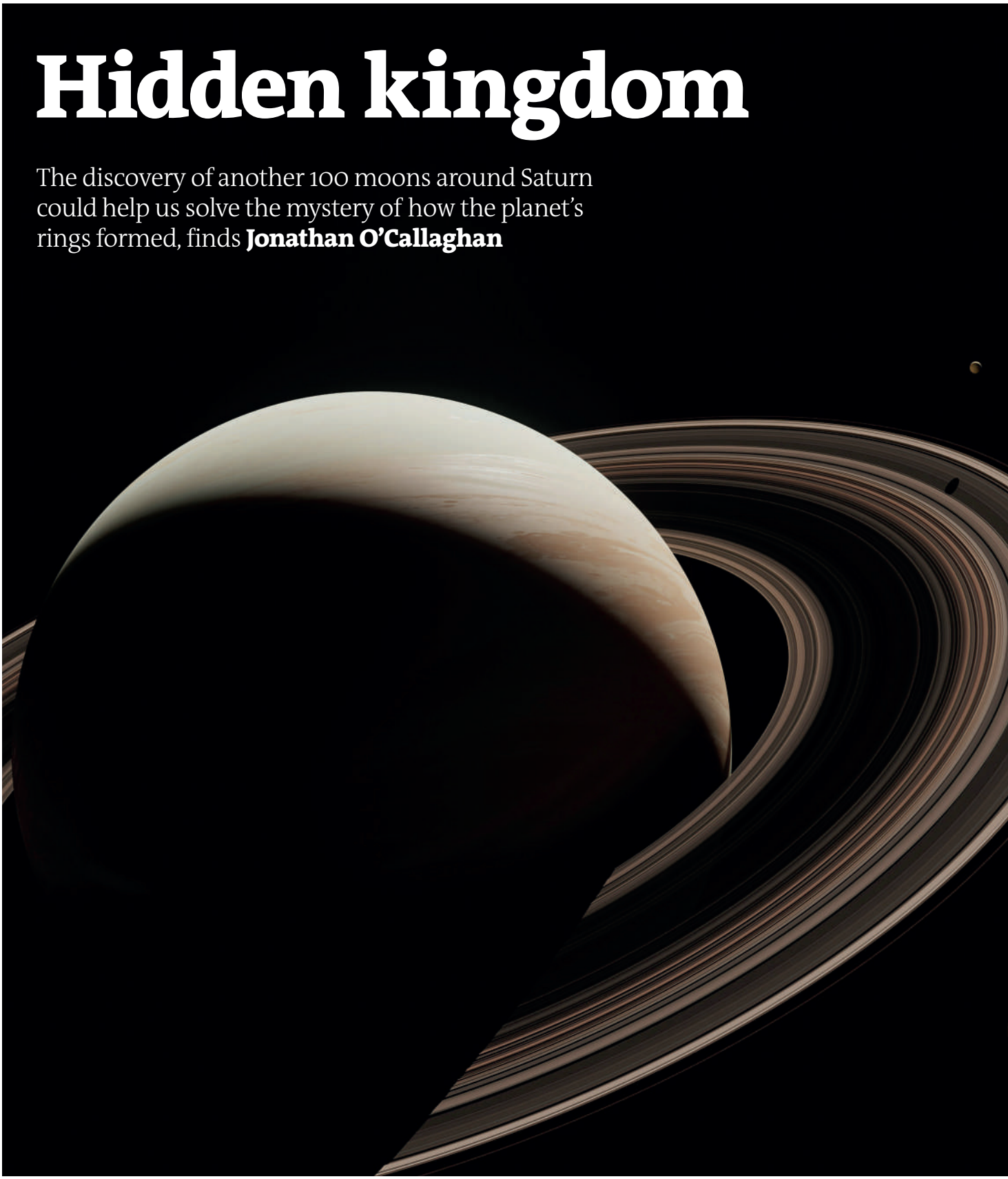
Hidden kingdom

The discovery of another 100 moons around Saturn could help us solve the mystery of how the planet's rings formed, finds **Jonathan O'Callaghan**



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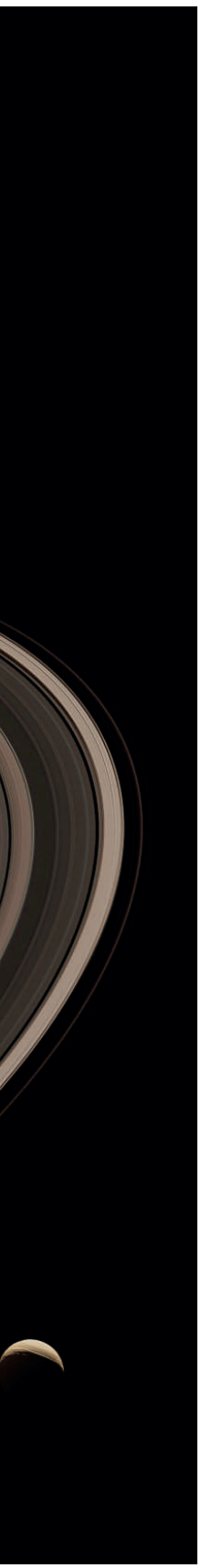

Saturn now has 274 known moons – more than Jupiter

IN THE far reaches of the solar system, the planetary neighbourhood seems quiet. Beyond Jupiter, the sun is no longer a blazing disc, but a cold, white lamp. The planets are separated by gulfs of darkness. Light takes just 8 minutes to get from the sun to Earth, but typically more than an hour to cross the yawning chasm between Uranus and Neptune.

But in the middle of what seems like an uneventful part of the solar system, astronomers recently made a mammoth discovery: a hidden population of more than 100 moons that, until recently, remained almost invisible. From Earth, they appear as faint, fast-moving points of light, easily lost in their planets' glare.

They aren't moons as we imagine them – grand worlds like our own pale satellite, Jupiter's volcanic Io or Saturn's haze-wrapped Titan. They are smaller, darker and far more unruly. Astronomers call them irregular moons, and with their numbers now so high, their hidden kingdom has become harder to ignore. "We have had this huge influx in the last year, [including an] eye opener at Saturn," says Marina Brozovic at NASA's Jet Propulsion Laboratory in California.

But it's not just the discovery of these moons that has astronomers excited. For one thing, they may hint that the outer part of our solar system might not be enjoying a quiet retirement, but instead has seen periods of incredible turbulence surprisingly recently. For another, these hidden moons may help us solve a mystery about one of our solar system's most iconic sights: how did Saturn get its rings?

What is a moon, exactly? If you looked up at our night sky, you would see our own natural satellite, more than 3400 kilometres across, keeping stately company with Earth. Many of the solar system's other moons fit that picture, too: big, round worlds circling close to their host planet, usually moving with that planet's spin.

But there is another kind of moon. These are small, misshapen things, often only a few kilometres wide, following distant, tilted and sometimes backwards paths. These are irregular moons and, for a long time, they were easy to overlook.

One of the first irregular moons to be recognised was Phoebe around Saturn in 1898, the largest of the planet's irregular moons at 213 km across. It was the herald of many more to come. As telescopes and digital cameras improved, especially from the early 2000s, astronomers began seeing smaller and smaller irregular moons around giant planets in droves. Then came last year's deluge. In 2025, researchers announced 128 new moons around Saturn alone, pushing the known total of solar system moons above 450.

For astronomer Scott Sheppard at the Carnegie Institution for Science in Washington DC, who has helped lead many of these searches, the broad pattern didn't come as a surprise. Astronomers were always sure there were more moons to be found around the gas giants, he says; telescopes just couldn't pick up such faint signals until recently.

Still, the scale of discoveries last year caught many off guard. "Everybody was surprised," says Brozovic. Astronomers had expected maybe a few dozen more moons to be found around these outer planets, but instead hundreds or even thousands are now thought to be awaiting discovery. "It really is starting to be pretty busy out there in the solar system," says Brozovic.

These moons might be small, but their implications are large. Their oddly elongated orbits suggest that they didn't form in the same place as their host planets, the way larger moons did. Many also travel in loose families, following similar paths around their planet (see "A family affair", page 37) – a pattern that seems to suggest they are the fragments of larger parent moons hundreds of kilometres across that broke apart in collisions long ago.

Thanks to these irregular moons, astronomers now think they can reconstruct this violent history and its role in shaping the solar system, says Jonti Horner at the University of Southern Queensland, Australia. "They are relics of the solar system's formation," he says.

To reconstruct this history, we need to first ask a pivotal question: how exactly did these irregular moons end up around these gas giants? For decades, astronomers thought the answer lay in the solar system's first flush of youth, because there just isn't an easy way for a planet to capture a passing object in the settled solar system we see today, says Sheppard. A comet or asteroid can wander briefly into a planet's gravitational grip, but unless something slows it down, it would simply fly out again. "The only way to capture a moon is to dissipate energy from its orbit," he says.

"IT REALLY IS STARTING TO BE PRETTY BUSY OUT THERE IN THE SOLAR SYSTEM"

However, soon after the birth of our solar system – about 4.5 billion years ago – there ›

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NASA/JPL/SPACE SCIENCE INSTITUTE

Hyperion (left) and Iapetus (above) are two of Saturn's more unusual moons

were several possible mechanisms of capture. One involved the atmospheres of the gas giants themselves, which were more swollen and extended back then. Asteroids or comets flying through them could have been slowed enough to be captured into the wild orbits we see today. But while that works for smaller bodies, it struggles to explain how planets captured the suspected parent bodies of irregular moons, which were later smashed apart.

A violent past

A more promising avenue for that is the Nice model, the most accepted picture of solar system evolution. It says Jupiter, Saturn, Uranus and Neptune didn't originally form where we see them now. They were packed much closer together when the solar system first took shape, before gravitational interactions sent them migrating outward. Their combined gravitational interactions during their migration could also have helped slow passing objects, including the larger progenitors of the irregular moons we see today.

This would help explain why today's irregular moons don't seem to have a common origin, instead resembling a cosmic jumble from across the solar system, according to papers published last year that used observations from the James Webb Space Telescope.

The chaotic nature of this early period was thought to also be when some of the once-larger irregular moons might have crashed together, creating the much smaller objects around the planets we see today.

But then came a puzzling discovery in 2025. A team led by Edward Ashton at Academia Sinica in Taiwan took a closer look at the Mundilfari group, a clutch of some 100 newly discovered small moons looping around Saturn.

At first glance, this strange family looks like the debris trail of some ancient cosmic smash-up. But when Ashton's team modelled their sizes, that timing didn't quite add up. If these fragments had been circling Saturn since the early days of the solar system, many of the smaller moons should have fallen into the planet by now, tugged inward by its gravity.

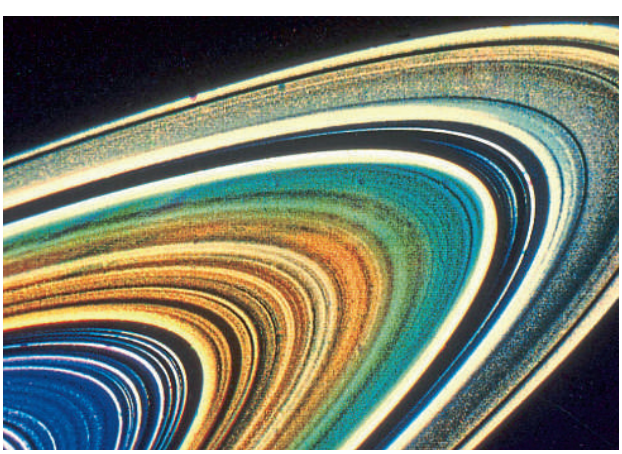
Instead, Ashton's team argued that the Mundilfari group may have formed in a collision just 100 million years ago. "[That might mean] these collisional processes are still alive and well," says Brozovic. If these collisions really were surprisingly recent, that would suggest the outer solar system is still being dramatically reshaped today, long after the main drama of planet formation was thought to be over.

Such collisions could be linked to other events, too. Ashton's paper was published in December 2025 and piqued the interest of Yifei Jiao at the University of California, Santa Cruz, because the age of the Mundilfari group seems suspiciously close to another number: the suspected age of Saturn's rings. Could the two be related?

For all their fame, Saturn's rings remain oddly hard to explain. We have seen them through telescopes for more than 400 years, yet the most important mystery lingers: how did they form? For a long time, Saturn's rings looked like an ancient ornament, a bright, almost permanent fixture that had circled the planet since the solar system's youth. The simplest story was that they formed early, perhaps from leftover material around Saturn or from a moon that shattered billions of years ago.

Then measurements from NASA's Cassini mission complicated things. In its final months, before it plunged into Saturn in 2017, the spacecraft repeatedly threaded the narrow gap between the planet and its rings. Those dives revealed rings that were surprisingly low in mass and remarkably clean. That was hard to square with great age: over billions of years, micrometeoroids should have darkened the ice and worn the system down. Instead, photos taken by Cassini made the rings look suspiciously fresh – perhaps only a few hundred million years old. That leaves a difficult question: what could have made them so recently?

The new moons may offer a way in. We already know that irregular moons can make a mess as they collide into each other or are struck by passing comets and asteroids. They can explode into clouds of dust that gradually fall towards their host planet. We already see evidence for this on Saturn's moon Iapetus, the outermost of the planet's regular moons, which has a strange, two-toned colouration. Its leading side – the face that ploughs forward



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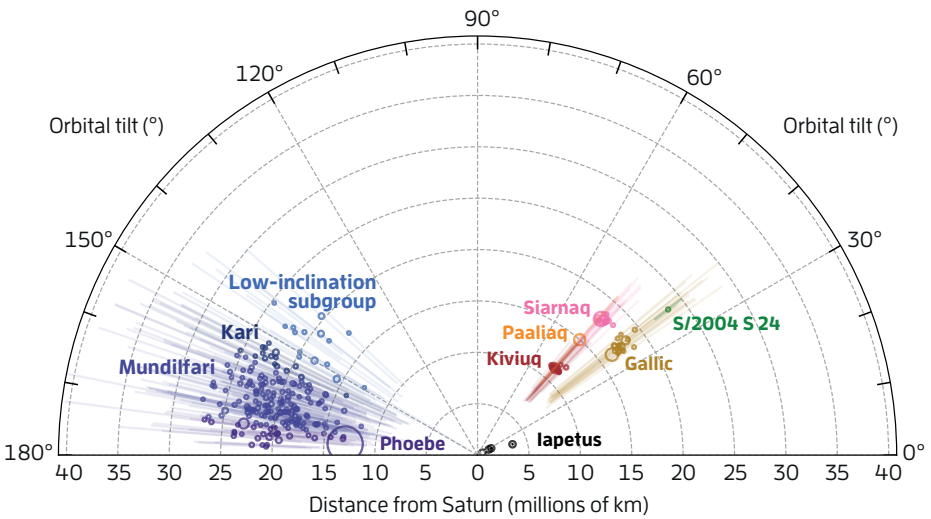
Saturn's iconic rings are hard to explain

A family affair

Plotted by orbital tilt and orbital distance from Saturn, many of the planet's irregular moons fall into distinct families. These clusters suggest the moons are fragments of once-larger bodies smashed apart in ancient collisions



through space – is extremely dark, while the trailing side is nice and bright. Sheppard says that Iapetus could be running through the reddish, carbon-rich dust shed by irregular moons "like a bulldozer".

Still, those distant, irregular moons of Saturn weren't thought to have much to do with the planet's rings. But in April, Jiao and his team published a paper suggesting a potential link. They first built on the idea that Saturn once had an extra icy moon about 1000 km across, called Chrysalis. Over the 4.5-billion-year history of the solar system, it fell into a gravitational rhythm with Titan, Saturn's largest moon. The mutual tug between both elongated Chrysalis's orbit from a circular shape into an ellipse.

Ring in the changes

Then, about 100 million years ago, the moon's distorted orbit carried it past a threshold around Saturn known as the Roche limit, the boundary within which a planet's gravity can tear a moon apart. In one catastrophic pass, Saturn stripped away much of Chrysalis's ice, almost instantly shrinking the moon to half its size.

What would have happened next is uncertain. The rocky core of Chrysalis may have been cannibalised by Saturn or ejected entirely, although Jiao notes we "haven't found such a body" orbiting the sun somewhere else. The ice, meanwhile, would have spread like butter, forming a broad, bright disc over a few thousand years – Saturn's rings.

But not all the debris would have stayed close in. Some chunks could have been flung into Saturn's outer reaches, where one piece struck another moon and shattered it, forming

> "SATURN'S RINGS AND SOME OF ITS HIDDEN MOONS MAY BE TWO REMNANTS OF THE SAME LOST WORLD"

the Mundilfari group of irregular moons at the same time. If so, Saturn's rings and some of its hidden moons may be two remnants of the same lost world, both formed about 100 million years ago.

"It is hard to imagine that all of these events occurred at the same time by coincidence," says Jiao. "I am quite excited about the possibility of linking the lost moon Chrysalis with the irregular satellite population."

While the timing adds up, there is some scepticism. "It's definitely a very cool study showing one way that the rings might have formed," says Horner. But he cautions that linking the destruction of Chrysalis to the formation of the Mundilfari irregular moons would require more evidence, such as impact scars on Saturn's other regular moons, which might also have been struck – something a future mission might be able to look for.

Brett Gladman at the University of British Columbia in Canada is also intrigued by the idea, although similarly not completely convinced. "It's certainly curious that these two wildly disparate events come out to be the same age, but that doesn't necessarily mean they have a causal connection," he says.

Jiao says that further modelling will be needed to test whether his idea is right. But Saturn's rings may be just one example where irregular moons are yielding fresh answers to old solar system puzzles. The next surprises may lie even further from the sun.

For a long time, astronomers expected Jupiter to be the solar system's great collector of irregular moons. It is the largest planet by far, with the strongest gravitational pull, so it seemed natural that it would have the biggest satellite system. But last year's discoveries put Saturn ahead, with 274 known moons compared with Jupiter's 115. That is surprising enough. But there is reason to question whether the solar system's other two outer planets may have even more.

As far as we know, Uranus and Neptune have far fewer moons – 29 and 16, respectively – but that may say more about the limits of our surveys than about what is really there. Both are distant, dim targets. Yet their position could make them rich hunting grounds. Their distance from the sun gives them vast regions of gravitational influence, known as Hill spheres, in which small bodies can remain bound; Neptune's stretches some 115 million km, almost twice Saturn's. Their proximity to the Kuiper Belt, a reservoir of icy debris, may also have given them plenty of material to capture.

"I fully expect that someday, a couple of decades away, we will find thousands of these objects at Uranus and Neptune," says Luke Dones at the Southwest Research Institute in the US.

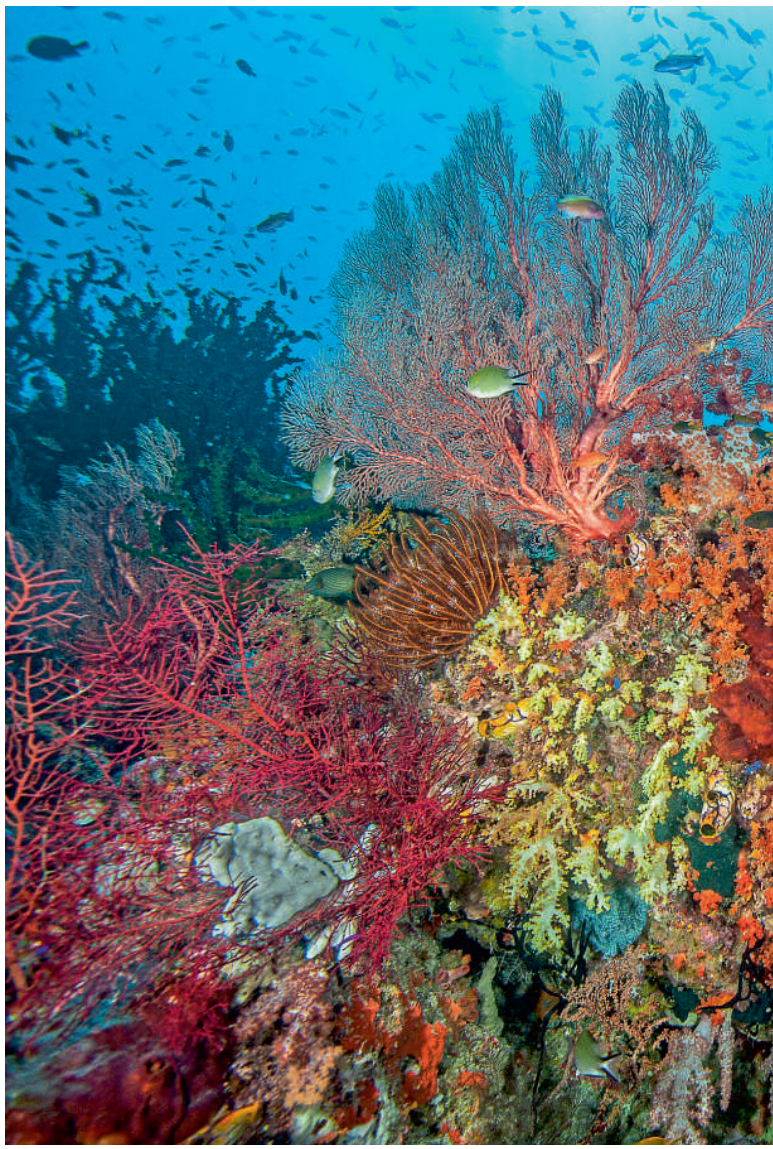
If Uranus and Neptune end up on top of the league table, that could reveal how efficiently the ice giants gathered material from their surroundings. If they don't, that absence would be just as telling, hinting that something stripped those systems bare or prevented captures in the first place.

And we may soon even have a chance to see an irregular moon up close, the second time a spacecraft has ever visited an irregular moon after Cassini's brief visit to Saturn's satellite Phoebe in 2004. Tilmann Denk at the German Aerospace Center says the European Space Agency is considering whether to adjust the path of its Jupiter Icy Moons Explorer spacecraft so that it passes close to Kallichore, one of Jupiter's tiny irregular moons, in 2031. It would be a fleeting encounter with one of these small, dark objects, but a worthwhile one. These overlooked moons may be among the best records we have of how the giant planets came to be. ▮

Jonathan O'Callaghan is a science journalist based in London who specialises in stories on astronomy, astrophysics and space exploration

Back from the brink?

Bleaching has devastated coral reefs around the world, but there are ways we can help them recover, discovers **Thomas Lewton**



HERON Island, in Australia's Great Barrier Reef, was once so bountiful that an image of it is hurtling beyond the outer reaches of our solar system – one of a handful of pictures stored on the Voyager Golden Records, a selection of the very best examples of life on Earth.

When marine ecologist Matthew Nitschke began studying how corals are entangled with other creatures on the reef, he was also drawn to the site's beauty. Then, just as he was finishing up his project in the mid-2010s, everything changed.

The colour had drained from the corals, bleached by a prolonged increase in water temperatures. "I just remember fields of white corals as far as you could see underwater. It was ethereal," says Nitschke. The grief of such rapid, widespread bleaching catalysed him, along with many other reef researchers, into action: "I felt that shift. It was like: what are the technologies we can develop?"

They began developing new ways to restore reefs, from larvae-spawning machines to coral probiotics. A decade later, these researchers find themselves racing against an escalating onslaught of marine heatwaves that last year pushed corals past the first-ever climate tipping point – an abrupt and potentially irreversible shift. "There's only so much time that we can buy," says marine biologist Emma Camp at the University of Technology Sydney.

Today, reef researchers are somewhat split on which path can best preserve coral reefs. Can these innovations be scaled up to bring corals back from the brink? Or are simpler solutions that rely on corals' natural ability to regenerate a surer route to rescue?

Corals can't flourish by themselves. Each coral polyp lives in a mutually beneficial – or symbiotic – partnership with algae, which capture sunlight and turn the energy into sugars that the coral uses to build the reef. "The symbiont is like an endless food particle. It's the snack that keeps on giving," says Nitschke, who is at the Australian Institute of Marine Science (AIMS).

But like all relationships, challenging circumstances can cause break-ups. Oceans have absorbed 90 per cent of the excess heat that has accumulated on Earth because of climate change, escalating the frequency and intensity of marine heatwaves, which alter how coral and algae share nutrients. "Neither of them are meeting their end of the bargain, but the coral seems to have the final say and ejects the symbiont," says Nitschke. Once coral kicks out its algal partner, it begins to starve and is likely to die.

In 1998, the first global coral-bleaching event, 21 per cent of reefs experienced bleaching-level heat stress (see "Corals in crisis", page 40). Reefs can be remarkably resilient, and many corals returned over the following years. But when back-to-back bleaching events strike, recovery becomes

DAVID HALL/NATUREPL.COM

The bright hubbub of reefs is under threat from climate change

harder. From 2014 to 2017, marine heatwaves bleached 68 per cent of reefs around the world; then, from 2023 to 2025, record ocean heat drove the most widespread bleaching event yet, affecting 84 per cent of reefs.

By 2025, the Global Tipping Points project announced that the first-ever climate tipping point had been breached. "We saw carnage across the majority of coral reefs," says Tim Lenton at the University of Exeter, UK, who leads the project.

Tipping points are self-propelling feedback loops that are abrupt and tough to come back from. This can occur for corals when bleached reefs become swamped by macroalgae, such as seaweed, a process that is supercharged by excessive nutrients washed from the land and the loss of fish that naturally keep seaweed in check. Other human disturbances, such as blast fishing and trawling, directly dismantle reefs, as do tropical storms, which are intensifying with climate change.

"Some coral reefs have shown an impressive ability to bounce back"

Meanwhile, the spread of disease and acidifying waters that are starved of oxygen compound the problem. "It's not just one stress," says Camp. "It's like you've gone through a cold and you've gone through covid, and now you've got cancer, now you've broken your leg."

Lenton offers an optimistic view, emphasising that tipping points can be positive as well as negative when virtuous cycles pull ecosystems out of the harmful ruts they have landed in. "It is about what you do afterwards," he says. "Like many parts of the biosphere, coral reefs have shown an impressive ability, in some contexts, to bounce back."

Coral gardening

In this vein, technology might help bring corals back from the brink. Coral restoration is an umbrella term for a variety of methods that have been around in one form or another for decades. Traditionally, this largely involved growing coral fragments in nurseries and then planting them out in the wild – known as coral gardening. "You multiply the same colonies, like a photocopier, over and over again," says Line Bay, a biologist at AIMS.

Most coral restoration still happens this way, but it is a slow process, and if corals planted on the reef are genetically similar, they may all suffer the same fate in disease-ridden or heat-stressed environments. The 2014-17 mass bleaching made it clear to some researchers that coral gardening wasn't enough. "That was a wake-up call. So much coral was lost," says ecological geneticist Madeleine van Oppen at AIMS. In 2017, a group of 18 leading researchers – including van Oppen and Bay – called for emerging technologies and riskier interventions to be embraced.

As well as cloning corals, researchers began sexually reproducing them to increase genetic diversity. Each year, seas around reefs become a blizzard of white and pink as eggs and sperm are released in spectacular spawning events. Some restoration methods tap into these natural processes, collecting eggs and sperm and then fertilising them on a mass scale in sea simulators that use robotic arms and artificial intelligence to work at speed.

More ambitious still are restoration methods that try to create corals and algae with traits that make them more tolerant to heat stress and bleaching. For millennia, humans have selected valuable traits in livestock and crops. Over the past decade, van Oppen has pioneered doing much the same with corals, but in an accelerated process called assisted evolution. "Even when there's a really bad thermal- ›

bleaching event, you will find some weird and wonderful corals that have somehow managed to survive that. So, you try to understand how they are different," says Camp.

Often, this comes down to the algae that co-exist with the coral. After heat-tolerant algae have been identified in the wild, they are subjected to even warmer temperatures in the lab. Each generation, many of the algae die, but the few that survive are selected and the process is repeated. Van Oppen and Nitschke have done this almost non-stop for over a decade to evolve algae that can survive at 31°C (87.8°F) – the peak temperature of recent marine heatwaves on the Great Barrier Reef. Heat-tolerant algae are then given back to corals in the hope that they keep living in harmony, despite the harsh conditions. Pilot studies in the wild, which are currently under review, "look very promising", says van Oppen.

Meanwhile, other researchers are trying to harness the microbes associated with healthy reefs, which help them feed themselves, ward off diseases and buffer stressful environments. "They act as the coral's first line of defence and adaptation," says marine biologist Raquel Peixoto at the King Abdullah University of Science and Technology (KAUST) in Saudi Arabia, who has developed a range of coral probiotics and nutritional supplements that have shown early signs of success in the field.

"Even to restore a tiny portion of what we are losing, the costs are astronomical"

Yet van Oppen cautions that the promise of these approaches might not be replicated everywhere. Reefs are complex ecosystems that respond differently to the restoration tools on offer, which must be tailored to the local environment. For instance, simple methods that have worked in the Coral Triangle in South-East Asia – such as stabilising rubble or sinking structures for coral to grow on – aren't effective in the Caribbean, where there are fewer free-swimming coral larvae, says Tali Vardi, executive director of the Coral Restoration Consortium.

Saudi Arabia, meanwhile, is throwing everything it can at the problem. The KAUST Coral Restoration Initiative, in partnership with NEOM, a mega-city and economic zone on the Red Sea coast, is advertised as part of its drive to shift away from fossil fuels towards a "blue economy" – although its carbon emissions continue to climb.

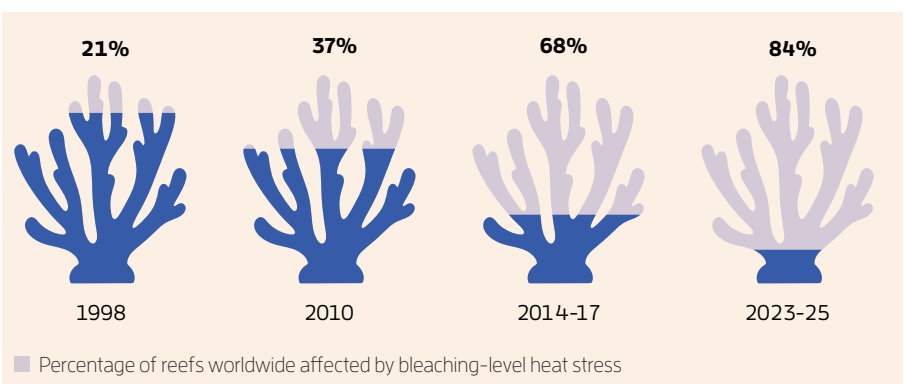
Marine biologist David Suggett, who leads the initiative, began collaborating with tourism operators on the Great Barrier Reef following the 2014-17 mass bleaching to try to scale up restoration. "Saudi Arabia came knocking on the door, saying that we've seen the model that you use", and asked how the country could go further, he says.

KAUST's field site covers about 1 square kilometre, while typical restoration projects are a small fraction of that size. In May, the initiative's coral nursery, which is 10 times bigger than any other in the world, opened and began its first restoration campaign, timed with the coral's annual spawning.

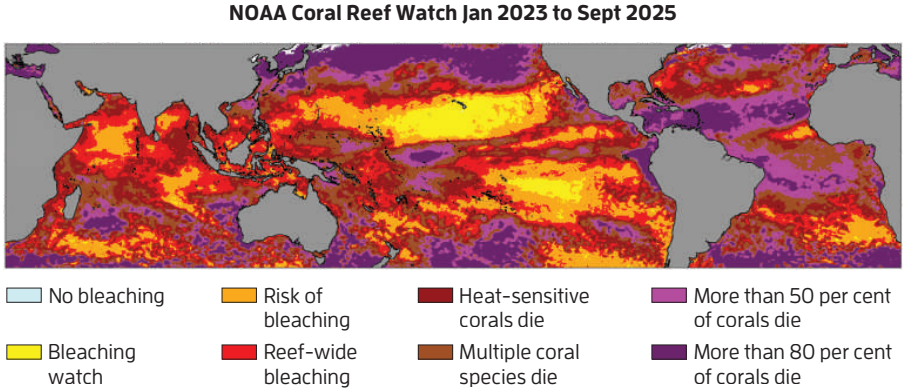
To monitor the site and decide where and how to restore coral, the team has built a 3D "digital twin" that is updated every six months using data collected by autonomous underwater vehicles, plus an army of boats and divers wielding high-resolution cameras. The digital twin is detailed and expansive: at around 22 petabytes, it is roughly 24 times the size of Wikipedia's entire contents.

Corals in crisis

Over the years, the proportion of the world's coral reefs affected by bleaching events has risen rapidly (top), with reefs around the world affected by the most recent event (bottom)



NOAA Coral Reef Watch Jan 2023 to Sept 2025



The restoration era

No doubt this initiative is impressive, but most countries supporting reefs can't tap into fossil-fuel revenues to build sophisticated systems like these. Suggett acknowledges it is "a bit of a white elephant globally", but sees value in the Red Sea site in demonstrating what is possible with enough backing.

Still, unless there is a clear road map to make high-tech solutions available to local communities, showstopping efforts can be "disempowering", says Vardi. "We're human beings. We're always going to shoot for the moon," she says. "But if you don't think about how that will be translated from the very beginning, you're just creating a new engineering problem."

Instead of building reef-monitoring systems with state-of-the-art cameras, you could do a good-enough job with a cheap, durable camera, she says. And instead of building a warehouse-sized aquaculture centre, you could build miniature, plug-and-play coral

laboratories that can be shipped anywhere.

There is psychological evidence that humans are biased towards active interventions, says ocean governance expert Robert Streit at the University of Melbourne. He and his co-authors argue in a recent paper that before throwing resources behind "heroic interventions", we need to pause and think widely about what kinds of conservation can lead to healthy reefs in the long term. Streit isn't opposed to innovations, such as assisted evolution, but cautions that we shouldn't overpromise or lose sight of the bigger picture.

Reefs covered with corals are a boon for snorkelling and scuba-diving tourists, but don't necessarily reflect a healthy reef – or one that meets the needs of local communities. Hundreds of millions of people rely on coral reefs to feed their families. Reefs can also hold cultural significance that can be overlooked when research is dominated by high-income countries, says Streit.

What's more, less-interventionist approaches, which protect the whole ecosystem, such as creating and enforcing marine parks or improving water quality, could be more impactful. "Let's put a buffer around things and have as minimum extraction and as minimum input as we can," he says.

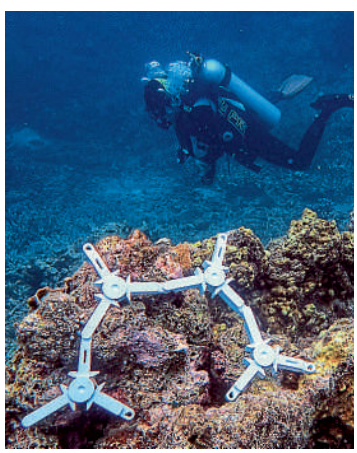
Intervening also necessarily comes at a cost. One recent analysis notes that between 2009 and 2018, around 11,700 square kilometres of reef were degraded and calculates that to rehabilitate a tenth of this would cost somewhere between $1 billion and $17 trillion – depending on the restoration methods used. "Even to restore a tiny portion of what we are losing, the costs are astronomical," says lead author Giovanni Strona, a quantitative ecologist at the European Commission's Joint Research Centre. "The main issue is: how much can you scale?"

Camp, Suggett and Vardi, among other researchers, argue it is still early days for coral restoration and wrong to make doom-and-gloom assessments based on the higher costs of experimental projects. There is also no need to pit technology and hands-off regeneration against each other, says Vardi. "There's a lot of this either-or mentality that is just plain idiotic," she says. "We manage all the ecosystems on Earth, as much as we don't want to face that."

Nonetheless, the success of restoration, and the ability to activate positive tipping points, often comes down to social factors as much as technological prowess, says Lenton. "If you give autonomy to the people of the reefs, then that seems to be a recipe for success. You have to build a relationship of trust." For instance, artificial reef structures can be constructed from local materials, such as pottery and natural fibres, and fishing communities can be given control over the marine park zones instead of national governments.


KAUST CORAL RESTORATION INITIATIVE/CHARLIE PINDER


CHRISTIAN MILLER/AIMS


AUSTRALIAN INSTITUTE OF MARINE SCIENCE

Coral-restoration projects include coral nurseries in the Red Sea (top) and in the National Sea Simulator in Australia (above left). Lab-grown corals are then released into the wild (above right)

Over the past decade, researchers have learned vital lessons about how novel restoration techniques could feed virtuous cycles within reef ecosystems. But as restoration efforts begin to be scaled up, the speed with which marine temperatures have spiralled during the current global bleaching event has taken everyone by surprise. "In some places, the coral tissue didn't even have time to bleach," says Vardi. "It just dissolved."

Bleaching events now happen almost every year, making it hard for coral restoration to keep pace. Strona calculates that the outlook for reefs restored so far is grim: 99.6 per cent of them are estimated to experience at least one bleaching event by the end of the century, with many of them experiencing dozens of bleaching events in this period. This has led some researchers to place hope in restoring reefs in "refugia", such as the Red Sea, which are buffered from climate stresses, while cryo-banks are being built around the world to preserve coral species until a time when, hopefully, ocean temperatures stabilise.

Most everyone agrees on one thing: the only real way to create a future for coral reefs is to drastically cut carbon emissions. "This isn't a replacement for action in the climate space," says Camp. "If we continue on the path that we're on, we're going to be asking too much of corals, even with the technologies that we have available." ▮

Thomas Lewton is a features editor at *New Scientist*

Seeing the invisible

The parts of the electromagnetic spectrum we can't see with our eyes reveal much about the cosmos, says astronomer **Emma Chapman**

MY FIRST encounter with invisible light came in my early years, and I thought it was magic. Radios filled every room of my childhood home: the kitchen, bedrooms, even the hallway. I would slowly turn the dial on older sets, listening as music and voices emerged from the static, before fading away again as I surfed the radio waves. Long before I understood I was tuning in to part of the electromagnetic spectrum, I felt the wonder of sensing something my eyes couldn't see.

Human eyes evolved to detect only a narrow band of light – enough to navigate landscapes and recognise danger – but the universe shines across a vast spectrum stretching from gamma rays to radio waves. Different wavelengths of light interact with matter in different ways, meaning each reveals a different side of the world, and universe, around us. We encounter these properties constantly in everyday life. Microwaves, for example, are just the right energy to excite water molecules, perfect for the noble application of reheating last night's leftovers. X-rays, meanwhile, have just enough energy to pass through soft tissue, but are absorbed by bone, allowing doctors to image our skeletons.

Radio light is the longest wavelength and lowest-energy light in the electromagnetic spectrum, able to travel enormous distances largely unimpeded, and pass relatively easily through Earth's atmosphere. This makes radio waves a powerful medium for communication on Earth, as I experienced as a child, but they are also an ideal messenger from the distant reaches of space and time. Years later, as my interests turned towards cosmology, it felt fitting that I would end up using radio telescopes to study the universe's first stars and galaxies.

The electromagnetic spectrum as we know it today follows centuries of scientific discovery, as researchers gradually discovered that the universe extended far beyond the limits of human vision. It started with a rainbow in 1665, when Isaac Newton used glass prisms to show that white light could be split into a spectrum of colours, from red to violet. By 1800, astronomer William Herschel had discovered infrared light, again with a prism, by measuring the temperature of different colours of light and noticing that his thermometer ticked higher just beyond the red end of the spectrum. By the end of the 19th century, advances in electromagnetism and laboratory technology had revealed radio waves, microwaves, X-rays and gamma rays, completing our modern view of the spectrum.

Optical astronomy is as ancient as civilisation itself, born from the simple fact that we come into this world already equipped to see sunlight or starlight. Other regions of the spectrum require additional tools: antennas and dishes for radio waves and microwaves, and specialised detectors for X-rays and infrared light. We can think of each of these subcategories as languages where, to understand the universe, we need

the ability to translate to the optical light our eyes more naturally comprehend or, in the case of household radios, sounds our ears can appreciate. Only then are we rewarded with a complete cosmos of unseen messages and hidden histories.

We need the entire spectrum to fully illuminate the cosmos. UV light, for example, traces water plumes erupting from the surface of the smallest of Jupiter's Galilean moons, Europa. The strong magnetic fields enveloping the giant planet interact with the atmosphere of the orbiting moon, generating auroras that shine brightly in the ultraviolet wavelengths. As water vapour from the plumes rises into the atmosphere, it temporarily alters the brightness of the auroras. Observing this allows astronomers to infer the presence and composition of the material erupting from the potentially habitable ocean below Europa's icy surface.

And for the infrared, we have the James Webb Space Telescope (JWST), which sits 1.5 million kilometres from Earth, shielded from the sun by a sunshade the size of a tennis court. With the clearest and coldest view of the universe ever achieved, JWST has been rewriting what we thought we knew about how the first stars and galaxies formed.

As the universe expands, light from the early galaxies is shifted into longer, infrared wavelengths (it moves towards the red end of the spectrum, so we say it is redshifted), which go on to be adeptly captured by JWST. With a simple translation, labelling infrared wavelengths with optical colours, as if completing a paint-by-numbers, we see galaxies just as they were only a few hundred million years after the big bang. Fascinating for sure, but there is a problem. A lot of these galaxies look more middle-aged then youthful – they are simply too big to be explained by star formation and galaxy evolution as we thought we understood it. How did they grow so fast?

To answer that question, astronomers are gathering older light that has been shifted into even longer wavelengths: radio waves that have travelled further, for even longer. Headquartered at Jodrell Bank Observatory in the UK, the Square Kilometre Array (SKA) will consist in part of over 100,000 antennas spread across the Western Australian outback into one enormous radio observatory, able to hear the faintest whispers from only a few tens of millions of years after the big bang. By detecting faint signals from the hydrogen gas that swirled around the primordial universe, the SKA aims to translate messages from the very first civilisation of stars and baby black holes.

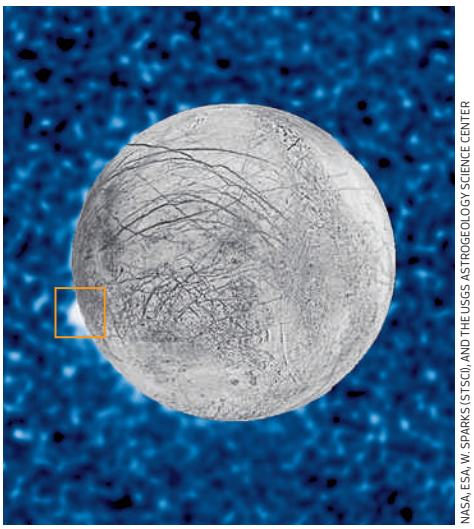
SKAO/MAX ALEXANDER

The Square Kilometre Array will listen out for faint radio waves from the early universe

Listening in

This is only one scientific application for the SKA, however. It will observe a multitude of celestial phenomena, mapping the furthest arms of the Milky Way, for example, and listening for signs of extraterrestrial life.

The search for extraterrestrial intelligence (SETI) is a research area that particularly fascinates me, because it beautifully demonstrates the complementary nature of observations at different wavelengths. With optical telescopes, such as the Transiting Exoplanet Survey Satellite (TESS), we are cataloguing thousands of planets outside our solar system, by measuring the infinitesimal drop in brightness we observe when a planet passes in front of the star it orbits.



NASA, ESA, W. SPARKS (STSCI), AND THE USGS ASTROGEOLOGY SCIENCE CENTER

A plume erupting from the surface of Jupiter's icy moon Europa is seen in UV light

Then, with infrared telescopes, such as JWST, we can measure the composition of the exoplanetary atmosphere, and flag it as potentially habitable. Finally, with radio telescopes, we can target the shortlist of planets promising for hosting life and listen for extraterrestrial messages, whether an intentional greeting, or the unintentional leakage of radio communications, like television broadcasts. After all, the laws of physics apply as much on exoplanets as they do on Earth, making radio the most obvious medium for communication. Perhaps one day, as we surf the radio waves from other star systems, an altogether alien voice will emerge from the static.

We are born fluent in only a single language of light, yet the universe is profoundly multilingual. The electromagnetic spectrum is a Rosetta stone, allowing our telescopes to translate unseen stories written in invisible scripts. When read together, these stories allow us to tune in to a universe far richer than the one our eyes alone can see. ▮

This is an edited extract from our subscriber newsletter Lost in Space-Time. Sign up at newscientist.com/lost-in-space-time/

Emma Chapman is an astrophysicist at the University of Nottingham, UK, and author of *Radio Universe: How to explore space without leaving Earth*

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Photograph: Mark Stratton

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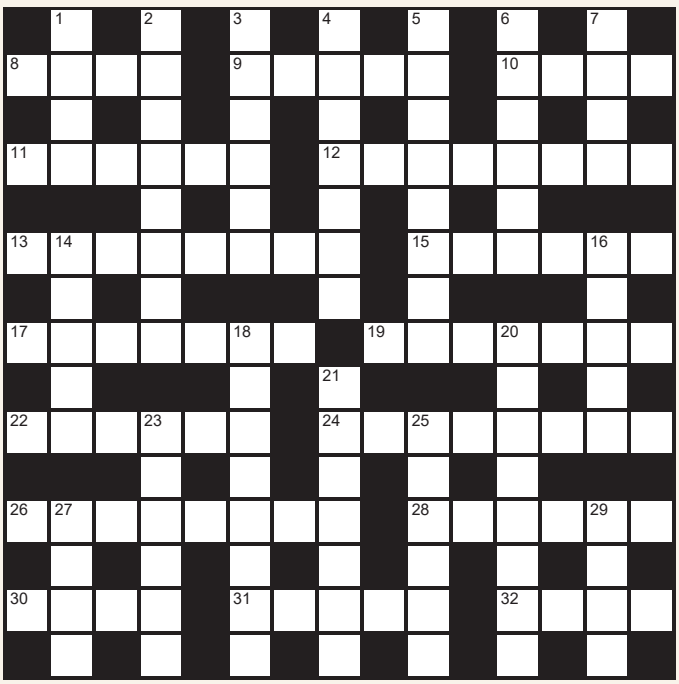
Quick crossword #210 *Set by Richard Smyth*



Scribble zone

Cryptic crossword next week

ACROSS

8 Cylinder (4)
9 Plant reproductive unit (5)
10 Red form of corundum (4)
11 Online discussion forum founded in 1980 (6)
12 Intestinal parasite (8)
13 Having a threaded cap (5-3)
15 C_2H_6 (6)
17 Malaria medication (7)
19 Unit of area equal to 10,000 square metres (7)
22 Male part of a flower (6)
24 Ate, consumed (8)
26 Two-terminal variable resistor (8)
28 Margin of freedom, latitude (6)
30 Collaboratively edited online knowledge resource (4)
31 Plant structure formed of sepals (5)
32 Middle layer of the eye (4)

DOWN

1 Covert listening devices (4)
2 Robert A ___, US science-fiction author (8)
3 Small, agile songbird (6)
4 Member of a narrower taxonomic category (7)
5 Type of synthetic rubber (8)
6 Progressive increase; maturation (6)
7 Online transport provider founded in 2009 (4)
14 Determine the number of (objects, occurrences, etc.) (5)
16 Component of the nervous system (5)
18 Engineering on a very small scale (8)
20 Sensory feature of the tongue (5,3)
21 Abnormal tube connecting body cavities (7)
23 Short-sighted (6)
25 The Milky Way, say (6)
27 Bristle, filament (4)
29 Highest point (4)

Our games are now playable online
newscientist.com/games

Quick quiz #356
set by Michael Dalton

1 In chemistry, what word is used to describe a substance that doesn't react with molecules from its surroundings?

2 Which type of clock uses a swinging weight to keep time?

3 Who is the current head of NASA?

4 Which mathematician came up with the unit distance problem?

5 The Pamir mountains in Central Asia are often referred to as what?

6 Which planet in our solar system was orbited by NASA's Messenger spacecraft?

7 What is the name for the phenomenon where a living organism absorbs and re-emits light at different wavelengths?

8 Optimus is the name of a humanoid robot built by which company?

9 Who is the author of the *Children of Time* series?

10 The LISA Pathfinder is a satellite launched by which space agency?

Answers on page 47

SHUTTERSTOCK/AROUND THE WORLD PHOTOS

This robot is called Optimus – but which company built it?

Start again

When the sun eventually expires and swells to engulf Earth, might the remnants of landfill and deeply buried nuclear waste be recycled to form the star dust that will become new planets or life forms?

Ron Dippold
San Diego, California, US
Quite possibly! Though you certainly won't be able to say, "Oh hey, that was my old shirt".

In the first stage, after the sun runs out of hydrogen in its core in about 5 billion years, it will initially collapse a bit from loss of outward pressure – but all of that gravitational energy from in-falling mass will be a huge energy injection. It will start burning some of the outer hydrogen in a shell around the core, and begin expanding into a red giant. It will get over 1000 times brighter. The intense radiation will blast Earth's atmosphere into outer space. Earth's surface temperature will reach over 1500°C. At that temperature, its crust and most other things will just melt into a sea of magma. A few things may survive intact – metals like tungsten and molybdenum can survive over 2500°C.

"When the sun expands, Earth's surface temperature will reach over 1500°C and most things will melt into a sea of magma"

Some synthetic materials, like aluminium oxide and zirconia, are similarly hardy, and many gems, like diamonds, sapphires and rubies, would be fine.

Earth will drift outwards a bit because the sun is losing mass, but in the second stage – about 7.5 billion years from now, according to most theories – the sun will still swallow Earth.

The entire planet will disintegrate before too long from the heat, the buffeting by dense plasma, and the tidal forces. At this point, everything will become ionised plasma like the rest of the sun – even those things that avoided melting in the first stage.

The sun is about eight times too small for a core-collapse supernova. However, it still has several coughing fits to go through as it runs out of various elements and starts fusing heavier ones. Eventually, it will blow off its outer layers in an expanding cloud of gas and radiation called a planetary nebula. The remaining sun will shrink to a white dwarf, which, in theory, can glow for trillions of years – if the universe lasts that long. Anything stuck in that is never getting out, unless a black hole rips it to pieces. But most of Earth would still be in those outer layers blown off as a planetary nebula. As that cools over millennia, the atoms in the nebula will arrange into tiny grains of cosmic dust and interstellar gas. In billions of years, these may become part of a large molecular cloud like the one that became our solar system, and might one day collapse again into a brand new solar system. My Iron Maiden concert shirt will live on!

Hillary Shaw
Newport, Shropshire, UK
The first question here is will the sun engulf Earth as it becomes a red giant? Probably it will, despite the reduction in the sun's mass – resulting in Earth orbiting further out – as the sun's extended atmosphere may cause drag on Earth, slowing its orbit and causing it to fall back further in.

Consuming the remains of Earth, Venus and Mercury, the red-giant sun expands, throwing off material like dust and gas that may well end up as part of another solar system, possibly hosting life. That life probably won't use our nuclear-waste atoms – which by then will have decayed to stable isotopes anyway – directly, but if it is intelligent, it may find uses for these heavy elements as we have.

However, if the red-giant sun doesn't consume Earth, its alternative is far more dismal, dark and lonely. The red giant loses fuel and transitions into a white dwarf. The husk of Earth orbits the white-dwarf sun for quadrillions of years as it cools to a black dwarf. A passing star may strip Earth away, or it may fall into another star, or a neutron star, or a black hole. At some point, this entity may collide with another black hole or neutron star, and some matter containing heavy atoms is ejected, possibly to seed another life-bearing planet.

Or this collision never happens, and Earth and the black-dwarf sun linger on, and in 10^{20} years, Earth's orbit decays so it falls into the black-dwarf sun. Or Earth survives, perhaps ejected and wandering space, and in 10^{33} years, proton decay may convert it to radiation.

Or proton decay does not occur,and in 10^{100} years, the last black hole has evaporated and the universe is now a thinning, cooling void of sparse radio-wave radiation and matter. Time becomes meaningless and a dark infinity of nothingness – containing odd lumps of matter, like Earth, that never fell into the now-extinct black holes – lingers on forever. Very occasionally, and ever less frequently, distant faint flashes of light occur as objects like black dwarfs and stray planets collide. Extremely unlikely, but possibly, a single, small, dim, red main-sequence star forms, with a life-bearing planet. It is doomed to a solitary, albeit

JVPHOTO/ALAMY

This week's new questions

Head banging **When wasps, bees and flies continually clatter against the glass of my conservatory attempting a means of escape, are they following a strategy?**
***Martin Kelly**, Overton, Hampshire, UK*

Tasty treat **Why is ice cream so delicious?**
***Anthony Woodward**, Oregon, US*

Are bees following a particular strategy when they repeatedly strike glass windows?

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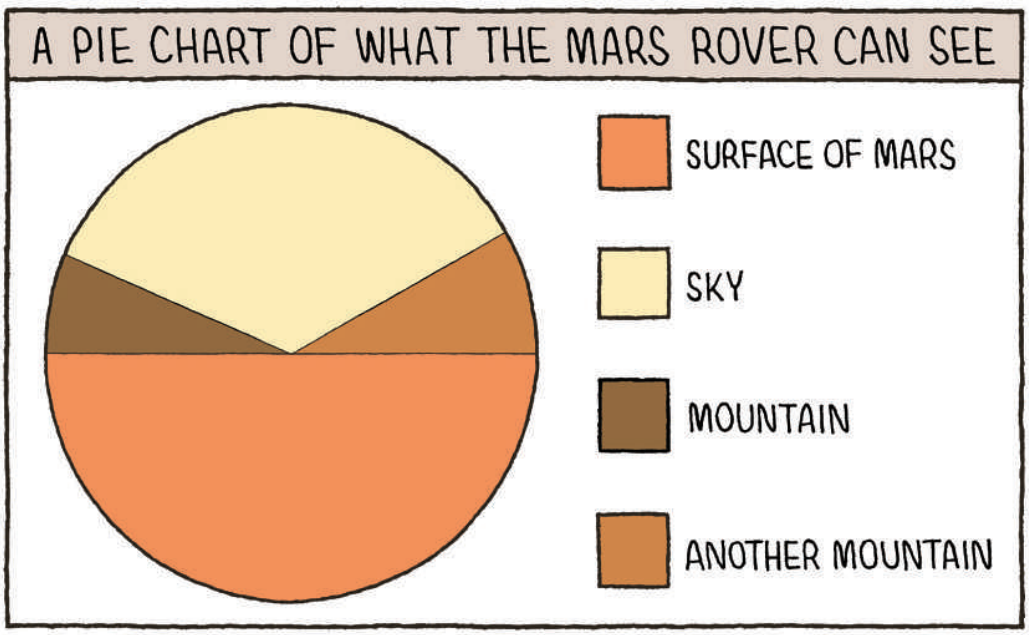


long, existence in the black, empty void. Then nothing. Forever.

It's a trap

Why do Venus flytraps and pitcher plants trap and digest insects if they are fully capable of photosynthesis? If this is an adaptation to ensure there is always food, then why don't other plants do the same? (continued)

David Muir
Edinburgh, UK
Plants require 17 essential nutrients. Through photosynthesis, carbon and oxygen are derived from carbon dioxide in the air, and hydrogen comes from water. The other 14 elements: nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, zinc, copper, boron, nickel, molybdenum, manganese and chlorine, would normally come from the soil for land plants. Aquatic plants get their nutrients directly from the water they live in, or from the substrate in which they are fixed. For these land and aquatic plants, the benefits of evolving insect-trapping mechanisms isn't worth the cost.

"Evolution can bring about adaptations that are beneficial, but only if the advantages outweigh the disadvantages"

Carnivorous plants generally grow in boggy places, often sunny, where they can photosynthesise. But such environments are nutrient-poor. To catch animal sources of essential elements, such plants have evolved adaptations: snap traps (Venus flytrap), bladder traps that use a vacuum to suck in prey (bladderworts), flypaper traps that use a glue (sundew), lobster-pot traps that use angled hairs to direct prey one-way to their demise (corkscrew plants) and pitfall traps that send prey down into a swimming pool of digestive enzymes (pitcher plants). For these plants, the benefits of evolving insect-trapping features is well worth the cost.

Under Mother Nature's cost-benefit analysis of natural selection, evolution can bring about adaptations that are beneficial, but only if the advantages outweigh the disadvantages.

Rob Leah
London, UK
Most carnivorous plants live in acidic, boggy soils, which are notoriously poor in various nutrients – particularly nitrogen needed to make proteins. They therefore evolved to trap and digest insects, to provide the nutrients that weren't available from the soil.

A surprising number of plants are weakly carnivorous (such as tomatoes, which have stems covered in sticky hairs that can capture small insects and absorb the nutrients from their decomposition), but presumably, the evolutionary cost of being actively carnivorous only makes sense in very specific environments. ▮

Answers

Quick quiz #356

1 Inert

2 Pendulum clock

3 Jared Isaacman

4 Paul Erdős

5 The roof of the world

6 Mercury

7 Biofluorescence

8 Tesla

9 Adrian Tchaikovsky

10 The European Space Agency

Quick crossword #210

ACROSS 8 Tube, **9** Ovule, **10** Ruby, **11** Usenet, **12** Tapeworm, **13** Screw-top, **15** Ethane, **17** Quinine, **19** Hectare, **22** Stamen, **24** Ingested, **26** Rheostat, **28** Leeway, **30** Wiki, **31** Calyx, **32** Uvea

DOWN 1 Bugs, **2** Heinlein, **3** Tomtit, **4** Subtype, **5** Neoprene, **6** Growth, **7** Uber, **14** Count, **16** Nerve, **18** Nanotech, **20** Taste bud, **21** Fistula, **23** Myopic, **25** Galaxy, **27** Hair, **29** Apex

Funny feeling

Scientific papers don't usually hit their readers in the feels. It's hard to become emotionally entangled with transcriptional regulators or muon neutrinos. But this week, Feedback was sent a study that made us feel positively queasy.

Assistant news editor Alexandra Thompson had spotted a paper by social psychologist Paul Silvia at the University of North Carolina at Greensboro and his colleagues. It's called: "Who laughs at their own jokes? Metacognitive judgments of self-rated funniness in creative humor production tasks".

Oh no, Feedback thought. We do tend to think we're funny – at least some of the time and not always on purpose – but what if we're kidding ourselves? What if this paper shows that people of Feedback's ilk are liable to laugh at their own jokes even if nobody else does?

The paper opens in confrontational style: "When we imagine someone who thinks that they're hilarious and laughs at their own jokes, we might have someone specific in mind, for better or worse, like an insufferable ex-boyfriend [or] a parent armed with a book of dad jokes." Feedback instantly had a mental image of David Brent/Michael Scott (delete as appropriate).

Silvia and his team go on to inform us that "most people view themselves as having a better-than-average sense of humor". They offer some stats to support that, like a classic study where fewer than 2 per cent of participants rated their sense of humour as below average. Then they go for the jugular: "The concept of a 'sense of humor,' however, is so abstract, ill-defined, and difficult to disconfirm that it is a perfect vessel for someone's unrealistic and self-enhancing beliefs."

At this point, Feedback started to feel like something nameless and malign was gnawing on our spinal cord. Are we funny? Have we ever been funny?

Silvia and his team later describe a series of experiments in which they gave people prompts and asked them for humorous responses, then got them to rate how funny their responses were. The prompts were things like: "Imagine you and a friend are ordering something to eat at a new food truck. After the truck's cook hands over your food, you and your friend walk off to a nearby bench to eat. You take a big bite – and the food is totally disgusting. You turn to your friend, and say, '…'"

It turns out that people rate their ideas as funnier if they have higher confidence, if they believe they are generally funny, if they scored higher on personality traits like extraversion and narcissism and – readers may feel there is a certain inevitability to this last one – "when they identified as male".

How reassuring: Feedback is nothing like that, so if we think we're funny, we probably are. We're still not telling you what we would say to that prompt, though.

Twisteddoodles *for New Scientist*

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

Satan versus gravity

In "The death of the author", Roland Barthes argued that individual readers' interpretations of books are just as valid as those intended by the authors. George Orwell may have intended *Animal Farm* as a parable about the Russian revolution, but if Feedback reads it as meaning that pigs are sneaky, we are not wrong.

We were reminded of this essay when reporter Karmela Padavic-Callaghan sent us a press release about Timothy Burbery's talk at the European Geoscience Union's annual meeting in May, titled "Meteoritics and Dante's Inferno: Examining Satan's fall as an impact event".

Burbery, who is at Marshall University in West Virginia, has taken a fresh look at Dante Alighieri's classic poem *The Divine Comedy*. Prior to the events of the story, Satan has fallen from heaven into hell. Burbery is interested in "the geophysical elements of Satan's fall from Heaven".

The press release goes into more detail. "Dante envisioned Satan as a high-velocity impactor hitting the Southern Hemisphere and tunnelling to the Earth's centre," it says.

"Burbery suggests treating the Prince of Darkness as an oblong, asteroid-sized body… Like the Hoba meteorite, which remains a 60-ton intact mass, Dante's Satan is modelled as a physical, un-vaporized impactor that permanently restructured the Earth's architecture."

This allows for a radical reinterpretation of the poem. "In this light, the nine circles of Hell are no longer merely symbolic tiers of sin, but rather a remarkably accurate description of the concentric, terraced morphology found in multi-ring impact basins across the solar system, from the Moon to Venus."

Feedback isn't entirely sure, but we think the circles might actually be symbolic tiers of sin, and that this is all taking the death of the author a little bit too far.

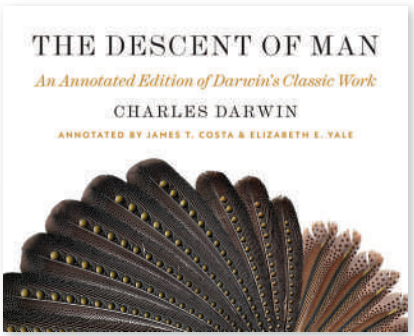
Waymo out of line

"Empty Waymos invade Atlanta neighborhood, keep circling cul-de-sac," announced The Atlanta Journal-Constitution on 15 May. Waymo said the driverless cars had experienced "a routing problem", causing them to get stuck in a loop that was both figurative and literal.

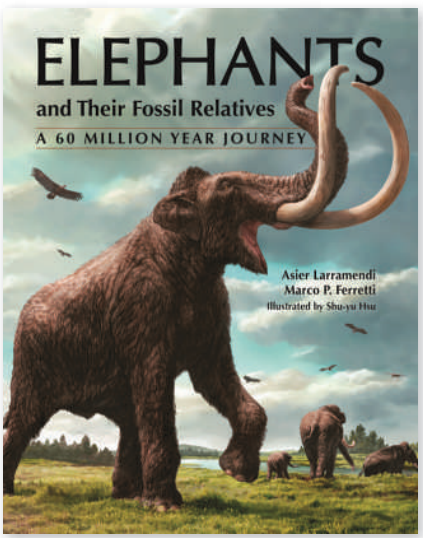
Footage on BBC News showed the cars endlessly puttering around a cul-de-sac, getting in each other's way, reversing, getting in another Waymo's way, and so on for hours. Feedback can generally get out of a cul-de-sac in two or three attempts, but maybe that's because we're not artificially intelligent.

Full marks to the anonymous Bluesky user known only as "Capitalist with a heart of gold" who described the self-driving cars as "traffic without transportation".

New from Princeton University Press



The first annotated edition of the book that shocked the Victorian world and continues to generate controversy today



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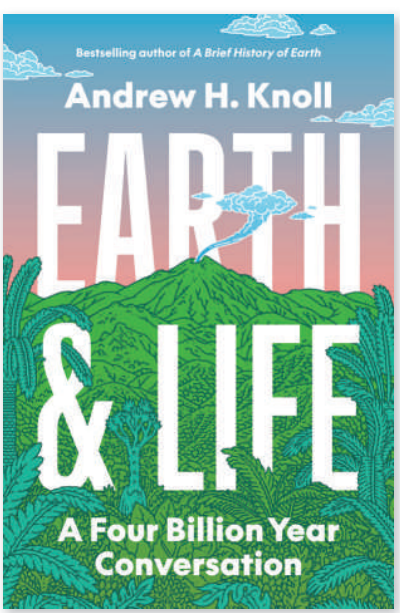
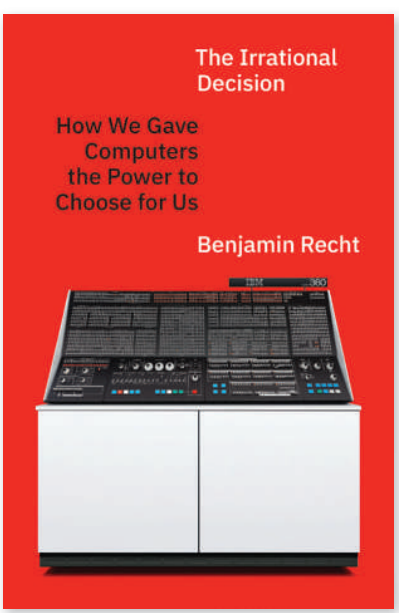
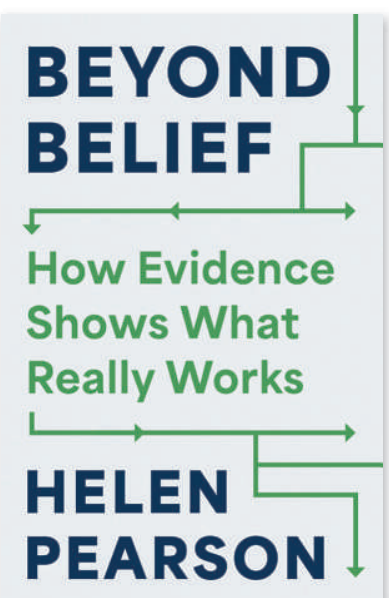
A leading neuroscientist describes the long evolutionary process that led to the human brain



From the world-renowned geobiologist and bestselling author of *A Brief History of Earth*, the epic story of a planetary conversation four billion years in the making



How the computer revolution shaped our conception of rationality—and why human problems require solutions rooted in human intuition, morality, and judgment



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