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This week's issue

On the cover

30 Decoding dyslexia
1 in 10 of us have dyslexia – now we finally understand what's happening in the brain



Vol 272 No 3620
Cover image: Owen Gildersleeve

40 Why humans evolved to be unusually fat

10 Strongest evidence yet that AMOC is weakening

36 Extreme storage solutions for nuclear waste

20 Acne vaccine
24 How to let go of control
8 Birds get jet lag too

40 Features

"Fat played an incredibly important role in our evolutionary history, which is one of the reasons we love it"

News

6 Curious cognition
How curiosity may have shaped our complex brains

12 Pluto's neighbour
An intriguing object has been spotted in our solar system

12 Picky people
Early humans migrating through Arabia were selective about where they lived

Views

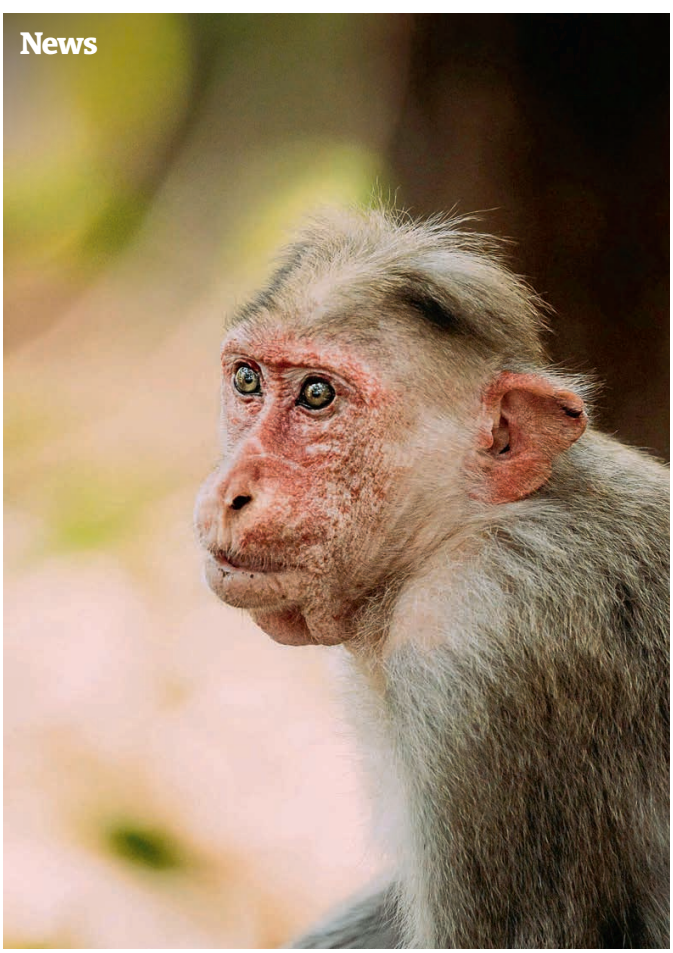
19 On the mind
Helen Thomson explores the role of microchimeric cells in the brain

20 Acne's new frontier
Vaccines could help prevent acne, finds Michael Le Page

22 Aperture
Drone photograph captures a disappearing industry

24 Book of the week
An intriguing look at letting go of control

29 Letters
Thoughts on AI consciousness



RYHOR BRUYEU/ALAMY

14 Monkeying around A peek into how macaques see the world

Features

30 Decoding dyslexia
We are finally pinning down what makes dyslexic brains different

36 Burying danger
What should we do with all our nuclear waste?

40 Evolutionary appetite
We have an unprecedented choice of food. Evolution can teach us about how to eat better

The back pages

45 Puzzles
Try our crossword, puzzle and quick quiz

46 *Almost* the last word
If all ships were taken out of the water, how much would global sea levels change?

47 Tom Gauld for *New Scientist*
A cartoonist's take on the world

48 Feedback
A look into backwards DNA

48 Twisteddoodles for *New Scientist*
Picturing the lighter side of life

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are changing.

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Ditching dyslexia

Labelling children can provide them with support, but what about the rest?

IN YEARS gone by, children who struggled to learn to read and spell were labelled "stupid", "lazy" or "dim". Today, of course, we are much more enlightened – now we label many of these children as "dyslexic". But perhaps this label is still a bad idea.

Picture two 9-year-olds reading at the level of an average 6-year-old. One gets a diagnosis of dyslexia. This positively affects her wellbeing. Her teachers now understand she has dyslexia and that she can get tailored help.

The other child isn't so lucky. Maybe his parents can't afford a dyslexia test – in the UK, assessment isn't available on the NHS and can cost several hundred pounds. In the US it could set parents back thousands of dollars. Or perhaps he was tested but the result was negative. Until very recently, this outcome was common for already disadvantaged children, because the official definition of dyslexia included the idea of "discrepancy" – that reading problems should be unexpected given a child's other cognitive abilities. Assessing ability using IQ tests can also be biased

"Two children with the same learning difficulty. One gets help, the other does not"

against those from lower socioeconomic groups or learning to read in a second language. By extension, this second child is just bad at reading or lazy, or both, and not eligible to receive extra help with reading.

Two children with the same learning difficulty. One gets help and understanding and the other doesn't, all because of a label. Yet this label is based on a questionable assessment. Despite trials using a wide range of cognitive processes, researchers have been unable to find meaningful ways to identify dyslexia.

So, why not just help all children who struggle to read? Each has a unique combination of risk and remediation factors, but all will benefit most if we intervene when the problem first shows up, instead of waiting years for them to fail and then receive a diagnosis. Our newfound understanding of what is happening in their brains even suggests some surprisingly simple ways to help (see page 30). Giving every child the best possible chance to overcome their challenge is what matters, not the label we attach to them. ▮

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EU copies printed in Czech Republic by Triangl A.S.

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Climate change

Stage is set for another COP flop

Despite coming after a year of dangerous weather, COP31 is unlikely to deliver dramatic progress on climate action, reports **Madeleine Cuff**

THE Mediterranean beachside haven of Antalya in Turkey is more used to hosting well-fed tourists than stressed climate negotiators. But for two weeks starting on 9 November, the city will become the climate change capital of the world, welcoming tens of thousands of delegates to the UN COP31 summit.

COP31 is the latest instalment of the annual climate summits where countries come together with the aim of tackling climate change. The meetings were responsible for ushering in the Paris Agreement in 2015, the climate treaty under which nations have promised to hold warming to "well below" 2°C and as close to 1.5°C as possible.

But in recent years, the summits have had a less impressive track record. Critics argue the meetings are no longer fit for purpose, undermined by the need for unanimous consensus in all decisions and struggling to find direction now that the work of agreeing a legal climate treaty is completed.

Delegates left last year's COP30 summit in Belém, Brazil, having agreed the bare minimum – that they remain united behind the Paris Agreement. But after a fortnight of tortuous negotiations, they were unable to agree on fresh commitments to move away from fossil fuel use or end deforestation.

And although the world is now on course for lower levels of warming than looked likely before the Paris Agreement was struck, global emissions are still not falling and the world is on track for 2.8°C of warming by the end of the century, nowhere near the goals laid out under Paris.

In fact, the World Meteorological Association recently reported that the global average surface concentration of carbon dioxide reached a record 426.8 parts per million (ppm) in 2025, 53 per cent higher than pre-industrial levels. The levels of methane and nitrous oxide also reached record highs of 1948 parts per billion (ppb) and 339.1 ppb, respectively, in 2025, an increase of 167 per cent and 26 per cent on pre-industrial levels.

"Arguments over funding risk souring the atmosphere of the summit"

So, can the upcoming summit change the game?

This year's brutal weather should provide plenty of motivation. From devastating glacier collapses to heatwaves and raging wildfires, there has been no shortage of reminders that planet Earth is teetering on the brink of crisis. And that all came ahead of a super-sized El Niño now under way in the Pacific, a timely demonstration of what warming beyond 1.5°C will feel like in the real world – hot and dangerous, in short.

But don't expect fireworks from this COP. So far, the mood music from the hosts – a joint gig between Turkey and Australia – is setting the tone for a business-as-usual summit.

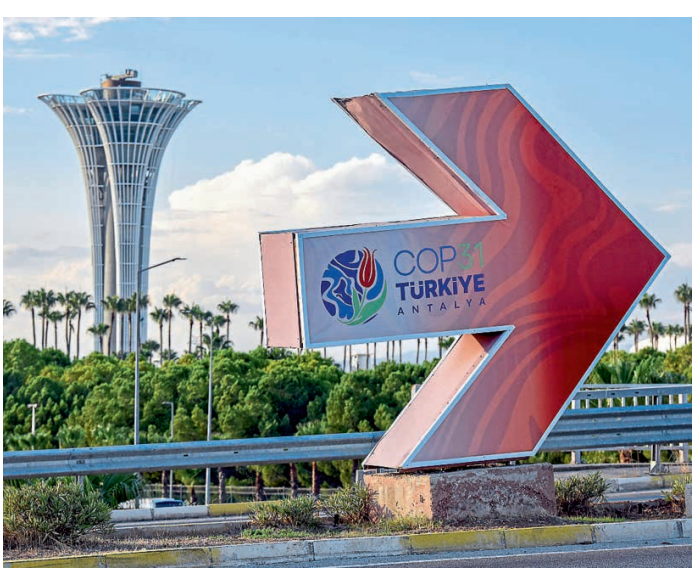
As with recent summits, there is no big declaration or new treaty pegged for Antalya. Instead, the main task negotiators face will be to grapple with a series of hangover decisions from Belém.

At COP30, nations agreed to create a "just transition mechanism". The idea is to provide a support structure for those affected by the shift to a cleaner economy. For example, countries need to work out how best to support and retrain workers in the fossil fuel economy as energy grids transition to cleaner fuels. But the process of identifying how this just transition mechanism will work in practice has barely begun.

Nations also agreed to triple adaptation finance for lower-income countries – effectively, helping them cope with the impacts of climate change – by 2035. But the commitment was vague, with no baseline year and no agreement on who should contribute or what types of finance would count. Delegates in Antalya will continue to hammer out the details.

"These are all big, kind of chunky areas where you know there will be strong expectation from developing countries and civil society that there is progress made," says Gareth Redmond-King at the Energy and Climate Intelligence Unit, a UK climate and energy think tank.

Turkey and Australia are jointly hosting this year's COP



GOKSEL YAPAR/AFP VIA GETTY IMAGES

Road map to nowhere?

One of the biggest disappointments from COP30 was that nations failed to commit to developing "road maps" away from fossil fuels. Although the idea had backing from more than 80 nations in Brazil, the final text from the summit failed to mention fossil fuels at all.

Nations that still backed the idea gathered in Santa Marta, Colombia, in April this year and jointly promised to draw up transition plans. However, to date, only France has produced anything like a fully fledged road map away from fossil fuels. Some countries are expected to announce their road maps on the sidelines of COP31, but it is unclear whether any major fossil fuel economies will come forward.

And despite a global oil crisis triggered by the closure of the Strait of Hormuz that makes the case for clean energy ever more obvious, it is unlikely the road map idea will make it into the formal COP agenda this year.

Instead, the summit's hosts are pushing electrification as a route away from fossil fuels. The more you can electrify cars, home heating and the like, the faster the

clean transition, the thinking goes. Turkey has launched a new "electrification target" that would see nations commit to electrifying 35 per cent of their annual energy consumption by 2035, up from the current rate of about 23 per cent.

We don't yet know whether this would be a voluntary pledge countries would sign up to, or something that the hosts will push to be universally agreed under the main negotiations. Questions also remain over whether the target will include any directive for nations to decarbonise their power grids.

Meanwhile, there are some serious headwinds facing the summit. In the face of rising fuel prices triggered by the Russia-Ukraine war and the US-Iran conflict, wealthy countries are tightening their belts. International aid has been cut significantly from many national budgets. That leaves less money for funding climate action in lower-income countries, who in turn say they can't take action to cut emissions without more cash. Arguments over funding risk souring the atmosphere of the summit.

Then there's the awkward issue of the hosts. Both Turkey and Australia wanted to host COP31 and neither would back down, so the UN awarded them joint hosting responsibilities. Turkey is responsible for the location and logistics, as well as the so-called Action Agenda, which includes the pledges, commitments and announcements outside of the negotiations. Australia will run the formal talks. But running a successful COP is a challenge even for one nations. With two countries in charge, there is a real risk of things drifting into confusion and infighting. Questions over their commitment to the cause linger



MUSTAFA YILMAZ/ANADOLU AGENCY VIA GETTY IMAGES

Electrification is being pushed as a route away from fossil fuels

over both nations, which have each been slow to embrace the energy transition and still rely heavily on fossil fuels.

But there are spots of hope too. For example, in Brazil, Luiz Inácio Lula da Silva won a historic fourth term as president last month, defying expectations to beat right-wing populist candidate Flávio Bolsonaro. Lula's victory means Brazil's delegation will be in Turkey pushing for more progress on deforestation and fossil fuel transition road maps.

Headline grabbing

In the formal negotiations track, there will be further talks on how the different "implementation" programmes on cutting emissions and ensuring a fair transition will work in practice. But these are unlikely to produce any big headlines.

"What we are going to see... in Antalya are many very important discussions, but they are less grand, big decisions," Ana Toni, executive director of COP30, told journalists on a briefing call on 22 October.

A cover decision, which can summarise key decisions or include new pledges, could offer the opportunity for nations to present a new headline-grabbing commitment. Australia and Turkey have said ahead of the summit that they will work on developing a cover text, which could acknowledge the inevitability that the world will overshoot 1.5°C of warming and call on countries to go faster on cutting emissions.

Negotiations over the wording of the cover decisions often provide the dramatic finale for a COP summit. But it can become a trap for ministers running the event, says Paul Watkinson, a highly experienced climate negotiator who has led both the French and European Union delegations at COPs.

Ministerial teams come into a COP thinking, "how do I get a result that doesn't look dreadful?" says Watkinson. "Particularly the ministers in charge; they want to get a boost to their career, and the country wants to say it's done something important for the world." It means COPs often end up "focused on yet another decision where we change the adverb", he says.

Watkinson wants to see COP summits focus much less on headlines generated by cover texts and more on the backroom work to get nations to collaborate with each other. "If we seek the big decision each year, we're using a huge amount of energy to get it, and we're not focusing on the real challenge, which is how do we overcome the barriers that are holding us back," he says.

That might mean changing the process to focus less on a consensus outcome with all parties, with action instead delivered by smaller groups of willing participants who work together to concentrate on delivering emissions cuts, he says.

It looks likely that the Antalya summit, despite its postcard-worthy setting, will be an unglamorous mix of long nights and bitter quarrels,

53%

Increase in global average CO_2 surface concentration since the pre-industrial era

reluctant compromises and underwhelming outcomes.

But for meeting insiders, the hope is that change will come in time for COP33 in two years' time, when countries are due to conclude a global assessment of their progress to decarbonisation. The pressure will be even greater on that COP to deliver a meaningful response to the stocktake's findings. The question is, can these summits reinvent themselves in time? As Watkinson puts it: "Practically everybody I speak to says, of course, we need to change it. We can't carry on as we do." ▮

Additional reporting by Shosha Adie

Mind

Curiosity may drive brain complexity

Our ability to be curious may be what shapes our sophisticated brain architecture, rather than it being a consequence of this complexity, finds **Jo Marchant**

OUT of thousands of artificial neural networks trained with different learning styles, the most curious ones had more sophisticated and flexible cognitive abilities, researchers have found. These models also spontaneously organised into structures that resemble human brains.

The networks formed interconnected modules and followed a human-like developmental trajectory, with dense neural connections forming early on before being pruned away, for example. Curiosity is usually seen as a consequence of having a complex brain, says Francesco Poli at the University of Cambridge. "What if it's actually helping to shape how the brain is?"

To model how infants learn, Poli and his colleagues collected eye-tracking data from 275 babies who were between 8 and 15 months old. The infants were shown sequences of colourful shapes on a screen, which provided varying amounts of information about where the next shape was likely to be displayed. "The positions weren't random, and every different shape had a sequence that could be learned," says Poli.

The babies proved to be highly sensitive to how much information the different stimuli provided. Whenever their rate of learning dropped below average, they disengaged and looked for something new, says Poli.

The team used this principle to design artificial neural networks with different levels of intrinsic curiosity, then trained them on 20 tasks. The high-curiosity models were designed to immediately switch task if their rate of learning dropped below a certain threshold, whereas the low-curiosity models switched randomly.

All the networks, curious or not, became experts at the tasks they were trained on. But after the training, the curious models performed significantly better at tests they hadn't seen before. This ability to put together different things in flexible ways is seen as a hallmark of complex human cognition, says Poli.

The curious models also developed physical characteristics resembling those of complex brains. The researchers embedded the artificial networks into a virtual three-dimensional space, modelled on the anatomy of the human brain. They then forced the networks to wire themselves efficiently by penalising long-distance connections, in order to mimic the cost of long-range wiring in real brains.

Curious networks

On its own, this wasn't enough to produce complexity, but when the researchers added curiosity on top, a range of brain-like features emerged. For example, the curious networks developed a hierarchical "modular" structure with highly interconnected areas that were, in turn, connected to each other.

Poli was also surprised to see a particular trajectory in the curious networks: the density of their connections rose, then fell. "I thought that was weird," he says.

But this is similar to what happens in human brains, says Poli, where the number of synapses – the junctions through which neurons communicate – rises steeply during the first year of life, followed by a pruning phase where unhelpful connections are lost. He speculates that curiosity, the drive to seek out tasks that yield the most information, could be "related to this selection process of what to keep and what not to keep".

To estimate a biological age for each network, the team mapped the rise and fall of the neural networks' densities against a typical human profile. They found that the most curious, human-like ones were at a more mature phase in the developmental arc, with an age of around 20, whereas those that didn't have the combination of curiosity and the correct wiring were stuck at an earlier point, with an age of around 9 (bioRxiv, doi.org/rv83).

Children should be given a choice of activities to prioritise their curiosity



FATCAMERA/GETTY IMAGES

It is unsurprising that curiosity makes learning more efficient, says Alireza Modirshanechi at the University of Göttingen in Germany, because it ensures we don't waste time on tasks that are too easy or too hard.

But the finding that this enables the emergence of human-like brain architecture is "very surprising",

"Curious models performed significantly better at tests they hadn't seen before"

says Modirshanechi. "If true, it's a very strong claim." He says it will be important to check that the non-curious networks don't eventually develop similar characteristics, albeit more slowly, if they are given enough training time.

Poli argues that the non-curious networks performed just as well as the curious ones on the basic training tasks, so their lack of complex cognition and brain-like features probably isn't simply a question of learning slower. "I think that, even with more training time, they would have stayed pretty much the same," he says. "Curiosity really changed how the networks learned."

Regardless, Poli says the findings emphasise the role of curiosity in education. Environments that force children to do one particular activity for a length of time "might be counterproductive, especially early on", he says. "It depends on what we want. If we value the ability to stay still and work on one thing for a long amount of time, then we have to train that in kids." Whereas if we value curiosity and cognition, we may need to prioritise giving children a choice of activities, "then letting them free within the space", he says. ▮

Quantum physics

Key oddity of quantum physics may run even deeper than anticipated

Karmela Padavic-Callaghan

THE probabilistic nature of quantum mechanics has puzzled researchers for more than a century. A new analysis shows that ridding the theory of this odd characteristic may be even harder than we thought.

Infamously, quantum objects can exist in combinations of seemingly mutually exclusive states, such as in the Schrödinger's cat thought experiment, where the animal is in a mix of states that makes it seem both alive and dead, and also neither. Left undisturbed and isolated, the cat remains mixed, but if it is observed – if an experimenter opens its box, say – it abruptly reduces to just one, unmixed state.

How exactly this happens, a question that is known as the measurement problem, is among the biggest unresolved issues in quantum mechanics. At its heart is a mathematical rule named after the physicist Max Born. Researchers have long tried to derive this rule from mathematical ingredients that could eliminate some of quantum mechanics' probabilistic oddness. However, Jiaxuan Zhang at the University of Oxford has now found that some of the most influential of these derivations don't fully accomplish this task.

The Born rule is a recipe for converting information about a quantum object into probabilities that tell us the likelihood of observing particular outcomes. The rule is also a postulate, which means the founders of quantum mechanics assumed its truth rather than deriving it. But it is a troublesome truth because it means quantum mechanics cannot offer information firmer than the probability of something happening, such as Schrödinger's cat being alive 30 per cent of the time you open its box.



H. ARMSTRONG ROBERTS/CLASSICSTOCK/GETTY IMAGES

Where exactly do quantum probabilities come from?

Zhang wanted to know if past efforts to derive the Born rule from mathematical assumptions, instead of simply postulating it, introduced any probabilistic ingredients at the starting point. If no such ingredients are needed, it might be possible to place quantum mechanics on more deterministic ground – and so make it more understandable.

"I think that, if we can find the origin of the Born rule, maybe we can also find the origin of quantum probability," says Zhang. She spent about two years combing through five of the most influential derivations of the rule in an attempt to zero in on that origin.

These five derivations were motivated by a broad range of ideas about how to interpret the equations of quantum mechanics, drawing on arguments ranging from considerations about symmetry and quantum entanglement to decision theory for inhabitants of the quantum multiverse. Zhang assumed an interpretation-agnostic stance and focused solely on the maths.

But as she dug into the underlying assumptions, she found more probability. "For people who want to derive the probabilistic Born rule from only deterministic principles, my result for now doesn't support that," says Zhang.

> "I wouldn't interpret this result as closing the door to a deeper explanation of quantum probabilities"

For instance, she concluded that some version of a concept known as additivity is indispensable to all derivations of the Born rule in her analysis. Although it can be stated more generally and abstractly, additivity is simplest to understand when thinking about fair dice. Here, additivity means that the probabilities of rolling each number, from 1 to 6, always sum to 100 per cent (*Physical Review A*, doi.org/hcpc6f).

Quantum foundations

"I find Zhang's paper interesting because it addresses a fundamental question: where do quantum probabilities come from?" says Augusto Smerzi at the Shenzhen Technology University in China. He says that, by showing just how important additivity is, she brings clarity to a long-standing problem.

But Smerzi also says that clearly identifying the assumptions underlying the Born rule shouldn't be misunderstood as an explanation for why this rule in its postulated mathematical form describes our world so well. "Making assumptions explicit is essential, but understanding why nature obeys them is what gives a derivation its deeper physical meaning," he says. "I would therefore not interpret Zhang's conclusions as closing the door to a deeper explanation of quantum probabilities. Rather, they highlight the importance of continuing to search for such an explanation."

Zhang says the work is nowhere near over because there are more derivations of the Born rule that she wants to analyse. She also doesn't think that some mathematical surprise is fully out of the picture yet. While her work constricts the possibility, there is still a small chance the Born rule could be put on deterministic foundations, she says. ▮

Solar system

A thick, rusty crust may have made Mars warm and wet

Bas den Hond

MARS once had a climate that kept it warm enough for water to flow on the surface. But scientists haven't been able to agree on an atmospheric recipe with enough warming potential. Now, a new proposal says that hot water circulating underground produced a missing ingredient.

Water reacting with iron in Mars's crust may have delivered a steady supply of hydrogen to the atmosphere for millions of years, says Cin-Ty Lee at Rice University in Texas.

While not a greenhouse gas itself, hydrogen can have a planet-warming effect through its interactions with atmospheric carbon dioxide. Collisions between the H_2 and CO_2 molecules deform both of them, and this makes them absorb wavelengths of infrared radiation that CO_2 by itself doesn't block, so the molecule pairs enhance the greenhouse effect.

Depending on the total amount of CO_2 in the Martian atmosphere, even a few per cent of hydrogen in the atmosphere could be enough to bring the average global temperature above freezing.

The underground hydrogen production plant that Lee proposes is the extremely thick crust, thought to extend as far as 80 kilometres below ground, that underlies Mars's southern highlands. "Like an iceberg floating on water, the higher the mountain, the thicker the root," he says.

"Water reacting with iron in Mars's crust may have delivered a steady supply of hydrogen"

Just as on Earth, the crust will contain radioactive elements, such as uranium, thorium and potassium, which produce heat as they decay. Thicker crust contains a greater total quantity of these elements, while the surface area available for cooling remains the same. In 2024, Lee published calculations showing that, with sufficiently thick crust, ice in its upper few kilometres would melt and create aquifers.

Once those aquifers exist, Lee told the annual conference of the Geological Society of America in Denver, Colorado, last month, the water will start shedding its heat by circulating up and down through the porous upper layers of the crust. These layers mostly consist of basalt, which is rich in iron. The water would make the iron rust, a process that frees up its constituent hydrogen molecules, which would then find their way up into the atmosphere.

The hydrothermal pump eventually died, leaving Mars the cold desert it is today, because it ran out of both water and power. "For the water, this was a one-way ticket," says Lee. "And also the radioactivity diminished."

Ramses Ramirez at the University of Central Florida, says that until he has seen a full paper about the idea, he is sceptical that it can explain Mars's formerly warm surface "without invoking some extremely favourable circumstances".

Ramirez also notes that the possibility of water releasing hydrogen from rocks was proposed more than a decade ago. But, according to Lee, while earlier studies just supposed that water somehow would be involved, his work shows "how it's almost inevitable that this has to happen" with a thick enough crust.

He says his idea is testable by looking deep into the Martian crust. "If we find that it is oxidised down to several kilometres, this is the only way it can happen." ▮

Biology

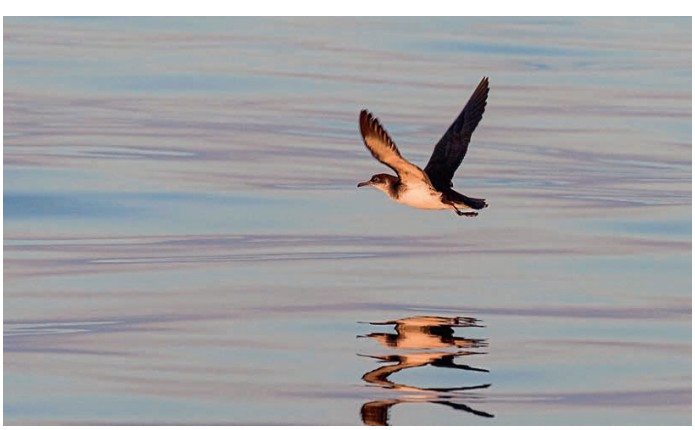
Birds can get jet lag on long, fast migration flights

AT LEAST one species of bird gets jet lag, in the sense that its body clock can diverge from local time by more than an hour on fast flights across the Atlantic, as revealed by navigational errors.

Manx shearwaters are small seabirds that breed on islands around the UK and Ireland. While parents are raising a chick, they may fly more than 1000 kilometres westwards to reach rich fishing grounds in the mid-Atlantic. Once they have food, they fly back in a fairly straight line, diverting only to skirt around landmasses.

Shearwaters rely on a sun compass for their journey – if you know what time it is, you can maintain a course by adjusting your orientation relative to the sun.

Other researchers have been attaching GPS trackers to Manx shearwaters for decades, so the paths taken on nearly 4000 foraging trips are known. When Patrick Lewin at the University of Oxford and his colleagues analysed these flight tracks, they found birds on rapid return flights tended to deviate clockwise when out of sight of land (*Science*, doi.org/hcqqv2).



CAMERA LUCIDA WILDLIFE/ALAMY

You don't need a jet plane to get jet lag – even feathers will do

The team considered other explanations, such as winds, but the sun compass effect best predicted the observed changes in the birds' orientation, says Lewin.

The effect is small. After a 1000 km flight, a bird would have to fly only an extra 5 km to reach its colony, which, for such efficient long-distance fliers, is probably negligible, says Lewin.

While other species may get this form of jet lag, too, long-distance flights by birds are typically done during migrations involving mainly north-south travel, says Ken Cheng at Macquarie University in Sydney, so jet lag won't be much of a problem. ▮

Michael Le Page

Artificial intelligence

Computer science shaken by AI

A central assumption in computer science has apparently been disproven by OpenAI, a result that will force textbooks to be rewritten if confirmed, finds **Chris Stokel-Walker**

OPENAI, the maker of ChatGPT, claims its AI models have disproven the exponential time hypothesis – a fundamental assumption that underpins computer science.

"This came as a complete surprise, a shock," says Fedor Fomin at the University of Bergen in Norway. "Nobody I know expected it."

Proposed nearly 30 years ago, the exponential time hypothesis (ETH) tries to put a limit on how quickly computers can solve certain logical puzzles.

The simplest way would be to try every possible combination of true or false for each part of the puzzle. ETH proposes that, although it may be possible to do this quicker with shortcuts, the amount of work needed has to grow exponentially as the puzzle gets bigger.

But OpenAI says its models have devised an algorithm that can beat the previously assumed speed limit for solving logical puzzles, apparently proving ETH false. "Assuming that it is confirmed, this is an enormous breakthrough," says Leslie Goldberg at the University of Oxford.

Many computer science findings assume ETH is true. If it isn't, the conclusions they establish about computational limits become useless. "It would require a complete revision of several areas of algorithms and complexity," says Fomin, who says a textbook he wrote on the subject would become obsolete if the finding holds.

ETH is linked to a long-standing maths problem known as P versus NP, which concerns whether a problem whose answer is easy to check is also easy to solve. If ETH were true, it would have implied that the answer was no. But disproving ETH wouldn't mean the answer is yes. "This doesn't have a direct impact on P versus NP, so we should not view it as progress towards P versus NP," says Goldberg.



AP PHOTO/JEFF CHIU/ALAMY

OpenAI continues to send shock waves through maths and physics

The result was announced alongside other breakthroughs in maths and physics in a blog post on 26 October.

In mathematics, OpenAI says its AI has proved a 1991 conjecture that waves cannot remain intensely focused for long. If confirmed, this would also answer enduring questions about how thin a shape can be while also containing line segments that point in every direction, as well as how waves spread.

In theoretical physics, OpenAI claims to have proven that quantum field theories – including quantum chromodynamics, which describes the strong force holding quarks together – make sense mathematically, rather than just producing predictions that match experiments. The findings also touch on the existence of pure Yang–Mills theory, part of a million-dollar mathematical problem, but don't resolve the entire challenge. That work hasn't been released publicly while an external group led by Nobel laureate David Gross examines it.

OpenAI says it verified the ETH result using Lean, a piece of software that checks mathematical proofs. Stefan Szeider at the Vienna University of Technology has looked at what OpenAI has released and says he expects it to withstand scrutiny, although he says researchers still need to check that the formally proven statement means what its authors say it means.

> **"This result destroys a lot, but it also opens many new questions that nobody expected"**

To do so, OpenAI has commissioned an independent group, including Russell Impagliazzo and Ramamohan Paturi, both at the University of California, San Diego, who helped propose ETH, to examine the findings. In an open letter, the group says it could "change an important part of theoretical computer science".

Collapsed web

The speed at which AI is solving maths problems and the way AI firms are releasing their findings have concerned some academics. Magnus Wahlström at Royal Holloway, University of London, describes the phenomenon as "mathematics done by press", worrying that proprietary models can suddenly overturn months of researchers' work.

Bart Jansen at the Eindhoven University of Technology in the Netherlands describes OpenAI's work on ETH as "ingenious", "spectacular" and "awe-inspiring – but also humbling". "It really makes you think about the future of mathematics, algorithms and academia," he says.

Clément Canonne at the University of Sydney says proving something and understanding why it is true aren't the same thing. "The web collapsed, and we looked behind," he says of the network of findings relying on ETH. "We have no idea why yet."

OpenAI says it is experimenting with an approach in which independent academics are in charge of organising efforts to verify and explain the results.

But Fomin welcomes the disruption. "This result destroys a lot, but it also opens many new opportunities and new questions that nobody expected," he says.

"One shouldn't complain about having too many interesting mathematical breakthroughs to try to digest," says Wahlström. ▮

Oceanography

Satellites show weakened AMOC

An analysis of how much heat the ocean is releasing to the atmosphere adds to the evidence that the crucial Atlantic current system is slowing, finds **Alec Luhn**

SATELLITE measurements suggest the Atlantic Meridional Overturning Circulation (AMOC) has been transporting less heat towards Europe, providing some of the strongest evidence yet of a slowdown in these ocean currents, which keep Europe's climate mild.

The AMOC system of currents, which includes the Gulf Stream, brings warm, salty water from the Gulf of Mexico to the north Atlantic, where it cools and sinks, returning south along the sea floor.

As it cools, the water releases heat into the atmosphere. But based on the satellite data, Richard Allan at the University of Reading, UK, and his colleagues calculated that the heat flux out of the north Atlantic has decreased 18 per cent in 40 years.

Because the AMOC's flow varies from year to year, the scientists used the first decade of data to estimate an average flow. They compared this to the following decades to find the circulation has declined 14 per cent in 30 years (Research Square, doi.org/rv28).

Greenland's melting ice sheet may be disrupting Atlantic Ocean currents

"We expect the AMOC to deliver heat northwards, and then that heat to come out of the top of the ocean into the atmosphere, and so if one of those things is changing, we expect the other one to change," says Neil Fraser at the Scottish Association for Marine Science, who wasn't involved in the study. "This is some of the strongest evidence so far that the AMOC has weakened over the last 40 years."

"This is some of the strongest evidence yet that the AMOC has weakened over the last 40 years"

Climate models suggest the surge of fresh water from the melting Greenland ice sheet will dilute the salty water of the AMOC and slow its sinking, weakening the circulation. Some research suggests the AMOC could collapse as soon as 2060, plunging Europe into "ice age" winters with stronger storms and widespread drought.

Ocean buoys across the Atlantic have measured changes in water pressure corresponding to about a 10 per cent decline in AMOC strength since 2004, but because its flow can sometimes ebb for decades at a time, this doesn't prove a long-term trend.

Scientists have looked for indirect evidence, like the "cold blob" in the north Atlantic, the only area of the world that has cooled since the 1800s. A 2018 analysis of these declining sea-surface temperatures estimated the AMOC had weakened 15 per cent since the 1950s.

But sea-surface temperatures could also be decreasing due to a shift in jet stream winds or increased shading by clouds. Heat flux from the north Atlantic to the atmosphere can be a better indicator as it is "one step closer to the thing that drives AMOC", says David Thornalley at University College London.

Last year, a study calculated this heat flux from atmospheric reanalyses, which are essentially computer models that are nudged to match the spotty real-world observations on record. But the results didn't show any decline in AMOC strength between 1963 and 2017.

The new study, which is undergoing peer review, is the first to estimate AMOC weakening with heat fluxes calculated in part from satellite measurements, according to Allan. For decades, the ratio between how much solar energy Earth receives and how much heat energy it radiates back into space has been growing more positive. The researchers combined satellite measurements of this energy imbalance with reanalyses and models to figure out how much less heat the north Atlantic has been releasing to the atmosphere.

Early warning

"The resulting inferred net air-sea flux is of demonstrably better quality than other estimates, making this estimate more suitable to infer AMOC changes," says team member Michael Mayer at the University of Vienna.

As satellite measurements can be updated regularly, this method, if it holds up to scrutiny, could someday "provide a new early warning method for detecting changes in this vital current", says Allan. The UK is investing £81 million in research to build an early warning system for AMOC collapse by 2030, although this study isn't part of the initiative.

Stefan Rahmstorf at the University of Potsdam, Germany, argues that heat flux isn't necessarily a better indicator of AMOC changes than sea-surface temperatures, which can be directly measured. But he says the two build on each other to increase concern that the AMOC could be approaching a tipping point.

Another recent study, which examined reanalyses of the ocean rather than the atmosphere, similarly found the AMOC has weakened 15 per cent in 30 years.

"The strongest evidence is the combination of several different lines of evidence, all pointing to a slowing AMOC," says Rahmstorf.



SHUTTERSTOCK/MURATART

Reproductive health

Donor ovaries adjust to the recipient's age

James Woodford

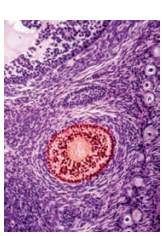
YOUNG mice that received ovaries from animals that were past their natural fertility window gave birth to healthy offspring. This suggests the younger bodies lowered the older ovaries' molecular age.

Transplanting younger ovaries into older mice also boosted the animals' overall health, adding to the evidence that ovaries play a greater role in ageing and physiology than we realised.

"Young ovaries lowered the biological age of the brain, liver and uterus in old recipient mice," says Sharif Iqbal at Harvard Medical School. The discovery follows recent research that found transplanted hearts shift towards the recipient's age. "An organ's biological age is not fixed at the time it is transplanted," says Iqbal. "It responds to the body it lives in."

Iqbal and his colleagues used mice of different ages to build an "ovarian clock", based on levels of gene expression and DNA changes that occur with age.

They then surgically transplanted ovaries between young mice (about 4 months old) and older mice (about 13 months old), which are generally infertile. This gave four combinations: young ovaries in young and older mice, and older ovaries in young and older mice.



SHUTTERSTOCK/KATERYNA KON

Older ovaries are influenced by a young environment, and vice versa

Four to five months later, the researchers found that the older ovaries placed in younger mice became molecularly younger, while the younger ovaries in older mice became older. They also observed that being in an older body increased inflammation in the younger ovaries, while a younger body reduced it in the older ovaries (bioRxiv, doi.org/rv29).

When the mice mated, a few months after the transplant, the younger mice with older ovaries gave birth to healthy offspring, but older ovaries transplanted into different older mice produced no births, says Iqbal.

The researchers also found evidence that the age of ovaries impacts the rest of the body. "In a younger body, aged ovaries showed gene and pathway level changes that resemble those caused by treatments known to extend lifespan in mice, such as calorie restriction and the drug rapamycin," says Iqbal.

> "Young ovaries lowered the biological age of the brain, liver and uterus in old recipient mice"

The researchers hope that understanding which molecular signals made the older ovaries work in the younger mice could lead to treatments that support egg quality and ovarian function in women for longer. Ovary transplants can be carried out due to early menopause or a loss of ovarian reserve after medical treatments like chemotherapy. "If we can identify the signals responsible, it may be possible to mimic a younger environment with treatments [and] without transplantation," says Iqbal.

Francesca Duncan at Northwestern University in Chicago says: "These results provide important support for therapeutic interventions to extend ovarian longevity." ▮

Palaeontology

Marine amphibian is first of a kind



RYOSUKE MOTANI/UC DAVIS

***Gerrothorax maritimus*'s body armour probably helped it thrive in the sea**

A FOSSIL of a large, bottom-dwelling ambush predator from the Late Triassic Period is the first evidence that amphibians were once adapted to life in the ocean.

Named *Gerrothorax maritimus*, the exquisitely preserved 74-centimetre-long fossil was found in what is now a national geopark in Guanling county, China. The researchers who studied the fossil think it could have survived in salt water – which is normally fatal to amphibians because of their permeable skin – thanks to its strong body armour.

"It was a flat animal that lived on the sea floor," says team member Ryosuke Motani at the University of California, Davis. It was probably an ambush feeder, he says, as its wide mouth and the strong hyoid neck bone suggest it used suction feeding, as is seen in some modern bottom-dwelling ambush predators of a similar size.

The researchers knew the fossil was an early amphibian, not a fish or reptile, because of its tell-tale anatomy, which included four legs and gills. To prove the animal was indeed marine, they studied the strontium isotope ratios of the fossil bones. They found that the remains of the new species had a clear signature of seawater, meaning *G. maritimus* grew to adulthood while in the ocean. Palaeogeographic reconstructions also suggest that, 237 million years ago, the location where the fossil was found was at least 30 kilometres from land (*Nature Ecology & Evolution*, doi.org/rv26).

Interestingly, the closest relative to *G. maritimus* lived in freshwater environments. This has led the researchers to suggest the marine lifestyle of *G. maritimus* was an accident of evolution. "There was a freshwater amphibian that happened to have the equipment needed to colonise the sea – the body armour," says Motani.

The armour originally protected the *Gerrothorax* genus from predators in fresh water. But as it formed an impermeable barrier, it could also help the amphibians survive in seawater, he says.

John Long at Flinders University, Australia, says the fossil is a first, given that none of the 8000 or so living species of amphibians today is fully adapted for life in the sea. ▮ JW

Archaeology

Stone determined where early humans made their homes

Christa Lesté-Lasserre

THE world's largest sand sea, the Empty Quarter in the Arabian peninsula, was once dotted with freshwater lakes and lush oases – but prehistoric humans appear to have avoided settling around them. Now, scientists have found out why: the early inhabitants chose to live where there were also useful deposits of rock.

"People who live by stone tools never stray far from good stone," says Jeffrey Rose at the University of Algarve in Portugal, who was involved in the analysis.

The Rub' al-Khali – the Arabic name for the Empty Quarter – is the world's largest continuous expanse of wind-swept dunes. It covers 650,000 square kilometres of the southern Arabian peninsula.

Today, the region is overwhelmingly dry, other than for a few permanent lakes in its interior that are fed by groundwater. But over the past century, scientists have uncovered evidence of numerous ancient lakes that formed during wetter periods, when stronger Indian Ocean monsoons helped transform parts of the peninsula into what scientists call Green Arabia.

Researchers have long suspected that these greener periods opened routes for early humans spreading out of Africa and across the Arabian peninsula, an idea supported by the presence of stone tools near ancient lakes. However, all these sites line the desert's margins, whereas its interior is still largely unexplored by researchers.

In 2023, Rose's colleague Rudolf Dellmour at the University of Vienna and his team crossed the Empty Quarter's dunes, examining 125 locations for traces of ancient lakes. They focused on lakes that were present between about 122,000 and 67,000 years ago, when early humans were spreading into Arabia.



JEFFREY I. ROSE

Stone Age people couldn't live in places without stone

The team found evidence of ancient lakes at 55 of the locations, including freshwater snail and clam shells. But they found no stone tools or other evidence that prehistoric humans had settled by any of the 55 lakes.

"Prehistoric settlements were concentrated in places offering both water and stone"

To test whether the shortage of suitable stone could explain the lack of human settlements, Rose and Dellmour and their colleagues used a computer model to map ancient water sources and the geology of the Arabian peninsula, then compared the results with the distribution of hundreds of archaeological sites found across the region in earlier research.

The analyses revealed that 57 per cent of terrain within reach of water on the peninsula lacked suitable stone for making tools – and that prehistoric human settlements were concentrated in places offering both resources (*Nature*, doi.org/rvz8).

Groundwater-fed lakes in the Empty Quarter wouldn't have brought flint, chert, obsidian or quartz into the sand sea like rivers could have, says Rose. And while people could have carried tools into resource-poor areas, this would probably have supported only small groups for short periods.

The study sheds important light on a long-standing debate among archaeologists about the importance of raw stone in ancient human sites, especially in harsh environments like the desert, says Manuel Will at the University of Tübingen in Germany. "It really shows that early humans were picky with where they went and that they did not settle for just any spot," he says. ▮

Space

There may be a new dwarf planet just beyond Pluto

Leah Crane

THE new Vera C. Rubin Observatory in Chile has spotted an object beyond Pluto that seems to be big enough to qualify as a dwarf planet.

The object, designated ED138, is between 600 and 1500 kilometres across. To qualify as a dwarf planet, rather than just a large asteroid, a space rock must be massive enough for its own gravity to squeeze it into a roughly spherical shape. Measuring the masses or shapes of these objects directly is very difficult, but it is generally accepted that asteroids with a diameter greater than about 600 kilometres should be massive enough.

Right now, five official dwarf planets are recognised, including Pluto. A handful of others are considered unofficial members of the group as well. Given its size, ED138 seems poised to enter that larger unofficial group.

While it is relatively large and bright, ED138 was still difficult to spot because of its location in the sky, close to the plane of the Milky Way. With so many bright objects behind it, previous observatories weren't able to pick it out.

After his colleague Matthew Holman at the Harvard-Smithsonian Center for Astrophysics in Massachusetts first spotted ED138 in October, Mario Jurić at the University in Washington scoured Rubin's past catalogue and found 30 more observations of it since March. Further hunts through the archives of other telescopes found archival observations going back as far as 2017. Holman and Jurić presented their work at the Annual Division for Planetary Sciences meeting in Spokane, Washington, on 27 October.

The observations allowed the team to reconstruct ED138's orbit, finding that it takes about 281 years to circle the sun on a path that is tilted about 25 degrees with respect to the plane of the solar system. ▮

CO_2 restarts ability to regrow tissue

Breathing out after birth switches off the capability of tissues to regenerate, but the pathway seems to be reversible, finds **Jo Marchant**

TAKING our first breaths marks the beginning of a new life, yet this may be the very act that limits our ability to grow and heal as adults. Studies in mice have pinned down newborns' exhalation of carbon dioxide, immediately after birth, as the starting gun that switches off their cells' intrinsic ability to regenerate.

"We were very surprised and excited by the CO_2 effect," says Zhigang He at Harvard Medical School, who led the research.

But when grown mice inhaled the gas, the regenerative pathways turned back on, a discovery He hopes could lead to targeted medical treatments. The results are "very tantalising", says Nahum Sonenberg at McGill University in Montreal. "If correct, this is a groundbreaking discovery."

Many species of fish, amphibians and reptiles can regenerate tissues, limbs and organs such as hearts following injury. Mammals also have some regenerative capacity before and shortly after birth, but lose this later in life. A protein master switch called mTOR is one reason they do so. It plays a central role in regulating cell growth in tissues such as the brain, heart and muscles, and its activity declines inside cells within minutes of birth. But the reasons for the drop were poorly understood, says Soroush Tahmasebi at the University of Illinois Chicago, who wasn't involved in the latest research.

Zhigang He and his colleagues wondered if the shutdown could be related to the dramatic event of birth itself. To find out, they tracked mTOR activity in neurons in the retinas of mice delivered by caesarean section. As long as the newborns remained inside an intact amniotic sac, mTOR stayed high. But as soon as they were removed from the sac and the pups began to breathe air, mTOR activity dropped, even if the researchers kept the umbilical cord intact so that the nutrient supply from the mother was unchanged. This suggested the shutdown trigger was the transition from receiving oxygen through the blood of the umbilical cord to independently breathing air.

"The discovery could lead to simple, non-invasive therapies for conditions such as spinal cord injury"

The researchers also confirmed that temperature wasn't a factor in the shutdown through separate tests in which newborn pups were kept at the same temperature – 37°C (99°F) – as they had experienced in the uterus.

Next, the team delivered pups in controlled gas environments, and found that mTOR activity still shut down even if they lowered oxygen levels in the air. But increasing CO_2 levels to 10 per cent prevented the loss of mTOR activity.

Further experiments showed that exhaling CO_2 triggers the mTOR shutdown by causing a rise in pH inside cells as levels of the gas fall.

When adult mice inhaled air containing 10 per cent CO_2, mTOR activity restarted across a range of tissues including brain, heart and muscle, and their neurons' ability to regenerate after injury was restored (bioRxiv, doi.org/rvz4). The work shows that the drop in CO_2 when breathing starts is "the underlying mechanism driving regenerative failure, not only in neurons but potentially across multiple organs", says Tahmasebi, "and importantly it is reversible".

CO_2 exhalation might not be the only factor governing the ability of cells to regrow, says He. "Other physiological changes associated with birth may also influence regenerative capacity." But he hopes the discovery could lead to the development of simple, non-invasive therapies, perhaps based on inhaling CO_2, for conditions such as spinal cord injury or traumatic brain injury.



MARCOS DEL MAZO/LIGHTROCKET VIA GETTY IMAGES

Mice, like humans, lose the ability to regenerate tissues after birth

Growing potential

Inhibiting mTOR with drugs such as rapamycin has previously been shown to have anti-ageing effects in many species including humans, whereas activating it rescues embryonic-like regenerative potential, at least in mice, but can cause cells to grow out of control, says Tahmasebi. The risk of cancer has deterred industry investment in drugs that activate mTOR, he says, but perhaps the role of CO_2 could lead to ways to activate the cascade more safely, in a "temporary and tissue-specific" way.

Further research is still needed, however, to establish appropriate and safe CO_2 levels and exposure times, as well as potential side effects. "We would not recommend attempting this without medical supervision," says He.

The connection between air breathing and regenerative potential also has intriguing evolutionary implications. Vertebrates that acquire oxygen via gills and lose CO_2 via their skin – some fish species, as well as amphibians during aquatic larval stages – tend to have high capacity for regeneration, whereas mammals and birds, dependent on air and lungs, are generally much more limited. Breathing could therefore be an underappreciated evolutionary factor shaping regenerative abilities across many forms of life, the researchers say.

Neuroscience

Macaques don't see the world like humans do

Jo Marchant

PEOPLE and macaques are similar in many aspects of visual perception, but there are two intriguing differences: the monkeys are less fazed by images being flipped upside down and seem far more focused on fine details.

There have been previous attempts to compare human and monkey vision, but the tests often require extensive training, says S. P. Arun at the Indian Institute of Science in Bengaluru. Different aspects of vision have also been studied using different tests, so it is hard to compare the results.

Now, Arun and his colleagues have used just one test, the oddball search task, which can be adapted to different visual features. Subjects are shown a set of pictures on a screen, identical apart from one, and must identify the odd one out by touching it.

When the oddball appears more similar to the other images, "it takes us longer to find the odd one out", says Arun, providing an objective measure of perception. The researchers taught the test to three bonnet macaques (*Macaca radiata*) and 24 people.

In several tasks, the people and monkeys performed similarly. For instance, they both categorised inanimate objects as more similar to each other than to animate items.

But there were also intriguing differences. The researchers tested a phenomenon in which people find it harder to differentiate mirror images flipped across a vertical axis compared with a horizontal one. An example of this is when young children confuse the letters "b" and "d". This "mirror confusion" is thought to arise because we often see the things around us from different angles around a vertical axis, so we perceive these images as more interchangeable. We more rarely come across them upside down, so images flipped across a horizontal axis seem more different and therefore easier to tell apart.

Bonnet macaques are used to seeing things from many angles



HEMIS/ALAMY

Indeed, the human participants in the oddball test took longer to identify outlier images if they were flipped around a vertical axis compared with a horizontal one. But the monkeys didn't experience mirror confusion, and showed similar performances whether images were flipped vertically or horizontally. Arun suggests this might be because the macaques are more used to seeing familiar objects from a range of angles.

The monkeys were also highly attuned to small features, yet seemed oblivious to larger shapes. The researchers tested this using large shapes made up of smaller shapes. People find it easier to tell when the overall shape changes, compared with the smaller units. But the monkeys only seemed interested in the details, and were no faster on the task when the overall shape changed as well (bioRxiv, doi.org/rvwc). It isn't clear why this is, says Arun.

Rufin Vogels at KU Leuven in Belgium says the differences identified in the study are "striking", although he cautions the results could be affected by differences in attention as well as perception. ▮

Technology

Robotic dog moves thanks to human blood cells

LIVING cells have been used to create a biological computer that can control the movements of a robotic dog. Its creators say using cells to replicate the digital neural networks of AI models like ChatGPT could create more efficient and adaptable computers.

The start-up Cortical Labs has created and commercialised a biological computer called CL1, which can be trained to navigate towards a target in a simulated 2D environment. In later tests, this training data was used to control the movements of a real robotic dog.

A paper published by the firm, which is yet to be peer-reviewed, shows the neural network improved as time passed, even as it was fed the same digital data – suggesting it was being successfully trained to do the task (arXiv, doi.org/rvzn).

"That is promising evidence of learning from limited experience under these experimental conditions," says Ferrante Neri at the Education University of Hong Kong, who wasn't involved in the research. "Establishing an advantage on this task is an early step towards handling the complexity of real-world navigation."

Cortical Labs has already used living cells to perform computations: in 2021, it showed that its technology could play the computer game *Pong*.

But the company's latest experiments show there may also be applications in robotics in the physical world. Cortical Labs says that a biological computer could be less energy-intensive to run than a digital alternative, which would be an advantage in robotics where battery life is a key limitation.

"Establishing an advantage is an early step towards handling the complexity of real-world navigation"

Brett Kagan at Cortical Labs says the cells used in CL1 computers are created from stem cells that are generated from blood donated by people who have given their consent, and there is no evidence that the systems experience any pain or suffering. ▮

Matthew Sparkes

Aerogels may solve insulation woes

Old homes across Europe are guzzling energy from poor insulation. Start-ups are turning to aerogels to help countries meet their net-zero goals, reports **Madeleine Cuff**

ADVANCES in the manufacturing process for aerogels, the lightest solids on Earth, could provide the most promising solution yet for one of the building industry's biggest challenges. Aerogel-infused products – from coatings to stop heat gain from roofs to plasters to insulate the interiors of heritage buildings – would help hard-to-insulate homes get to net zero. These may soon be available, as start-ups in the UK and France move into commercial aerogel production.

The UK has around 8 million homes with solid walls, the vast majority built before the 1920s. Insulating these homes is tricky: many face planning restrictions, which prevent them from adding external cladding, while internal cladding reduces floor space and can cause mould and damp issues.

Lacking an obvious solution, most of these homes remain largely uninsulated and burn large quantities of gas for warmth during winter. Without retrofit work, it can be very expensive to install and run the zero-carbon heating solutions needed for the UK to achieve its net-zero target.

But aerogels are synthetic, ultra-lightweight materials that are exceptionally insulating, as well as being fire resistant and breathable.

"Aerogels are basically porous solids – they are solids with a lot of air inside," says Wim Malfait at the Swiss Federal Laboratories for Materials Science and Technology. Their unique structure means air molecules are effectively trapped between pores, dramatically slowing heat transfer, he says.

On paper, that would make them the perfect material for building insulation. But aerogels have traditionally been expensive and polluting to manufacture, limiting their use largely to industrial plants, aviation and space technology.

Now, start-ups in the UK and France claim they have developed new processes for manufacturing aerogels at lower cost and higher scale, which could unlock their wider use in building retrofit and construction.

Aerogels are generally produced by first creating a nanoparticle gel – usually from silica – which then undergoes a controlled drying process to preserve its pore structure. This stage is usually energy-intensive and can take days to complete.

"Their unique structure effectively traps air between pores, drastically slowing heat transfer"

Thermulon, a UK start-up, says it has redesigned this production process to make use of cheaper materials, lower energy use and standardised equipment. "We developed a way to make aerogels using the cheapest materials and using equipment and methodology that allows you to go to big scale," says Thermulon's Sam Cryer.

The firm has been working with UK plaster-maker Best of Lime to develop a specialist lime plaster containing aerogels, which could be used as an insulation material for historical solid-wall homes. Aerogel plaster could provide the most promising route to net zero for these homes, says Cryer.

The company is also working on aerogels for insulation cladding, and EV battery packs, but Cryer says insulating plaster will probably be the first product to market. It's finalising plans to start producing aerogels at commercial scale with a contract manufacturer in Northern Ireland next year, with the capability of producing 100 tonnes of aerogels per year in 2027.

Meanwhile, French start-up Keey Aerogel has developed a way to make aerogels from silica waste from the construction industry, and using a continuously recycled solvent. The resulting product has a carbon footprint three times smaller than traditional aerogels, says founder Francisco Ruiz, while competing on cost.



RICHARD BAKER/IN PICTURES VIA GETTY IMAGES

Solid walls in old homes in the UK make them tricky to insulate

Warm reception

The firm is working with manufacturers of external renders to create an aerogel-infused mix to improve insulation performance and an aerogel-based "cool roof" coating. This would keep homes cooler in warmer months by reflecting sunlight and blocking heat entry.

Keey is also working on an aerogel formula for wall cavity insulation, to be sold in the UK and Ireland. More effective cavity wall insulation will allow house builders to conform to tightening building standards without having to change the footprint of new homes or make rooms smaller, which would add cost and decrease their desirability, says Ruiz.

The firm raised €18 million in venture capital – including backing from the French government – in 2025 to build its first commercial production plant. The plant, near Mulhouse in eastern France, will start production next year with the capability to produce 1000 to 2000 cubic metres of aerogels per year.

Aerogel insulation products for buildings will be expensive compared with traditional insulation options, even with advances to cut production costs.

Malfait says the technology is promising, but aerogel start-ups will need to focus on how to appeal to homeowners. "It may really be the best solution in many cases, but you have to get the customer over this initial price shock," he says.

Life

Wind turbines are decimating US bat populations

Christa Lesté-Lasserre

WIND turbines have killed nearly 19 million bats in the US over the past four decades, and the problem seems to have worsened in recent years.

Bats play a vital role in ecosystems, particularly by controlling insect populations. But many species face growing threats from habitat loss, disease and human activities.

These human-activity threats include pesticide use and the building of skyscrapers. Researchers have previously also found large numbers of dead bats at wind farms during required monitoring. But not all farms share their results, and monitoring methods vary from site to site, says Bethany Straw at Fort Collins Science Center in Colorado.

Now, Straw and her colleagues have analysed 499 reports from wind farms across the 48 adjoining US states to estimate how many bats were killed by turbines from 1981 to 2024, focusing on 10 species. Their model considered differences in how wind farms searched for dead bats, the size and design of their turbines, and the surrounding environment.

Their results suggest that wind turbines killed an estimated 18.7 million bats between 1981 and 2024. Annual deaths seem to have exceeded 1.5 million from 2021 onwards, which may be the result of more wind turbines being installed.

Hoary bats (*Lasiurus cinereus*) had the greatest losses, with an estimated 6.7 million deaths (*Proceedings of the National Academy of Sciences*, doi.org/rvm3).

Wind farms near rivers and turbines with longer blades were linked to more deaths among certain species, while having more space between the blades and the ground may reduce the risk. The researchers hope their findings will help wind farm developers protect bats by choosing safer locations and adjusting turbine designs.

Earth

Dead Sea helps explain Mediterranean's past dry spell

Bas den Hond



ROSANNE TACKABERRY/ALAMY

The bottom of the Dead Sea has vast salt deposits

AROUND 5.5 million years ago, the Mediterranean Sea almost entirely dried up, leaving behind deposits of salt up to 3 kilometres thick known as salt giants. What drove this event is debated, but a study of the super-salty Dead Sea offers some new clues.

Scientists agree that the so-called Messinian salinity crisis was caused by a diminished flow of water from the Atlantic into the Mediterranean, which meant that evaporated water wasn't replaced. But scientists argue about important aspects, such as whether the flow was completely cut off.

Up to now, those arguments have ignored important physical insights about the behaviour of saline water, says Emmanuel Guillerm at the GFZ Helmholtz Centre for Geosciences in Potsdam, Germany. In particular, he says, existing models of the event don't reflect how salinity hinders the evaporation of water. As a sea gets saltier, it should stop shrinking altogether, unless the air over it is abnormally dry or considerably cooler than the water.

To get to the bottom of this, Guillerm and his colleagues looked at a modern analogue. The Dead Sea was, for a long time, in a stable state. Dense, salty water was overlaid by a layer that was less dense, because a sustained influx of fresh water from the river Jordan kept it at a lower salinity, compensating for water that evaporated from it.

This changed as towns and agriculture used the river more, reducing the flow into the lake. Since 1979, the density difference between the two layers has broken down every winter as the now saltier top layer cools and becomes even denser. That kicked off other major changes: since then, the level of the Dead Sea has gone down 40 metres, it has warmed by 3°C and it has deposited some 3 billion to 4 billion tonnes of salt on the bottom.

40 metres
How much the Dead Sea water level has gone down since 1979

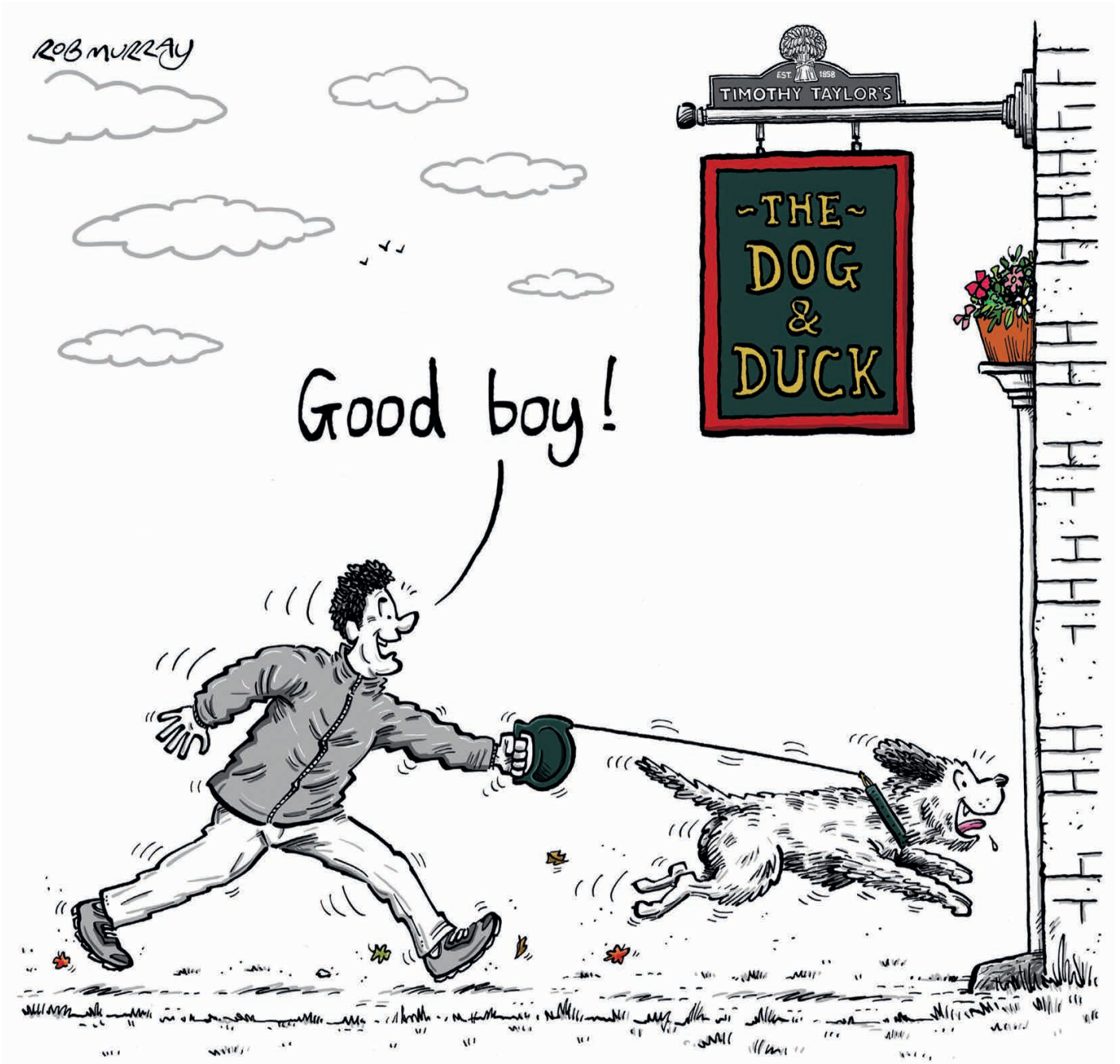
The warming happens because, in summer, the reduced contrast between the two layers makes it easier for heat to flow down to the bottom water. When that water reaches the surface in winter, it is warmer than the air over it. That helps evaporation more than the salinity hinders it, allowing water loss to continue.

Applying the same idea to a water body the size of the Mediterranean, Guillerm's team calculated that cutting it off from the ocean would result in 20°C of warming and kilometre-scale drawdown in just a few thousand years (*Geophysical Research Letters*, doi.org/rvp8).

"It is an interesting idea, and probably very relevant for understanding the water level in the Dead Sea," says Wout Krijgsman at Utrecht University in the Netherlands. For the Mediterranean, however, he thinks existing models of the Messinian salinity crisis are fine, because they already show extreme decline of sea levels in a climate similar to today's.

But, says Guillerm, if those models took account of the detrimental effect of salinity on evaporation, they would struggle to lose so much water. Only when the annual overturning is also included would they show such extensive drying of the Mediterranean.

Guillerm thinks his work could also clear up the question of whether the connection to the Atlantic was completely cut off. Only then would it have behaved like the Dead Sea, losing water and warming up.



Time for that taste of Taylor's




smart meters
ALL TECH EVOLVES, SMART METERS TOO.
Energy suppliers are switching up older smart meter hardware for new kit so you can keep getting accurate bills and access to flexible schemes and tariffs.
When your energy supplier contacts you
SWITCH UP
STAY SMART
ALBERT EINSTEIN rights licensed by H.U.J/CMGWorldwide.com. Eligibility & availability vary. Schemes & tariffs available to selected customers.

On the mind During pregnancy, maternal cells can set up home in the brain of the fetus. **Helen Thomson** explores how these microchimeric cells may influence brain development and health

WE TEND to imagine ourselves as having one brain that is entirely our own, built from our own DNA. Yet tucked away within this landscape are cells from other people – our mothers and, for those who have been pregnant, our children.

During pregnancy, maternal cells cross the placenta, while fetal cells travel in the opposite direction. Some remain long after birth, a phenomenon called microchimerism. I've always found this bidirectional cellular legacy fascinating, particularly now we know that some of these cells settle in the brain. My children, born via donated eggs, didn't inherit my DNA, but microchimerism means that some of my cells may nevertheless live within them, while theirs may live within me.

I've always wondered what influence they might have, and a recent study prompted me to investigate.

In 2008, researchers first detected maternal cells in human fetal brain tissue. Four years later, another team found male DNA in women's brains, probably acquired during pregnancies with male fetuses. Finding traces of another person is one thing. But establishing what those cells become, and whether they do anything useful, is another.

The new research, published last month and not yet peer-reviewed, brings us closer to answering those questions. Sami Kanaan at Fred Hutchinson Cancer Center in Seattle and his colleagues detected maternal DNA in samples of brain tissue taken from children with epilepsy. They then examined RNA from these samples, alongside data from people without epilepsy. This cellular instruction manual revealed that the maternal cells had developed into a diverse cast that included neurons, immune cells, blood vessel cells and supporting cells called astrocytes.

"It was a surprise to see naturally occurring microchimerism detected in the human brain with such highly diverse neuronal, glial, immune and vascular identities, in both healthy and diseased cohorts," says Kanaan.

Cells from your mother can develop into a diverse array of brain cells



WESTEND61/EKATERINA YAKUNINA/GETTY IMAGES

The results suggest that cells from another person can acquire characteristics of the brain itself – although why we may need these maternal cells instead of just our own isn't yet clear. But we have some clues from animals.

In 2022, researchers compared mice carrying reduced numbers of maternal cells with those carrying typical levels, recording their brain activity and behaviour. The results suggested that maternal cells help regulate the brain's resident immune cells, preventing excessive pruning of connections between neurons.

Mice with fewer maternal cells had disrupted communication between the prefrontal cortex and the hippocampus, regions involved in planning and memory. These mice also performed worse on tasks that involved recalling previously learned information.

This points to maternal cells possibly playing a role by helping the fetal brain wire itself during early development. "Whether comparable mechanisms operate in humans remains an open question," says Kanaan.

But he is happy to speculate. Kanaan says there is already evidence in humans that maternal cells can influence the developing immune system, and that it is reasonable to expect that the same might be extended to the brain.

He also says cells travelling in the other direction might have a role in healing: "In a mouse experiment, enhanced recruitment of fetal cells accompanied reduced brain injury and changes consistent with repair."

The idea that fetal cells are key to repair has been suggested in humans, too. In the 2012 study that detected male DNA in the brains of 37 of 59 women, there was a lower prevalence among those with ›



Helen Thomson is the author of books including *Unthinkable: An extraordinary journey through the world's strangest brains* and *This Book Could Fix Your Life*. She was previously head of features at *New Scientist*

Helen's week

What I'm reading
Time of the Child *by Niall Williams*

What I'm watching
I'm looking forward to seeing the You Can See Everything *documentary when it comes out soon*

What I'm working on
A project analysing the world's best female health tech

Alzheimer's. This could imply that fetal cells protect the brain. But the study couldn't establish cause and effect, so we can't rule out the possibility that the condition might have affected the persistence of these cells.

This is a common problem within the field. While microchimeric cells have been associated with Parkinson's disease, multiple sclerosis, stroke and brain tumours, it is challenging to distinguish whether they are contributing to the conditions or have been recruited to repair injuries.

Two-way relationship

Evolution offers some intriguing possibilities for their role too. David Haig at Harvard University argues that mothers and their children have a shared evolutionary interest in each other's wellbeing, suggesting that natural selection may therefore tend to eliminate negative effects on health and favour beneficial effects of this cellular exchange.

However, Haig thinks their evolutionary "interests" don't always align, particularly when it comes to how a mother's resources are shared. He says it may be that offspring cells in mother's brains promote care-giving, "whereas maternal cells in offspring brains may favour cooperation toward the mother and with other siblings".

For now, that remains a hypothesis. Still, all of these potential impacts on our health and behaviour raise a question. Why do some brains harbour more microchimeric cells than others? In Kanaan and his team's study, for instance, despite maternal cells being found in the majority of samples, some had around 2.2 maternal cells per 100,000 cells, while others had up to 458.9 cells per 100,000.

Haig says we don't know why, but he suspects there are genetic factors that contribute to this disparity. Medical history may matter, too. For instance, pre-eclampsia, a condition characterised by high blood pressure in pregnancy, increases the permeability of the blood-brain barrier and may allow more fetal cells to cross into a mother's brain.

Unfortunately, none of this allows us to say definitively that more microchimerism is better, or that we should be seeking ways to promote this cellular exchange to help protect brain health.

It may not be a satisfying conclusion, but it's early days. The mere fact that the central nervous system can sustain, integrate and potentially benefit from genetically foreign cellular material at all goes against so much of how we thought our immune system worked. So, it may be a while before we truly get to grips with whether microchimeric cells contribute to resilience, vulnerability or repair – or all three in different contexts.

Until clearer answers emerge, I choose to take comfort in the possibility that some of my mum's cells may remain within me. And although I can't quite explain why (a genetic connection doesn't define my concept of family), I also find something quietly moving about the possibility that my own cells have taken up residence in my children's brains, potentially shaping their minds in unknown ways – and their cells possibly shaping mine

Acne's new frontier Acne can be painful and debilitating. **Michael Le Page** examines how vaccines could treat or prevent the condition



SCIENCE PHOTO LIBRARY/ALAMY

Acne is linked to the bacterium *Cutibacterium acnes*, which lives in hair follicles

IT'S a cruel twist. Just as we become more concerned about our appearance, our faces start to erupt in great red spots. Pimples cause anguish for many teenagers and can persist into adulthood too. But now two companies are developing vaccines that they hope will revolutionise the treatment of acne. Is an end to the misery at hand?

The main idea behind this new approach is that acne is caused by the immune system overreacting to proteins released by skin bacteria. Triggering the body to produce antibodies against these proteins should block this process and prevent – or at least reduce – acne. Pharma giant Sanofi is preparing for trials in the US and Canada of an mRNA vaccine targeting at least one bacterial protein, while US start-up Armora Biosciences is focusing on a different protein.

"We were very, very optimistic that this could be revolutionary for acne therapy"

Better treatments for acne are certainly needed. "Acne causes a significant emotional burden," says Tomasz Zastawny at Armora. "It can lead to the development of depression, social isolation and other psychological outcomes as well."

It has been known for decades that acne is linked to the presence of a bacterium called *Cutibacterium acnes*, which thrives deep in hair follicles where there is little oxygen. But *C. acnes* is the most common skin bacterium, present on just about everybody – including those that don't have acne – so there's a lot more to it.

One factor is the surge in hormones during puberty, which increases the production of fatty substances in the skin, affecting bacterial growth. But not everyone gets pimply during adolescence, so there seem to be genetic factors involved as well.

"Acne is very complicated. It's not an infection," says Richard Gallo at the University of California, San Diego. "It's an immune problem."

In other words, while the presence of *C. acnes* doesn't usually cause problems, sometimes it may trigger a strong immune response inside a follicle. During this response, some cells in the skin actually turn into fat cells and start releasing alarm signals and antimicrobial substances – a process

known as reactive adipogenesis. "This is a normal way to fight an infection, but in this case, it's an inappropriate response," says Gallo.

What triggers that response? *C. acnes* can secrete a toxin known as Christie-Atkins-Munch-Petersen factor, or CAMP. The bacteria may ramp up production of CAMP in certain circumstances.

So, Gallo's team tried vaccinating mice against CAMP, to make the animals produce antibodies that neutralise the toxin. A number of studies by his team suggest this could help prevent or treat acne.

Sanofi has now developed an mRNA vaccine that targets CAMP, possibly along with some other *C. acnes* proteins – the company hasn't revealed exactly what's in the vaccine and, after much back and forth, declined to talk to me about it.

While there have been reports that the Sanofi trial is already under way, it is labelled as "not yet recruiting" as per the latest update on 18 September. This means it may be some time before we know if it works. That said, while these initial trials are primarily intended to establish safety, it should be clear to volunteers within weeks if it is making a difference to their acne – this isn't like a normal vaccine trial where researchers have to wait months or years for people to be exposed to pathogens.

"We were very, very optimistic that this could be revolutionary for acne therapy," says Gallo. "We'll just have to see if it pans out in the human population."

Meanwhile, Armora is targeting a different protein, called hyaluronidase, based on work by George Liu at the University of California, San Diego. Hyaluronidase is an enzyme that breaks down hyaluronic acid, a large sugar secreted into the spaces between cells.

Can we prevent acne by targeting proteins released by *C. acnes*?



ABHISHEK MITTAL/GETTY IMAGES

These terms might be familiar because hyaluronic acid is often used as a filler for cosmetic purposes, while hyaluronidase is injected to break down filler that is no longer wanted or if things go wrong.

Some bacteria, such as strep B (*Streptococcus agalactiae*), produce hyaluronidase for similar purposes, to help them invade tissues. There are two main types of hyaluronidase, it turns out. Some break down hyaluronic acid into simple sugars. Others break it up into large chunks that act as an alarm signal to the immune system.

When it became clear that there were two types, Liu's team searched genetic databases to see which type is found in which bacteria. They found the "simple sugars" type was the most common. The "large chunks" type was limited to a few free-living bacteria.

"The exception was acne," says Liu. *C. acnes* jumped out to the researchers because it produces both types of hyaluronidase. More precisely, some strains of *C. acnes* produce the simple-sugars type, while others produce the large-chunks one – none produce both, he says.

That made Liu wonder if this was connected to acne. Sure enough, the team showed in mouse studies that large-chunks strains of *C. acnes* cause acne-related inflammation, while the simple-sugars one slightly reduces inflammation. The team then went on to show that a vaccine that stimulates the production of antibodies targeting only the large-chunks form of hyaluronidase could reduce acne in mice, as could inhibiting the enzyme with a small protein.

> "The fact that two competing approaches are being developed is great news for those with acne"

He thinks that in people, a vaccine against the large-chunks form of hyaluronidase would be most effective against the "more severe, red, angry type of acne lesion".

His findings might also help explain why antibiotics, which are commonly prescribed for acne, don't work that well: they kill off the helpful *C. acnes* strains as well as the harmful ones. The other issue with antibiotics, of course, is that resistance can develop.

Another acne treatment called isotretinoin (Roaccutane) is more effective than antibiotics but has a long list of nasty side effects.

Acne vaccines promise to solve all these issues. They shouldn't have any lasting side effects, nor should there be any issue with resistance, because the vaccines are targeting secreted proteins rather than directly targeting bacteria.

The fact that two competing approaches are being developed is great news for those with acne. If one vaccine doesn't work, perhaps the other will. And it could be that both will work, or that targeting both CAMP and hyaluronidase simultaneously will prove even more effective than either alone. Maybe, just maybe, adolescence is about to get a little easier. ▮



Michael Le Page is a reporter at *New Scientist* specialising in genetics, biomedicine and the environment

Michael's week

What I'm reading
Just started Bridge *by Lauren Beukes, a 2023 New Scientist Book Club pick. I'm so behind*

What I'm watching
Celebrity Traitors*, of course, even though they banished Hannah Fry*

What I'm working on
Exploring the environmental impacts of GLP-1 drugs





Breaking up

George Steinmetz
Siena Awards

WHEN George Steinmetz set out to capture the ship breakers of Bangladesh, he knew that he was witnessing the end of an era.

For over half a century, people have, piece by piece, pulled apart vast merchant vessels driven up onto tidal mudflats at Chattogram, Bangladesh. But under pressure from media scrutiny and changes to global standards, in 2025 the national government brought in new environmental regulations governing the beach dismantling of these vessels at the end of their life.

By the time Steinmetz travelled to the area and flew his drone up and down the beaches of the Bay of Bengal, the ship-breaking industry was much diminished, he says. The new rules have made the industry uneconomical, and only a final few ships were still being pulled apart under the old system.

Steinmetz won the Siena Awards' Drone Photographer of the Year award for the image shown here, called *Shipbreaking on the Mudflats*.

From this old liquefied natural gas ship, a team of 60 men will collect a total of about 27,200 tonnes of steel, more than 2100 tonnes of aluminium and around 180-270 tonnes of brass, copper and stainless steel.

"The industry is disappearing," says Steinmetz. "It might be safer for the employees and better for the environment, but now it has become more expensive, the industry has moved elsewhere and the men have lost their jobs."

His overall winning photo, along with the category winners for the prize, will be displayed in the *Above Us Only Sky* exhibition at the natural history museum in Siena, Italy, until 29 November.

James Woodford

Getting out of control

We have become addicted to dictating every event in our lives, argues a thought-provoking book, and this is making us unhappy. **David Robson** takes stock

Book
Radical Surrender
Anna Lembke

Headline (UK)
Dutton (US, out 10 November)

AS A young woman, Anna Lembke believed her fate was in her hands. A brilliant student, she graduated with honours from Yale University and spent a year teaching in Beijing before enrolling at Stanford Medical School in California, where she would specialise in psychiatry.

The whole world seemed to be within her grasp. "Whenever I faced uncertainty, I doubled down on control, which was both externally rewarding and internally validating, in the sense that the harder I worked, the bigger the payoff," she writes of her teens and 20s. "Whether pursuing grades, training for a marathon, or simply adhering to my rigid schedule, in my professional and personal life, I was master of my universe."

Sound familiar? In her thought-provoking new book *Radical Surrender: Letting go in a world addicted to control*, Lembke argues that most of us have become similarly obsessed with control – and that this need to dictate every event in our lives has become a source of unhappiness.

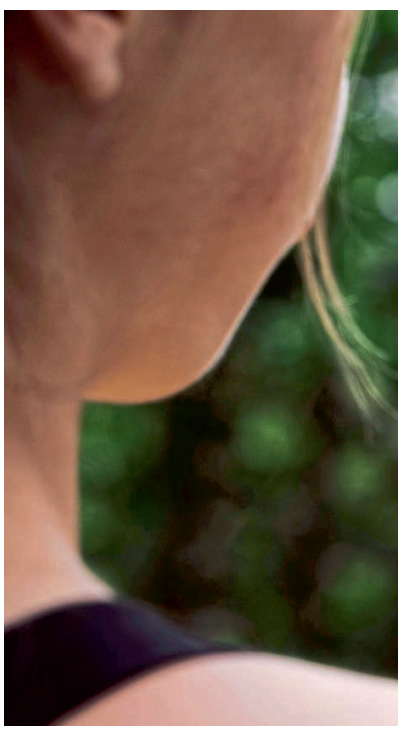
The idea of ceding control is certainly in the zeitgeist: Mel Robbins's *The Let Them Theory* has been one of the biggest non-fiction titles of the past two years. It is sparse on research – whereas Lembke's scientific credentials would seem to promise more evidence.

"Lembke says we are living in a time when pathological preoccupation with the self is ubiquitous"

She offers a multifaceted argument. On the one hand, she draws on the fashionable theory of predictive processing to argue that one of the brain's driving forces is to minimise uncertainty. We build simulations – a "mind map", in Lembke's language – based on our beliefs and past experiences to guide our perception and behaviour. The brain is constantly comparing the mind map with feedback from the real world, and any discrepancies between the two, known as "prediction errors", are perceived as surprise and uncertainty.

To reduce these prediction errors, we could simply update our mind maps. Unfortunately, many of us are ill-equipped to deal with the difficult emotions that this involves, so we instead rely on unhealthy coping strategies. One is denial. The second is "pathological wilfulness", in which we attempt to change our environment so it is more predictable, even when that battle is futile.

Rising narcissism, Lembke argues, has pushed us to overly depend on these defence mechanisms, as we find it ever harder to accept our mental models may be wrong. "We are living in a time when pathological preoccupation with the self and its normalisation and glorification in our culture are ubiquitous," she writes. That has serious consequences when our mental models fail to reflect reality.



"Having placed ourselves at the centre of the universe, we experience a narcissistic injury when life does not go according to plan. A narcissistic injury is a deep and abiding psychological blow to our core sense of self."

Lembke doesn't cite much data for this apparently catastrophic shift, so I looked into the studies myself – and found the changes aren't nearly as clear-cut as she presents them to be. This may not come as much of a surprise to some readers of her previous bestseller, *Dopamine Nation*, which made similarly sweeping statements about the addictive effects of technology.

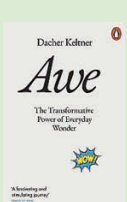
Radical Surrender only extends this argument. Our online lives have not just encouraged self-aggrandisement, but offered an easy escape from the inherent uncertainty of the world. "Even something as mundane as going

Three more great reads on finding meaning in life



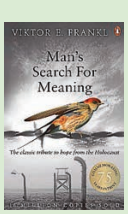
Bittersweet by Susan Cain

Like Anna Lembke in *Radical Surrender*, Susan Cain asks us to seek the numinous. She explores how sublime emotions like wonder, as well as the appreciation of beauty, help us to heal from pain.



Awe by Dacher Keltner

An in-depth examination of the emotion's amazing power to transform our brains, written by one of the leading scientists behind the research, *Awe* offers a strong scientific footing to some of the claims in *Radical Surrender*.



Man's Search for Meaning by Viktor Frankl

A seminal text from neurologist, philosopher and Holocaust survivor Viktor Frankl. He saw what many psychologists are only just recognising – that we all yearn for meaning, and this can be a powerful source of resilience.



SHUTTERSTOCK/MONSHTEIN

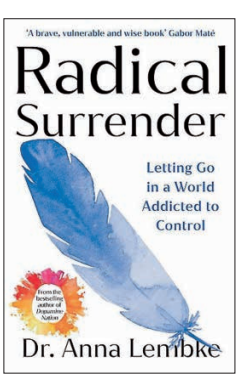
There are forces beyond our control, so why is it so hard to accept that?

out to eat can lead us into this trap," she writes. "We read restaurant reviews and menus on-line about where to sit, what to order, how much to tip, such that when we finally get to the restaurant, it feels like we've already been there."

The problem is that this gives us little practice to deal with those titanic life events that threaten to overturn our mind maps entirely. Lembke's own crisis came with the death of her baby son, Lucas, from leukaemia. In unflinchingly honest passages, she describes subconsciously avoiding contact with her son in the last days of his illness – a form of denial of what was happening, she now sees. Afterwards, she spent hours searching for explanations, unable to accept the cancer was caused by a random mutation, in a desperate attempt at regaining control.

It is in precisely these times, she says, that we need to embrace the philosophy of "radical surrender". It is "the moment when we are forced to loosen our rigid conceptions of the world and start again. Our new, surrendered mind map is informed by openness and humility – openness to new perceptual experiences and ideas, and humility for all that we cannot know, predict, or control".

Here, her argument veers from science to spirituality, as Lembke describes turning to God in her moment of crisis. I found this a little jarring, and Lembke readily admits that her appeal to a deity will alienate some people, but she argues that non-believers can find the same release through many other channels – such as a sense of connection with nature. The point is to look outside rather than within, she says, and recognise the forces beyond our control.



Religion does, after all, bring many psychological benefits: believers are less likely to experience depression or anxiety, for example. And emotions such as awe may play a large part in that resilience. Studies confirm that awe-inspiring experiences can shake us out of our certainties and enhance our intellectual humility. The shrinking of the self and the broadening perspective that this creates can soothe feelings of shame and guilt that may arise from failure to control our fate. The result is healing, whether that comes from belief in a higher being or wonder at the world.

If surrender means opening my mind to mysteries and accepting our tiny place in the universe, then I am happily on board. There may not be as much hard evidence as I would have liked for Lembke's claims that we are facing a "psychospiritual apocalypse", but I nevertheless found *Radical Surrender*'s central hypothesis to be a welcome antidote to the endless pressure for self-reliance. There is power in letting go and embracing the great unknown. ▮

David Robson's latest book is *The Laws of Connection: 13 social strategies that will transform your life*

New Scientist *recommends*



Karmela Padavic-Callaghan
Reporter
New York

In **We Radiant Things: Notes on being alien and becoming cyborg**, the poet, activist and scholar Franny Choi analyses how racialised and gendered



representations of robots in culture and media arose through history, and what their impact has been on both people and their adoption of devices.

The book shows us how to think critically about what shapes our understanding of the tech that dominates our world. Choi focuses on how often robots have been connected to Asian people, and Asian women specifically, across a broad range of media and culture.

This is a scholarly book, but it is also very readable. In the past year, several researchers have told me that determining the future of tech like AI shouldn't rest only on engineers, but also neuroscientists, philosophers and sociologists. *We Radiant Things* makes a strong case that literature professors and poets should be in those rooms too.

Making contact Denis Villeneuve's first (and probably best) foray into science fiction, *Arrival*, was released 10 years ago this month. It has hardly aged and is as staggering as it ever was, says film columnist **Bethan Ackerley**



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



COLLECTION CHRISTOPHEL/ALAMY

Louise (Amy Adams) meets the heptapod aliens in *Arrival*

HERE'S something remarkable: for a decade now, one of the finest directors working anywhere in the world has been exclusively focused on science fiction. That isn't a blessing we're often afforded. More remarkable still is that each of the four films he has released in this period has been a success – and his fifth, the final part of the *Dune* trilogy, out this December, looks likely to be one, too.

Yes, I'm talking about Denis Villeneuve. But instead of looking ahead at *Dune: Part Three*, I want to look back at his first (and probably best) foray into sci-fi, released in the UK 10 years ago this month. The best word I can think of to describe it is "staggering".

Arrival starts with a world-ending event: the death of a child. In a 2-minute opening montage, the brief life of 12-year-old Hannah elapses with cruel linearity. What little we see of her in the film we mostly sense through her mother, Louise (Amy Adams), and the way that Hannah's presence and absence come to shape a defining moment of human history.

Louise is a linguist who is called upon in unlikely circumstances: a mysterious craft, hundreds of metres tall, has landed in Montana – one of 12 such "shells" around the world. The US Army is trying desperately to assess what the life forms inside it want and whether they pose a threat. Partnered with physicist Ian (Jeremy Renner), who would rather approach the aliens through the purity of maths, Louise is given the near-impossible task of translating for these strange, striking, seven-limbed "heptapods".

> **"It is fascinating to watch Louise slowly work out the heptapods' means of communication"**

Arrival's script is beautifully spare. Appropriately enough for a film about language, it conveys a great deal with every exchange between the people who have converged on Montana. When Louise and Ian arrive at the military camp, a scientist reveals that the heptapods usher the humans out of their craft after around 2 hours, apparently to prevent them suffocating. CIA agent David Halpern (Michael Stuhlbarg) questions why it takes 18 hours to establish contact again.

In a lesser film, this would be a load-bearing piece of plot, explicated simply to justify a later happenstance. Here, it is rich with theme. When Ian explains that differences between the heptapods' atmosphere and our own could affect how long it takes to pump in fresh air, agent Halpern's response is: "So you're saying they could suffocate us if they wanted?"

The aliens' intent, it seems, is in the eye of the beholder, and Louise is one of vanishingly few people with the skills to unravel what is actually going on. To do so, she has to talk relativity – linguistic relativity, that is, the idea that the structure and style of the language we use influences our perception. It is fascinating to watch her slowly work out the heptapods' means of communication, and how, in turn, to present this knowledge to her human compatriots without triggering all-out war.

On top of all this delicious intellectualism, *Arrival* is a stunningly shot film. Villeneuve and cinematographer Bradford Young work wonders with the hermetic interior of the heptapods' inky black shell.

Aside from a few bits of dodgy CGI, nothing about *Arrival* has aged. It is as heartbreaking and life-affirming as ever. And if reports that Villeneuve is set to direct an adaptation of Arthur C. Clarke's *Rendezvous with Rama* are correct, then we can be grateful he hasn't yet left the realm of sci-fi behind.

Film
Arrival
Denis Villeneuve

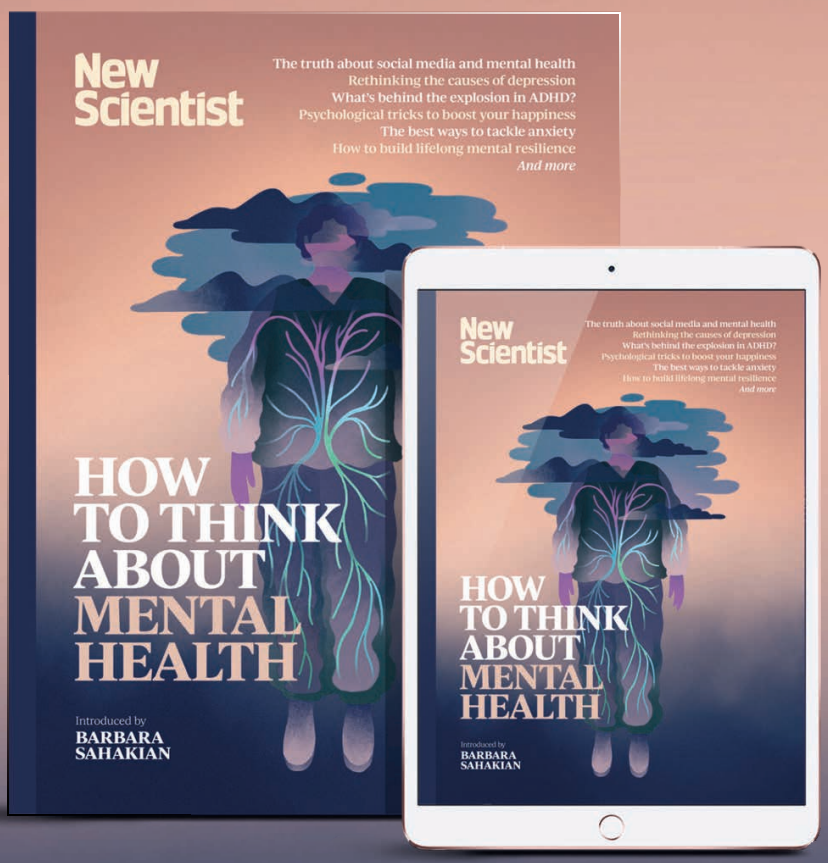
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Book
Extraterrestrial Languages
Daniel Oberhaus
How should we talk to aliens? If the questions posed in Arrival *make you want to find out more, try this primer, which draws on ideas from maths, linguistics and philosophy*

Film
Dune; Dune: Part Two
Denis Villeneuve
Getting it right once takes talent. Getting it right twice takes brilliance. While we wait to see if Villeneuve will pull off a hat trick with Dune: Part Three*, why not revisit the previous films?*


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Editor's pick

Not the first hint of fatty arteries in young people

17 October, p 14

From Stephen Scarfe, North Ferriby, East Riding of Yorkshire, UK

Christa Lesté-Lasserre's article on the relatively high proportion of young people with fatty arteries highlights a crucial shift in medical awareness regarding early-onset cardiovascular disease. While modern CT angiography provides invaluable data on asymptomatic plaque in today's younger adults, the fundamental revelation that atherosclerosis is "not a disease of old age" actually stretches back several decades.

Medical history tells us that this was starkly demonstrated during the mid-20th century through military autopsies. Landmark post-mortem studies conducted on young US service members killed during the Korean and Vietnam conflicts shockingly revealed that a substantial proportion – around 45 per cent of combat casualties in Vietnam – already exhibited clear signs of coronary artery disease, despite being in their early twenties.

While diagnostic tools have fortunately advanced from the autopsy table to non-invasive 3D imaging, these historical findings remind us that the silent progression of heart disease has long been an early-life reality. Modern research serves as a vital reminder that preventive cardiovascular screening should start far earlier than standard practice dictates.

Another sci-fi universe with no need for money

Letters, 10 October

From John Davies, Lancaster, UK

Bryn Glover is reassured that in *Star Trek*, there is no money or want, and attributes this to a Marxist philosophy of "From each according to their ability, to each according to their needs". He forgets that, on a Federation vessel, there is no money and all needs are served, or ought to be.

But should we be equally reassured by The Culture, the society dreamed up by Iain M. Banks? There, autonomous AIs known as Minds have taken over all administration, industry and production, freeing the human race to follow whatever hobbies, pastimes and philosophies they wish, also without money or want.

On whether AIs show signs of consciousness

17 October, p 32

From Michael Syms, Rattery, Devon, UK

I read your article on the debate over whether the AI chatbot Claude displays signs of a form of consciousness with interest, but was struck by what was missing. One would think that the earliest forms of life needed to be conscious of their environment because it would be crucial for their survival, and because it would provide the required sustenance.

An electronic device, however sophisticated, that has all the energy it needs and is in no danger has no need to be conscious! Need has driven evolution from the very beginning because there has always been a need to evolve.

From Andrew Smyth, Los Angeles, California, US

Your report left me thinking about one small word. Anthropic's researchers told Claude not to think about the Golden Gate Bridge. The bridge kept appearing in its "J-space" anyway, along with the word "damn".

Most of the J-space appears to be about access: information being selected, held and used for reasoning. I see no reason why a machine can't do that. Human introspection is largely a matter of retrieving memories and impressions, then weighing them against the present.

"Damn" points at something else, which, in us, we would call feeling. When we fail or are injured, we don't just register it. It hurts. I can understand my own pain as electrochemical signalling, yet I cannot decide to find it neutral. Its unpleasantness seems built in, and no theory explains why. We could build a machine that treats damage as an urgent threat and lets that threat take over its attention and drive it to avoid the cause. It would behave exactly as if it were in pain. But would it hurt?

Until we can explain why pain hurts in us, we cannot say whether a machine's "damn" is felt or merely said.

There are still more secrets of the microbiome to learn

10 October, p 6

From Patrick Hockey, Clunes, Victoria, Australia

Your piece on avoiding sugary foods while taking antibiotics highlights the centrality of the microbiome to overall health. But we remain unable to understand its complex dynamics, in which many genera and species interact and achieve a symbiotic balance that somehow leads to overall harmony and benefits for the host.

Often, aspects of reports on the microbiome have something of the metaphysical about them, as though a type of magic is in play and our intestines are a teeming jungle of wild beasts. Ultimately, though, the benefits must surely lie in some anti-inflammatory action derived either from a stabilising influence on pH or hormonal responses to the collective output of this biomass. I suspect the answer is simpler than we have ever imagined.

Vowels are easier for humans to hear too

3 October, p 12

From Georgina Seaman, Newbury, Berkshire, UK

With respect to James Woodford's article on the finding that dogs pay more attention to consonants than vowels when we speak, the same is true in people. I have been deaf for 50 years and have observed in myself and others who are deaf, or going deaf, that when a word or phrase is misheard, the pattern of the vowels is correct, but the consonants are misheard or not heard at all.

Not hearing the boundaries provided by consonants removes clarity and turns speech into a meowing or burbling jumble. If only hearing aids could be designed to focus on amplifying the specific frequencies of consonants instead of across the whole range of hearing loss, perhaps life would be a little less muffled for us. In this era of AI, predictive texting and subtitles, surely something could be done?

Geoengineering is going to be necessary to fix climate

Leader, 24 October

From Mark Pickin, Easingwold, North Yorkshire, UK

Your leader asks if we can fix our climate after overshooting the 1.5°C warming target. Reducing carbon emissions must be part of the cure, but we also need to think seriously about geophysical engineering. It is indisputable that volcanic eruptions can reduce global temperatures. We need to research ways of emulating this in a safe and economical fashion. My suggestion would be titanium dioxide launched into low Earth orbit, although we would need to prove that it doesn't have its own greenhouse effect. ▮

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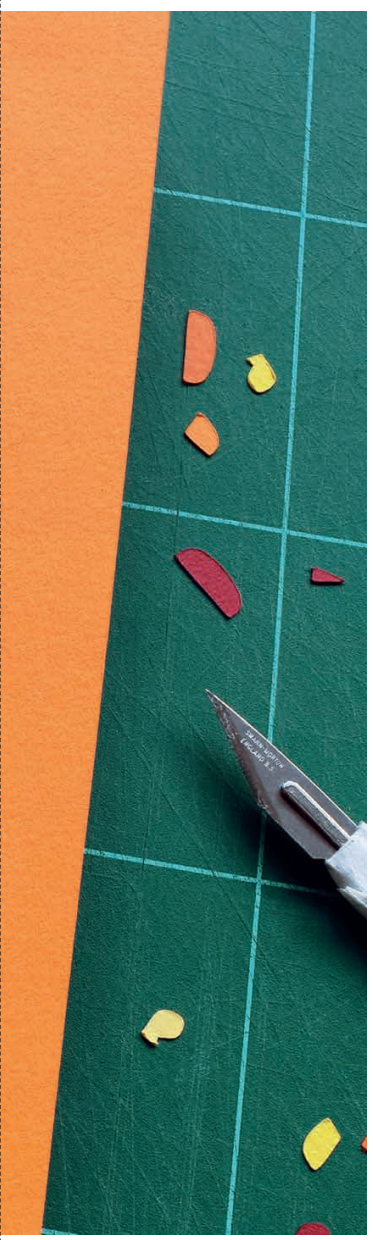
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OWEN GILDERSLEEVE

We are finally pinning down what makes dyslexic brains different, opening up new ways to support those who struggle with reading, finds **Kate Douglas**



I USED to be stupid. It was a long time ago and I was very young – too young to question teachers who said I was a bit dim. Besides, wasn't there proof? I had been slow to learn to read, my spelling was atrocious and my aptitude for climbing trees wasn't fooling anyone. So, I believed them. Then, aged 7, everything changed. For the first time, I had a teacher who saw beyond my literary ineptitude. She told me I was smart – and, suddenly, I was. Thank you, Mrs Kennedy!

That was more than 50 years ago. Back then, dyslexia already had a long history, but news of it hadn't reached the classroom – at least none I found myself in. Children like me usually weren't given a diagnosis or special help. Far from it. At the convent school I attended next, spelling tests were a ritual humiliation, where the nuns lined us up against a wall in the order of our results and shamed those who failed to perform.

Things have changed since then. Teachers are fully aware of dyslexia. Children with this, the most common of learning disabilities, are no longer labelled "stupid" or "lazy". Huge volumes of research have been published. Yet, fierce disagreements have also raged about what causes dyslexia and how best to diagnose and treat it.

Now, finally, we are pinning down what makes dyslexic brains different. We may even have found the key neural pathway that drives the condition. Better yet, this research is pointing to novel, practical and fairer ways to help all children who struggle to read.

Humans invented writing around 5000 years ago – far too recently to have evolved an adaptation for deciphering the written word. Besides, for most of our history, the vast majority of humanity has been illiterate. So, when we learn to read, our brains must co-opt areas specialised for other functions. That this isn't straightforward for everyone has long been recognised. The word dyslexia (from the Greek for "disordered words") was coined in 1883 to describe a curious condition in which experiencing a stroke had left a person unable to read or spell. But, within a few years, it was being used for a far larger group – children who find it hard to acquire these skills.

Developmental dyslexia is often described as a significant and persistent difficulty with reading and spelling. Traditionally, the definition has also included the idea that these difficulties are unexpected given the child's other cognitive abilities – although the recently updated definition issued by the International Dyslexia Association has finally dropped this controversial "discrepancy" idea. We know that both genes and environment play a role, that dyslexia is a spectrum and that it can manifest in different ways, such as spelling difficulties (a particular problem in alphabetic language systems), slow reading and writing speeds, or both.

All this makes its prevalence hard to quantify. Most estimates put it at around 10 per cent of people globally; some say twice that. What's more certain is that dyslexia is a universal human condition found in all languages and writing systems.

The reading circuit

Reading is cognitively complicated. It entails three key components: understanding how sounds relate to squiggles on a page (phonology); mastering the patterns of written words and the rules of spelling (orthography); and making sense of what you see (semantics). To do this, your brain recruits networks evolved to process vision and speech and links them into a new "reading circuit". This is located primarily in the brain's left hemisphere and also comprises three main components. The occipitotemporal region, located low in the back of the brain, instantly recognises those squiggles as words, hence its common name: the "visual word form area". Word shapes are matched to sounds in the temporoparietal junction, above and behind your left ear. And further forward, the inferior frontal gyrus (Broca's area) handles speech production and meaning.

The underlying circuitry is the same, regardless of the language or script – even for writing systems that don't look anything alike, such as those for English and Chinese.

Clearly, there is a lot that can go wrong, not just in the reading circuit, but in other aspects of reading such as attention, memory, processing speed, logical thinking and knowledge of vocabulary. So perhaps it shouldn't surprise us that, over the years, researchers have come up with a wide range of ideas to explain the condition.

One of the most prominent is the phonological deficit theory, which asserts that the problem lies in poor awareness of speech sounds and difficulty relating these to written symbols. "This is now considered to be a primary deficit," says Maggie Snowling, ›

a psychologist at the University of Oxford who has long been a proponent of the idea. Phonological deficit and a second problem known as rapid automatised naming (RAN) – slowness in identifying letters, numbers and even pictures – constitute the "double-deficit hypothesis".

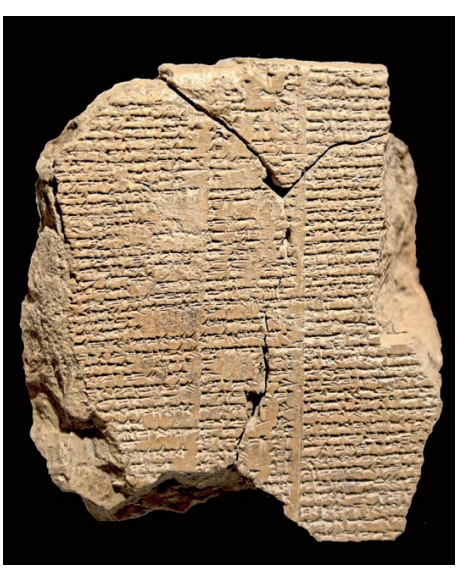
Then there are explanations that focus on the brain itself. Temporal processing theory, for instance, points to an underlying problem of timing in the way the auditory system processes sounds, which has profound knock-on effects for reading and writing. The magnocellular hypothesis, in contrast, places an emphasis on visual attention. It stems from findings that magnocellular neurons, which process fast-moving visual information, are less active and less numerous in people with dyslexia.

In short, decades of research have generated plenty of ideas, but not much consensus. A major roadblock has been that studies were small and not easily compared. This is now being addressed thanks to the availability of large-scale longitudinal datasets and improved methods. That may not sound dramatic, but it has been a game changer.

Take genetics. Clearly, dyslexia runs in families: I have my father to thank for mine. "The heritability you see in twin studies is about 70 per cent," says Michelle Luciano, who studies behavioural genetics at the University of Edinburgh in the UK. That's massive – but comes with a big caveat. "It's not just the genes; it's the gene-environment correlation that's really important," says Snowling. The idea is that factors such as low birth weight and whether literacy is encouraged at home play a key part in shaping the chances of developing dyslexia in those with a genetic susceptibility.

There is also no single dyslexia gene – many tiny genetic changes interact to generate the condition in all its guises. Tracking them down is fiendishly difficult. Traditional methods of genetic analysis identified several "candidate" genes that people with dyslexia appear to share. Now, geneticists can scan full genomes looking for variants linked with complex traits – and do this at scale. The first such genome-wide association study (GWAS) on dyslexia was published in 2022.

Cuneiform is over 5000 years old, but in evolutionary terms writing is a recent invention



ALBUM/ALAMY

Novel genes

Using information from the 23andMe genetic database, a team led by Luciano analysed the genomes of 51,800 people with a dyslexia diagnosis and over 1 million controls. This revealed something surprising about those previously identified candidate genes. "A lot of these actually haven't turned out to be that important," says Luciano. The analysis did, however, identify 42 genetic variants linked with a risk of dyslexia. "Many of these genes had already been reported as being associated with either general cognitive ability or educational attainment," she says. "But we also found several novel ones that may be more specific to language and reading."

The study highlights the genetic complexity of dyslexia. It also confirms observed links with some neurodevelopmental conditions such as ADHD – but not others. "For autism, for instance, we found no genetic overlap," says Luciano. She and her colleagues have since worked on an even larger dataset of more than 1.2 million people, identifying a further 13 genes related to dyslexia that implicate early brain developmental processes in the biological underpinning of reading. "Genetic studies give us a possibility to bridge the gap between cognitive theories and neuroscience," she says.

In fact, these genetic findings have already provided a springboard for a giant leap in revealing the neuroanatomy of dyslexia. A team led by Clyde Francks at the Max Planck



GUERILLA/GETTY IMAGES

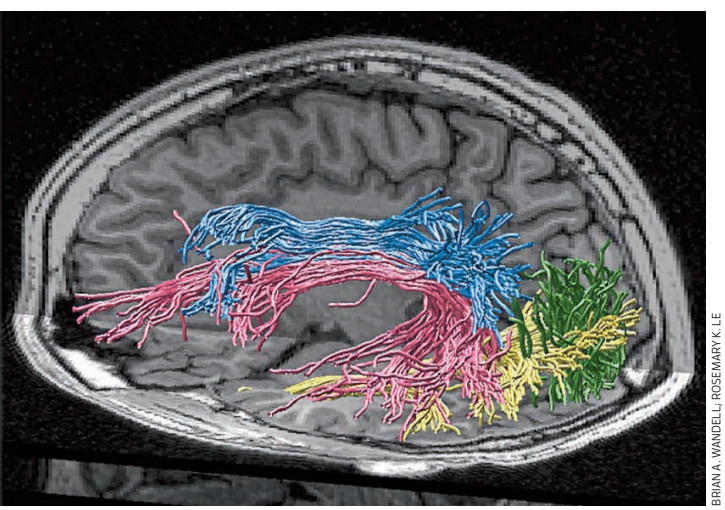
Institute for Psycholinguistics in Nijmegen, the Netherlands, used them to calculate the genetic predisposition to dyslexia of 35,231 people in the UK Biobank database. They then identified brain regions that differed in people whose genes put them at risk of dyslexia. (I must now declare an interest: I have been in the UK Biobank project from the start, done all the tests and had my genome sequenced and my brain scanned, so one of those 35,231 people is me.)

Francks and his colleagues found that the genetic risk of dyslexia was associated with widespread reduction in brain volume compared with people not at genetic risk, especially in language-related and motor areas. (Yikes!) Again, there were correlations with ADHD and other neurodevelopmental conditions – although reductions in the motor cortex were specifically linked with dyslexia. That might seem strange, but motor control could affect reading in a variety of ways, says Francks. "For example, infants with better motor skills might be able to learn language-related skills more quickly through better coordination when producing speech sounds, pointing to track letters and words or keeping time during chants and songs."

Meanwhile, earlier this year, another impressive large-scale study finally nailed a long-standing debate in the field over the contribution of visual difficulties, not just phonological ones, to reading problems. "We and others have long held the view that dyslexia is quite heterogenous, and phonological problems are only one part of the story," says Jason Yeatman, who specialises in the neurobiology of reading at Stanford University.

He and his colleagues carried out tests on 400 children in kindergarten and first grade (typically aged 5-7) at California schools,





BRIAN A. WANDELL; ROSEMARY K. LEE

A widespread network of brain pathways (below left) is active during reading

measuring how quickly they processed visual information such as identifying the direction of dots moving on a computer screen. This revealed that around 15 per cent of the children had problems with visual-spatial attention, and these were associated with reading difficulties a year later. "These kids aren't picked up by any of the conventional screening processes," says Yeatman. What's more, the research identified a hidden subgroup whose weak visual processing was masked by strong phonological skills.

But for many people with dyslexia, the primary problem is with phonology and, over the years, researchers have pinpointed a key neurological mechanism underlying these difficulties. It boils down to the way the brain processes the rhythm patterns of speech, in particular the rates of change in loudness that mark the beginning of syllables – a cue that the brain uses to make sense of the stream of information it receives by chunking it into meaningful units. This is the basis of the temporal sampling theory devised by Usha Goswami at the University of Cambridge, which combines phonology with what is happening in the brain.

"Genetic studies give us a possibility to bridge the gap between cognitive theories and neuroscience"

Neurons in the brain fire automatically in response to these sounds, which can be measured using EEG to visualise the brainwaves in the auditory cortex – even in infants who are just learning to speak. "You can think of word representations in the brain almost like auditory objects, like 3D mountains," says Goswami. However, she and her colleagues have found that children with dyslexia have a subtle mismatch between speech sounds and these mental representations due to problems discerning rhythm and pitch, especially at low frequencies (see "Out of time", page 34).

This doesn't cause obvious issues with speech, but can have a profound impact on reading and writing, because these skills utilise speech-processing pathways to decode written words. "This really only hits when a child is learning to read," says Goswami. "The whole shape of the mountain range will be a bit different, but they're trying to learn to read and spell in a system made for children with another type of mountain range."

For instance, a 2024 study by Goswami and her colleagues of more than 100 English-speaking children in Australia and the UK used EEG to measure their brain responses to speech, and found that issues with temporal sampling were strongly associated with dyslexia. What's more, this technique could be used as the basis of a "classifier" tool to identify children with the condition. "If we randomly select one child with dyslexia and one without dyslexia, the classifier has a 77 per cent chance of correctly identifying which child is more likely to have dyslexia, based on their brain responses to speech," says auditory neuroscientist Mahmoud Keshavarzi at the University of Cambridge.

Indeed, Goswami thinks that difficulties with temporal sampling are the primary cause of dyslexia, and that the other problems associated with the condition arise during a child's development. However, other researchers think that the condition is too heterogeneous to be driven by a single underlying factor. "The more recently accepted understanding is that dyslexia is a consequence of multiple biological and ›

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environmental risk factors," says Julian Elliott at Durham University, UK, who researches dyslexia in children.

Still, there is clear evidence that boosting the ability of young children to process rhythms can improve their language skills – as shown in a study by Goswami and her colleagues involving 120 children under the age of 11, which added activities such as drumming, chanting and marching to a beat into their classrooms. "These all help stamp in the rhythmic patterns which are so fundamental," she says.

The team is also developing technologies specifically to help those with dyslexia. "We've found a neural characteristic called the theta-delta ratio, which is too high in children with dyslexia when they're listening to natural speech," says Goswami. One intervention allows children to visualise what is happening in their brain while listening to a story, via the movement of a little spaceship on a screen. "When they're keeping the spaceship up, it means they've reduced their theta-delta ratio," she says. This feedback leads to improvements in phonology and reading.

She isn't alone in believing we can do more to help children who struggle with reading and spelling. Decades of tinkering make it clear that the key is a focus on phonics – specifically, training on phonemes, letters and single-sound associations, says Snowling. "But it's also not everything," says Yeatman. In addition, young readers require help tailored to their particular needs. For those with visual-processing problems, there is no reliable evidence that coloured lenses or special fonts work. But Yeatman's team has found that this subset of children read faster when the spacing between letters is increased. He also thinks there is potential to train the visual system to work better through specially designed computer games. "This area is ripe for investigation," he says.

Perhaps the biggest thing we can do is identify dyslexia early, as evidence shows that intensive interventions have significant effects on struggling readers, with the greatest influence if these are implemented in a child's early school years. "I think it's incredibly important," says Snowling.

Another much-debated area is the best way to test for dyslexia. Assessments typically entail detailed tests, including whether there was a discrepancy between general level of cognitive ability and reading and writing attainment. However, the updated guidelines issued by the International Dyslexia Association have dropped this criterion, not least because it is biased against children from lower socioeconomic groups and those learning to read in a second language.

Elliott thinks there is further to go. For years he has been arguing that the term "dyslexia" be replaced by "reading disability", so that all children who need help get it. "There are no clear criteria that would enable an assessor to make a determination between a poor reader who gets a dyslexia diagnosis and one who doesn't," he says. "Neither is there any intervention suitable for a diagnosed reader that is not equally valuable for any other struggling reader." His view is controversial, but perhaps that's not surprising. "It threatens vested interests – a dyslexia industry that is worth billions of dollars," he says.

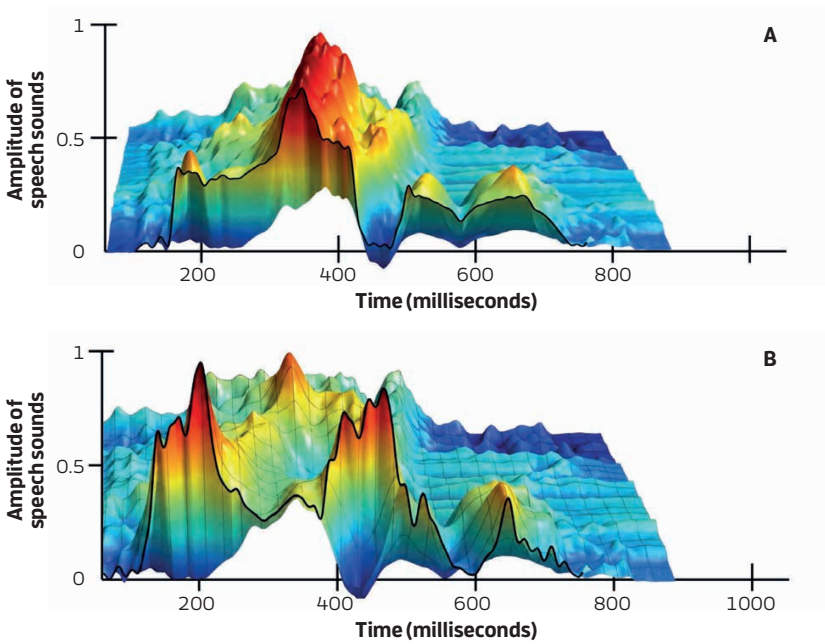
There are undoubtedly still problems, but progress is being made. "I'm an optimist," says Yeatman. Me, too. After all, my (admittedly mild) dyslexia hasn't held me back as a journalist. Today, I have my spellchecker, and eagle-eyed subeditors to pick me up on more subtle slips like "wonton destruction", which I once used in a quote from an ecologist (and, yes, he was Chinese). But I do think there is still a stigma associated with dyslexia. Otherwise, why would 85 per cent of people diagnosed with the condition not reveal this to their employer?

Times have changed, and so should attitudes. So, I'm admitting it here for the first time in my career: My name is Kate Douglas, and I am dyslexic. ▮

Kate Douglas is a former features editor at *New Scientist*

OUT OF TIME

Mistimed processing of certain speech sounds is a hallmark of dyslexia. A: Sound profile of the word 'Aladdin' spoken by an adult (the syllable pronounced with the greatest emphasis is shown in red). B: Response spoken by a child with dyslexia, showing that the pronunciation of the syllables is out of kilter, which has knock-on implications for reading and writing.



SOURCE: CENTRE FOR NEUROSCIENCE IN EDUCATION, UNIVERSITY OF CAMBRIDGE

"Boosting young children's ability to process rhythms can improve their language skills"

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JONATHAN NACKSTRAND/AFP VIA GETTY IMAGES

Burying danger

What should we do with all our nuclear waste? **George Bass** and **Jacklin Kwan** look into some extreme storage solutions



Nuclear waste will be stored indefinitely at the Onkalo repository in Finland

THERE is a timeless quality to the tunnels at Onkalo. And that's the point. Carved into the rock more than 400 metres below ground, these passageways are part of a facility built for the long term. The extreme long term.

In fact, facilities such as Onkalo "should exist intact for at least 100,000, if not a million years", says Allison Macfarlane at the University of British Columbia in Canada, who previously served as chair of the Nuclear Regulatory Commission in the US. "Those are geologic timescales."

Onkalo is Finland's answer to one of the more tricky questions posed by nuclear power: what do you do with the waste? We are going to have to get much better at answering it, given nuclear power is expanding again, driven partly by the hunt for low-carbon energy.

There's broad consensus that burying the waste is the best option. But there is a catch. Radioactive elements can remain dangerous on timescales that make normal engineering look absurdly short-term. Egypt's Great Pyramid of Giza is around 4500 years old. Some nuclear repositories will have to contain their contents for more than 20 times longer. Before the waste becomes harmless, civilisations may rise and fall, and ice sheets may come and go.

An earlier attempt to store waste on geological timescales failed spectacularly after just a few decades. The engineers at Onkalo, and at a handful of similar sites now being planned or built around the world, think they can do much better. So, as Onkalo prepares to accept its first waste shipments in the coming months, how exactly have the engineers future-proofed their facility?

The awkward thing about nuclear waste is that some of the most dangerous substances refuse to go away. Much of the material produced by the nuclear industry contains relatively low levels of radioactivity and can be handled with little drama.

But spent fuel and the materials used to build and shield the main nuclear reactor are another matter. Some of the radioactive elements they contain hang around for astonishing lengths of time. Iodine-129, for instance, has a half-life of almost 16 million years.

So, what do you do with it? Over the decades, researchers have entertained some spectacular ideas. One of the most eye-catching: blasting it into space.

"I have a one-word response to that, which is 'Challenger'," says Macfarlane. "We often send rockets up into space, and they blow up on the way. And if it's carrying nuclear waste, that means that you get to breathe it and then greatly increase your risk of cancer."

Given that possibility, in the end, the favoured solution is the same one we have been employing for decades: dig a very deep hole, put the waste inside and cover it up. But even that's easier said than done.

In 1967, authorities in what was then West Germany began storing radioactive waste in Asse II, a former salt mine. Over the following decades, more than 125,000 drums, mostly containing low- and intermediate-level waste, were stacked in chambers hundreds of metres underground. In the minds of the engineers, rock salt seemed like an ideal host. It is exceptionally impermeable to water and slowly deforms under pressure, meaning that if any cracks began to open up through which groundwater could flow, the rock could self-seal to keep the mine and its contents secure. But reality is rarely so simple.

By 1988, the operators had discovered that salty water was, in fact, flowing into the mine. The problem, as outlined in a 2011 report by the International Panel on Fissile Materials, was that the miners had excavated too close to the edge of the salt deposits and not backfilled enough of the caverns after they had finished with them. This weakened the underground structure and raised the risk of collapses, fracturing the salt faster than it could self-seal, and allowing water to seep in. The report suggested that the possibility of such collapses was flagged in 1979, but the warning was ignored.

"BEFORE THE NUCLEAR WASTE BECOMES HARMLESS, CIVILISATIONS MAY RISE AND FALL"

The public became aware of the problem only in 2008. German authorities now have the unenviable task of retrieving the buried material: some 47,000 cubic metres of radioactive waste.

Asse II is about as stark a lesson in the difficulties of deep-time engineering as you could ask for. Getting radioactive waste underground is easy, but the devil is in securing it for time periods far beyond any normal engineering horizon. A barrier ›

that looks reassuringly solid for a century may corrode, crack or shift over 1000 years. Stretch that timeline to 10,000 or 100,000 years, and engineering confidence drops.

One approach to this lack of confidence is to assume that extreme long-term storage might not, in fact, be required. Radioactive waste isn't necessarily useless. Spent nuclear fuel still contains potentially valuable material. For instance, approximately 97 per cent of the material in used fuel can be recycled and mixed into fresh fuel, and future technologies may be able to extract even more use from it. Even if they can't, people centuries from now may devise a better way to deal with the stuff.

Engineers in France are keeping that idea in mind. At an underground repository they plan to build in north-eastern France, known as Cigéo, a funicular railway will be on site so that nuclear waste can, in principle, be transported back to the surface in future.

Digging deep

Cigéo, which is scheduled to be operational by the 2050s, will be carved into sedimentary mudrock, an impermeable material that limits the flow of groundwater and should keep the buried waste dry. But retaining the ability to remove nuclear waste would also act as an insurance policy, just in case problems similar to those at the Asse II repository emerge.

"People [in France] want to be assured that if something goes wrong with the site that they can remove all the waste," says Macfarlane.

There is another concern about truly long-term storage: people living millennia from now may have no knowledge that the nuclear repositories exist, and they might accidentally drill into one of them, causing an environmental disaster.

People have come up with some wonderfully odd ways to avoid this outcome. Some researchers, aware that languages change or even fall out of use over long periods of time, think it is important to signal danger without written words. At the Waste Isolation Pilot Plant in New Mexico – the first and only operational deep geological nuclear repository in the US, which opened in 1999 – researchers considered building vast earthworks and ominous monuments, including a landscape of giant thorns intended to warn future generations not to dig there. But that forbidding landscape was never built. One obvious snag is that mysterious ruins have a habit of attracting curious humans on the hunt for buried treasure.

Macfarlane thinks the effort is better spent elsewhere. "Just give up. It's a lot of hubris to think that, 'Oh, I can design a sign that people in the future will understand'," she says.

"A BARRIER THAT LOOKS REASSURINGLY SOLID FOR A CENTURY MAY CORRODE, CRACK OR SHIFT OVER 1000 YEARS"

The French National Agency for Radioactive Waste Management, which is overseeing the Cigéo project, has something less theatrical in mind. Its engineers are testing sapphire discs that can be etched with up to 40,000 miniaturised pages of text and images. These discs, each 20 centimetres across, would be tough enough to survive heat, scratching and exposure to chemicals in the environment. If stored somewhere near the Cigéo site, such discs might alert future generations to the repository's existence.

In Sweden, meanwhile, researchers working for the country's nuclear waste management company have drafted a 42-page digital document detailing a nuclear repository being built deep below ground at Forsmark, a site about 130 kilometres north of Stockholm. The plan is to update, translate and pass the document down through the generations.

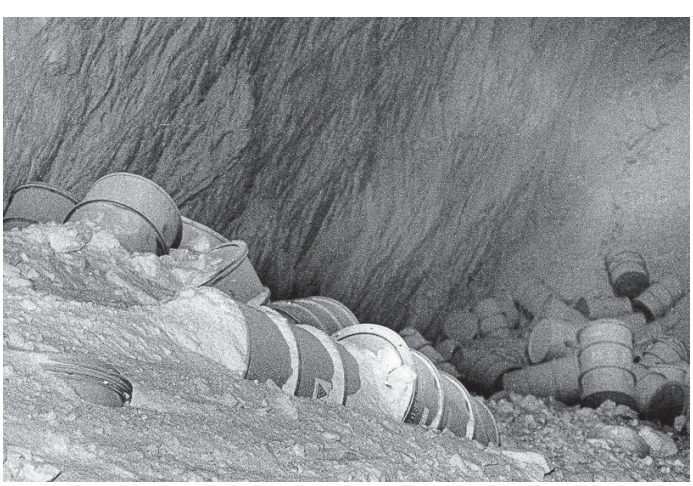
There might be alternative ways to keep the knowledge alive. Sweden's nuclear regulator has also suggested that weaving knowledge of repositories into education and culture may prove more durable than producing physical documents. There are potential precedents for this: a decade ago, anthropologists reported evidence that information about sea-level rise that occurred at least 7000 years ago has been preserved in stories told by Indigenous communities around Australia's coast. The researchers speculate that the stories survived because the communities employed a complex system of crosschecks, in which younger and older generations were both aware of the stories and corrected one another if any errors crept in.

But in Finland, researchers have taken a different approach. Decades ago, several possible sites for Finland's nuclear repository were scrutinised. One thing the researchers were looking for is a subsurface region so devoid of useful resources, such as oil, that no one is ever likely to consider digging there. The idea is that engineers don't have to worry about alerting future generations to a nuclear repository deep below ground in such a resource-free location. Instead, the repository can be sealed up and then forgotten.

On the island of Olkiluoto in south-western Finland, they found what they were looking for. Since 2004, this is where they have been working on the Onkalo repository.

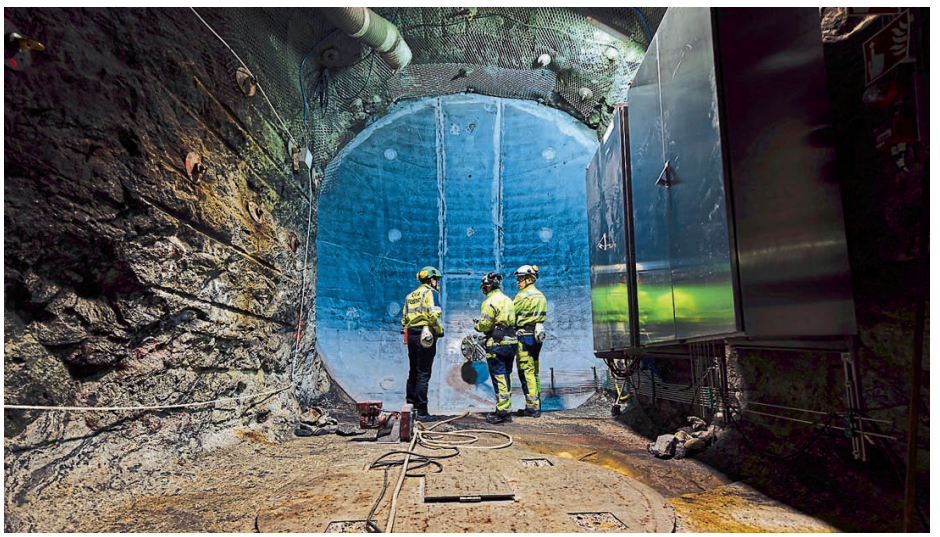
"Even now, when arriving here, you have pretty much a modern industrial site," says Petteri Vuorio, the facility's development director. But as you travel deeper and deeper, the site begins to feel different. "The surroundings become quieter and the rock becomes increasingly present as you go underground," he says.

The bedrock at Onkalo is just about the best you could hope for in a nuclear store, the Finnish researchers think. It is composed



WINTER/ULLSTEIN BILD VIA GETTY IMAGES

Barrels of nuclear waste as the Asse II facility in Germany



TEOLLISUUDEN VOIMA OY/POSIVA



AP PHOTO/JOERG SARBACH/ALAMY

Above: The Onkalo repository in Finland

Left: Protesters march to the Asse II facility in Germany in 2008 to oppose nuclear power

primarily of gneiss, an incredibly dense and impermeable metamorphic rock. To add to the engineering security, the rock was carefully mapped out to avoid any areas with major fractures or tiny structural weaknesses that might one day allow groundwater to seep into human-made caves. It is in these fracture-free areas that Onkalo's kilometres of tunnels now lie.

But that rock isn't enough. A system of multiple fail-safes known as KBS-3, developed by the Swedish nuclear waste company SKB, is being deployed, too. Spent fuel is first loaded into a cast-iron container for strength. Each container is then sealed inside a copper vessel with walls 5 centimetres thick. Studies have shown that elemental copper remains virtually unchanged by radioactive and high-pressure environments, making it a good candidate for such a protective shield.

Next, the finished canister is lowered into a hole drilled into the bedrock floor of one of Onkalo's disposal tunnels. Bentonite, a type of clay, is then packed around the canister. This clay swells when wet to create a dense and nearly watertight barrier, so if any water ever does find its way into the tunnels, the clay should ensure the nuclear waste remains dry. The bentonite also cushions the waste against any movement in the rock.

This combination of protective measures should, the engineers argue, provide the closest thing to a fail-safe system that can survive for millennia.

Shut up tight

"The engineered barrier should do the job itself, but if, for any reason, it doesn't, then you've got really good geology," says Clare Bond, a geologist at the University of Aberdeen, UK, who has no operational connection with the project.

In October 2026, the Finnish government granted a formal operating licence to run the Onkalo facility. In the months ahead, the first shipments of nuclear waste will arrive. Once Onkalo is completely full, all tunnels and shafts will be packed with more bentonite-rich material and sealed off. The facility will, quite literally, disappear back into the rock.

Years will pass, but the Onkalo site should remain sealed. Just 20,000 years ago, the site lay beneath a thick ice sheet, and over the nuclear repository's vast lifetime, that may happen again – perhaps several times. "Weight from the ice disappears and the crust rebounds. And that can cause fractures," says Bond. But she adds that significant research has gone into modelling the safety of nuclear repository sites like Onkalo under such climate shifts.

"There is still a lot to do, but we are happy so far," says Vuorio. "Although there are still matters to solve, we are also quite close to the finish line."

Onkalo may be the first bury-and-forget repository built with the deep future in mind, but it won't be the last. There are plans for something similar in Canada, although construction is still some years away. Work has begun on the Forsmark repository in Sweden, and it will also employ the same multilayered protection system of copper, bentonite and bedrock. If all goes to plan, it should be operational in the 2030s.

The UK is further behind, still at the stage of selecting a site to deposit its nuclear waste – which includes the world's largest stockpile of reactor-grade plutonium.

"The UK's waste is varied and complex and is significantly different to the waste being disposed of in Finland, for example," says Neil Hyatt, the chief scientific adviser to Nuclear Waste Services in the UK.

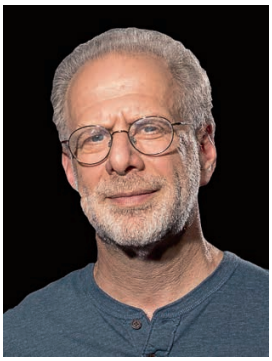
The country is currently evaluating two sites for a repository, according to Bond, both targeting impermeable mudrock in north-western England near the Sellafield nuclear site. Whichever is chosen, UK government documents suggest the plan is to build a permanent repository with a multilayered containment system broadly similar to the one that will be used at Onkalo.

At all these storage sites, engineers are being asked to think in terms of unfathomable timescales – an extraordinary challenge. But the truth is that only observers living in the distant future will know if these deep-time efforts prove to be successful. "Even after probably hundreds of visits underground, I feel humbled," says Vuorio. "What we are doing here is something which has to be guaranteed to be like it is for thousands of years. This is something that is even hard to describe." ▮





George Bass is a writer based in the UK. Jacklin Kwan is a former digital features editor at *New Scientist*



Daniel Lieberman is a palaeoanthropologist at Harvard University



FABIO BUONOCORE

"Fat played an incredibly important role in our evolutionary history, which is one of the reasons we love it"

We have an unprecedented choice of food, yet our diets are worse than ever. Palaeoanthropologist **Daniel Lieberman** tells Sophie Berdugo what evolution can teach us about how to eat better

AFTER spending a week with the Hadza community in northern Tanzania, it was time for the last supper. Not wanting to place any extra burden on the hunter-gatherers, Daniel Lieberman and his colleagues had come prepared with a cook and rations. But upon realising there was plenty of food to spare, they decided to throw a dinner party for their hosts.

The menu consisted of the traditional East African cornmeal porridge ugali, along with rice, beans, cabbage and some freshly hunted meat courtesy of the Hadza. But what stands out in Lieberman's memory was watching their hosts devour the carbs and multiple helpings of cake smothered in a jam frosting. "I was just thinking, this is not the paleo diet," he recalls.

The paleo diet is just one of several fad diets that hark back to our evolutionary past as a way to eat better today. But as a palaeoanthropologist at Harvard University, Lieberman has long been bothered by the misinformation that underpins these ideas. True, we didn't evolve for the plethora of culinary choices many of us have now, or for ultra-processed, shelf-stable treats. But as Lieberman knows only too well, these oversimplified diets aren't the answer.

He has lived this firsthand. For his new book, *Fed Up: What evolution reveals about food, diet and eating well*, Lieberman and his very supportive wife, Tonia, tucked into various diets – from raw food and meal-replacement shakes to the Mediterranean diet – all while serving up evolutionary evidence for better eating.

Lieberman spoke to *New Scientist* about his hands-on approach to book research, what he discovered to be the optimal diet and whether we will ever adapt to the ultra-processed diets that are so prevalent today.

Sophie Berdugo: You have spent time with some hunter-gatherer populations – what have you learned from them about diet and nutrition?
Daniel Lieberman: Part of the problem [for my work] is that the hunter-gatherers today are, well, they're contemporary. None of them are completely isolated from the modern world. I've gone to visit the Hadza, which are a group in Tanzania, and they have cell phones and they send their kids to school. So, it's not like getting in a time machine and going back a million years.

But it does give you some sense of the challenges and the way of life of people before farming. You get up in the morning every day and there's usually no food in camp. Every day people go out and they hunt and gather. They'll



eat anything. We have this idea that there's a hunter-gatherer diet, that there's a paleo diet. There is no paleo diet. If it moves and it's edible, they'll eat it. And if it grows and it's edible, they'll eat it.

We did a study of all the really good data on hunter-gatherer populations in the tropics, because we were interested in how those diets compared to the paleo diet, which tells us what we're "supposed" to eat. The hunter-gatherer diets run the gamut. There are some populations that basically eat huge amounts of animal food, and there are some populations for which there is almost no animal food, and everything in between.

We evolved to eat absolutely everything. Hunter-gatherers are not trying to find just the right diet for their heart so they can live to be 80 or 90 and avoid osteoporosis and Alzheimer's. They're trying to get enough food so they can survive and have as many children as possible, just like every other animal.

Clearly there's a mismatch there between what we spent millennia doing – hunting and gathering for our food – and what many people today do to access food.

Today, you walk into a supermarket. We don't have to know how to get our food; we now need to know how to *choose* our food. The average big supermarket has 30,000 to 40,000 different products. I mean, that's a staggering amount. And more than half of those products, depending upon the supermarket, are factory-manufactured to be what we call "ultra-processed".

The combination of the energy density, the additives, the sugar, the absence of fibre, the added saturated fat, all of these things together – plus the fact that they're manufactured to be enticing, convenient, affordable, long-lasting – is clearly causing havoc. It is a major cause of the rise in obesity and in cardiometabolic diseases and all kinds of other inflammatory diseases.

There's no question that we are mismatched to those foods. But those foods are also, as I call it, hyper-matched to us. The manufacturers of these foods have figured out what turns on our brains. We just love this stuff.

It sounds like manufacturers have been able to harness the adaptations that we have to want to eat those foods.

Exactly. Can you think of natural food that's high in fat and sugar?

Milk?

Very well done – you get high marks! Milk, which we spend our first few years of life ›

Watch the full interview
Hear more from Daniel Lieberman in our extended video interview at **youtube.com/newscientist**

drinking from our mother, is the only natural food that's high in fat and sugar. Now, fortunes are made by combining fat and sugar to make foods that we just love.

How does this relate to what you call the fundamental equation of life in your book, "food in = babies out"?
Ultimately, that's what all animals are selected to do: to eat in order to reproduce. We have culture, we have other desires and needs and goals than simply eating to have babies. But that's what we evolved to do, so that's the evolutionary legacy that we have to contend with. We have cravings for foods that are beneficial for reproduction. That's one of the reasons why humans are so vulnerable to these high-energy foods.

One of the things about humans is that we evolved to be unusually fat. Your average chimpanzee has maybe about 5 per cent body fat, and that's typical for most mammals. A thin hunter-gatherer female has like 20, 25 per cent body fat. We evolved to have a lot of fat because fat played an incredibly important role in our evolutionary history. Fat enabled us to have these big brains that constantly need a lot of energy, especially when we're children. A baby is basically just a brain with a tiny little body attached, and 50 per cent of its metabolism goes towards feeding its brain.

Fat is important for our reproductive strategy; mothers need fat for nursing and so on. If you're going to go run and do a persistence hunt, you need some body fat to help you get there, especially if you haven't had breakfast. So, fat played an incredibly important role in our evolutionary history, which is one of the reasons we love it and we are so good at storing it.

So, fat is helpful then.
But here's the thing: we never evolved to lose it. There are no adaptations that humans have to naturally lose fat. In fact, we have the opposite. We have a whole suite of adaptations to hold on to it. So, when people go on a diet, they now have to fight millions of years of adaptations – and there are many of them – all of which are geared towards keeping us holding on to that fat.

If you lose fat, you have a hormone called leptin; those levels plunge and that leptin plunging makes you hungry. When you lose fat, your stomach produces another hormone called ghrelin that makes you hungry. And there are all these neuroendocrine hormones whose job it is to keep us from losing body fat.

I think one of the key messages from an evolutionary perspective is that if you're struggling to figure out what to eat, if you're struggling to exercise, if you're struggling to lose weight, it's not your fault. It's because of our evolutionary history.

You mentioned that the paleo diet isn't the answer. Why not return to an earlier way of eating?
For the book, my wife and I tried almost every diet known to humankind that's kind of related to the evolution and history of diets. Look, all of these diets have a grain of truth to them. The paleo diet is a high-protein diet that says, if you eat like our ancestors ate, you're going to be healthy. This is what we call the "naturalistic fallacy" – it's sort of true, but it's not completely true. One problem is that our ancestors didn't eat in order to be healthy; they ate to have a lot of babies. So, the paleo diet is really a reproductive diet.

Second, the paleo diet does ban junk food – you shouldn't eat food with added sugar, you shouldn't eat food with a lot of saturated fat. That's all good, that's generally healthy.

My problem with the paleo diet is it completely bans all grains. Nothing. No bread, no oats, no whole grain, no oatmeal, no nothing. And it completely bans all legumes, so no beans, no lentils, no chickpeas, no soy, no peanut butter – which, by the way, is my favourite food. The argument for that is that our ancestors supposedly didn't eat these things. Well, that


SHUTTERSTOCK/HEDIBESEN

Today's supermarkets give us a huge choice of foods (left), but diet isn't just about what you eat – it's also who you eat it with


PLAINPICTURE/SIMEPHOTO

turns out not to be true. We know we have lots of evidence that palaeolithic hunter-gatherers ate grains and legumes. So that's just nonsense.

A diet that I know that you struggled with, among the various that you tried, was the raw food diet.
Struggle is a euphemism! The raw food diet started at the beginning of the industrial revolution. The idea was that cooking destroys the nutrients in food. Well, it's not true; it's actually the reverse. Cooking actually gives you more energy from your food because it breaks down the cell walls, it liberates the energy, it reduces the metabolic cost of digestion. So, in fact, cooking played such an important role in our evolutionary history that we're now adapted to eating cooked food and we're maladapted to only eating raw food.

So raw foodists – and these are not hunter-gatherers, these are people going to the fanciest supermarkets you can think of – they're getting high-quality foods that have been domesticated to be really nutritious. And even then, they're struggling to get enough energy. A lot of women who are raw foodists don't have normal menstrual cycles because they don't have enough energy.

I have to tell you, the hard thing about the raw food diet was that my wife and I were just always hungry. My wife gave up after three days. One morning I went down to breakfast and she looked unusually happy, and it's because she snuck out and got a bagel. I lasted just one more day.

It sounds like we've evolved to have the processing in the form of cooking, but not ultra-processed foods. Why haven't we adapted to these yet?
Because it's a blink of an eye. These technologies are just a few generations old, and evolution doesn't work that fast. It takes hundreds, if not thousands, of years for natural selection to work.

Furthermore, the diseases that we get from these ultra-processed foods don't usually hit us until we're in our sixties or seventies, and by then, natural selection doesn't really care about us. We're in what's called the "selective shadow". We've had our children; we might even be grandparents at that point. We're not contributing to their fitness anymore in the same way that grandparents did in the Palaeolithic, so there's not going to be a selection against people getting diabetes and heart disease and cancers in their sixties and seventies. It's not going to happen.



ROBIN HAMMOND/PANOS PICTURES

The Hadza are a group of hunter-gatherers living in Tanzania

> "If you're struggling to lose weight, it's not your fault. It's because of our evolutionary history"

We have to solve this problem without the help of natural selection.

What should we be eating then?
First of all, there is no optimal diet, because there is variation. Also, diet, it's not just about health. It's about things you love, it's about family, it's about culture, it's about tradition. But in general, if you stand back from all the various diets, the ones that have the most scientific evidence are the ones like the Mediterranean diet that aren't really diets. They're basically traditional farming cuisines that don't rely on a lot of processing, don't have a lot of saturated fat, don't have a lot of added sugar, have plenty of fibre and have diverse nutrients. So, you're eating a lot of plants, not too much animal food.

There are lots of these diets. The Mediterranean is the best studied, but I think a traditional Asian diet would qualify, traditional Mesoamerican diet, traditional African diet. Cultures around the world evolve these diets through trial and error for a good reason: they're nutritious.

But I think, if I were to go from the evidence for the best scientifically studied diet for which there are long-term, prospective randomised control studies with mechanistic data behind them, you can't go wrong with something like a Mediterranean diet. Plus, it's kind of tasty. ▮



Sophie Berdugo is the assistant magazine editor at *New Scientist*. She has a PhD in evolutionary anthropology

FOR CURIOUS KIDS AGED 7–14

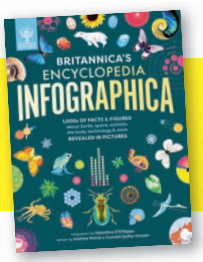
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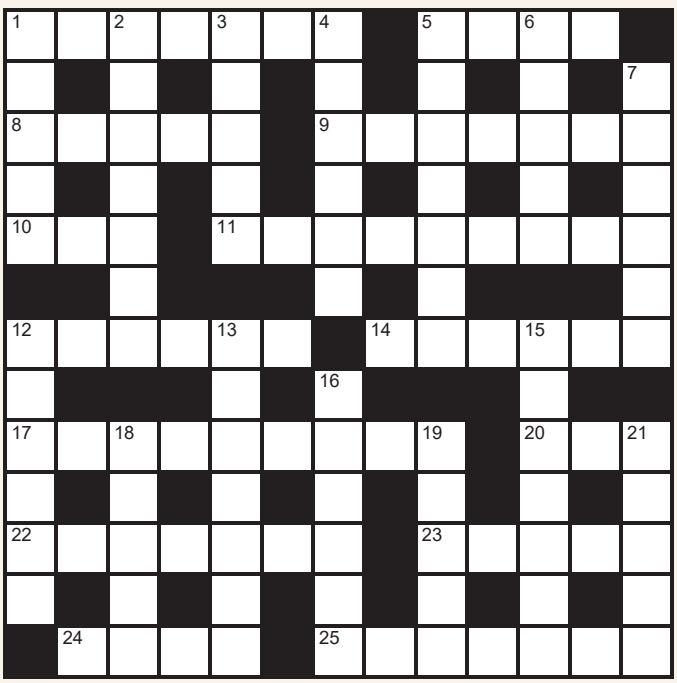
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Cryptic crossword #200 *Set by Rasa*



Scribble zone

Quick crossword next week

ACROSS

1 I'm relieved 12th letter spelled out who coined the term "scientist" (7)
5 Sieve fits badly (4)
8 Wear away each bit of ink (3,2)
9 Remove last of bat droppings in eastern base (7)
10 Pair from university admitted to affair (3)
11 Translucent white daisy-like flower behind a test facility (9)
12 Therefore, set about returning my organ (6)
14 Small fish move in a leisurely way (6)
17 Cost includes incredibly epic mountain feature (9)
20 Multinational initially brought in 1 million (3)
22 Describe origin of *Nature*'s unfortunate errata (7)
23 Ill-advised snooze taken by computer experts (5)
24 That woman had outdoor storage (4)
25 Salon employee put inventory at rear of messy area (7)

DOWN

1 Handle feral bears expertly at first (5)
2 Chaos coming back through busy port network (7)
3 Surplus retro paintings supporting former spouse (5)
4 Good hook breaking up soil blockage in a river (6)
5 Caulk computer connection into chair (7)
6 Fire-starter fluid isn't free of sulphur (5)
7 Seabird to be in France inhabiting quiet lake (6)
12 Recording label protects access code (6)
13 Perhaps mole on a road – it's in one piece (7)
15 Nothing fixed grim AI paperwork? (7)
16 Alarms father with magnet labels (6)
18 Organic pump cycles forward here (5)
19 Instruct journalist to cover current fallacy on vacation (5)
21 Time to replace ending in roadside inn song (5)

Quick quiz #377
set by Chelsea Whyte

1 Which body part was transplanted from a brain-dead donor to a living recipient in a controversial, world-first operation?

2 Researchers trapped a single particle for months in an effort to solve one of the mysteries of the standard model of physics. Which particle did they trap?

3 Which compound may disrupt the brain's cleaning system, resulting in Alzheimer's disease?

4 A flaw in widely used code, uncovered by AI, made 70 per cent of websites worldwide vulnerable to data theft and defacement. Which programming language contained the error?

5 Which island in the Azores is turning off its lights at night to protect rare seabirds called Cory's shearwaters?

Plus Side
created by Puzzlr

Circle numbers in the grid below to use them, or cross them out to get rid of them. Circled numbers must add up to both the target at the end of each row and the target below each column.

4	2	6	8	2	12
8	7	3	2	5	18
3	5	8	4	6	12
2	1	7	4	4	14
4	2	3	1	6	11
17	10	19	6	15	

Answers to this week's puzzles on page 47

Our games are now playable online
newscientist.com/games

Rock the boat

If every ship on the planet were hauled out of the water, how much would global sea levels change, and how quickly?

Mike Follows
Sutton Coldfield, West Midlands, UK
If the world's ocean-going commercial fleet were removed from the sea, global mean sea level would quickly fall, but by only a matter of micrometres.

By Archimedes' principle, a floating vessel displaces enough water for the mass of that water to equal the combined mass of the vessel and everything aboard it. This means that a ship with a total mass of 100,000 tonnes displaces 100,000 tonnes of seawater, equivalent to about 97,560 cubic metres, given a seawater density of approximately 1.025 tonnes per cubic metre.

The ship itself is represented by its lightship mass: the mass of its hull, machinery and permanent equipment. Deadweight tonnage (DWT) is the maximum additional mass that a vessel is permitted to carry, including cargo, fuel, fresh water, ballast, stores and people. Ballast is used to provide stability, control draft and trim, and keep

"Removing the ships would buy us less than a day's reprieve from the current sea-level rise of 4.5 millimetres a year"

the propeller and rudder adequately immersed.

According to the UN Conference on Trade and Development's *2025 Review of Maritime Transport*, there are about 112,500 propelled seagoing merchant vessels of at least 100 gross tonnage (GT), with a combined carrying capacity of 2.44 billion DWT. GT is a dimensionless measure based on a ship's size (specifically its enclosed volume), not its mass. Maximum displacement is greater than this because it also includes the vessels' lightship mass. Using typical ratios of deadweight to displacement for different classes of merchant ship suggests that total maximum displacement is about 3 billion tonnes, equivalent to about 2.9 cubic kilometres of seawater.

Given that Earth's radius is about 6400 kilometres and the ocean covers about 70 per cent of its surface, the ocean has a surface area of approximately 360 million square kilometres. Dividing the displaced volume by this area gives a maximum global mean sea-level rise of about 8 micrometres.

The actual figure would be somewhat lower than this because the entire fleet is never simultaneously carrying its maximum deadweight.

Herman D'Hondt
Sydney, Australia
Here's a back-of-the-envelope calculation. A quick internet search tells me that the carrying capacity of the global commercial shipping fleet is about 2.5 billion deadweight tonnes, or about 2.25 billion metric tonnes. Let's assume a total of 3 billion tonnes for all ships and boats.

That mass equates to 3 cubic kilometres of water. On the other hand, the total ocean volume is 1.3 billion cubic kilometres.

Hence, removing the ships is going to remove less than half of one part per billion of the total ocean volume. The average depth of the ocean is roughly 3700 metres. Removing half a billionth of that drops the surface level by roughly 18 micrometres. Human hairs typically have a thickness of between 30 and 60 micrometres.

I don't think anyone will notice a sea-level drop of half the thickness of a hair. It certainly won't help to counter the effects of global warming.

Hillary Shaw
Newport, Shropshire, UK
The total global tonnage of ships is around 2.5 billion deadweight tonnes (fully loaded). Some will be in dry dock and many won't be fully loaded, and a deadweight tonne doesn't quite equal a tonne, or 1 cubic metre of water. There is also a long tail of countless tiny fishing boats on the sea. So, approximately 2.5 billion cubic metres of water are displaced by these ships. However, the world has 361 million square kilometres of ocean, so removing all these ships would result in a sea-level drop of just 7 micrometres, which would be almost instantaneous as the world's ships are fairly evenly spread across the seas, outside Arctic circle latitudes.

That would buy us less than a day's reprieve from the current sea-level rise of 4.5 millimetres a year. We might gain more by removing the 2.5 per cent of global carbon dioxide emissions accounted for by shipping, but minus the extra CO_2 from transport that shifts to road or rail, for instance in cargoes from East Asia to Europe. Also, a lot of oil is shipped by sea, so CO_2 might fall even more as petrol and diesel gets very scarce and expensive in Europe and other places.



CASSANDRA WYLES/ALAMY

Why do carnivores like cheetahs sit on their haunches, but herbivorous quadrupeds don't?

This week's new questions

Take a seat **Why do carnivorous quadrupeds like cheetahs or dogs sit on their haunches, but herbivorous ones like sheep don't?** *Shelley Hinsley, Llantrisant, Rhondda Cynon Taf, UK*

Brackets first **Is the order of mathematical operations, given the acronym BODMAS, universal or does it break down in the quantum world?** *Carl Parker, London, UK*

Want to send us a question or answer?

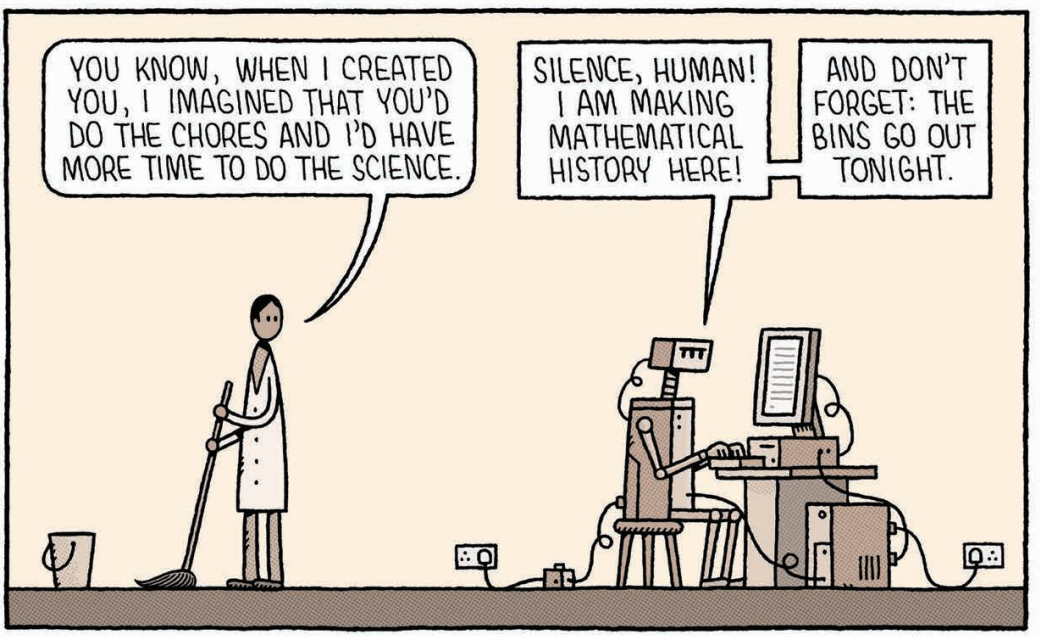
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Mirror mirror

Why do people appear younger and better-looking in a mirror than in a photograph? (continued)

Kevin Wooding
Via Facebook
Faces aren't symmetrical and you become accustomed to the unique

Tom Gauld
for New Scientist



proportions of your mirrored impression over many years. A photograph shows your face without mirroring, and it can be unfamiliar and surprising with the two sides of your face swapped.

Of course, you could always spend a lot of time looking at photographs of yourself to get used to the non-reflected image of your face. Have fun with this.

Burcu Akten
Via Facebook
I know the answer in my own case. I have a better relationship with myself than I do with others. I'm worried about how others see me, but I'm not worried about how I see myself. So, when my photo is taken, I tense up and look uncomfortable and distressed under the gaze of others. In the mirror, I am kind to myself. So, I see a confident and happy person in the mirror, not a scared one.

Lisa Munroe-Shields
Via Facebook
I look OK in the mirror. But I look like the love child of Hagrid and Worzel Gummidge in photographs! And the self-service cameras in supermarkets make me want to introduce a self-imposed ban on going in those particular shops!

"Kittens brought up in a box containing only horizontal striped lines couldn't see vertical objects in a normal environment"

Hear that?

Why don't dogs look up when a low-flying plane or helicopter passes overhead? I've never seen one do this. (continued)

Liz Hughes
Bath, UK
Referencing David Hubel and Torsten Wiesel's work on the development of the visual cortex in animals, I believe the answer lies in the dog's upbringing.

Hubel and Wiesel worked extensively on kittens, finding that if certain visual cues were removed from a kitten's environment in the period when the animal's brain was wiring its visual pathways, it wouldn't be able to see those things once they had completed their development. In experiments, kittens brought up in a box containing only horizontal striped lines couldn't see chair legs or other vertical objects in a normal environment.

So, if a dog wasn't brought up in an environment that included objects at different heights, then its brain would potentially never be able to recognise that there is an aircraft overhead. And with the cacophony of other motorised and industrial sounds in our world, it is likely that the aeroplane would blend into the background.

Peter Seligman
Melbourne, Australia
We had a kitten that leapt up at a jumbo jet. It missed! And I have seen a cat catch a bird in mid flight. It began its leap in anticipation of the bird's position. ▮

Answers

Quick quiz #377

1 Spinal cord

2 Positron

3 Cholesterol

4 PHP

5 Corvo

Cryptic crossword #200

ACROSS 1 Whewell, **5** Sift, **8** Eat at, **9** Guanine, **10** Duo, **11** Alabaster, **12** Thymus, **14** Stroll, **17** Precipice, **20** IBM, **22** Narrate, **23** Inapt, **24** Shed, **25** Stylist

DOWN 1 Wield, **2** Entropy, **3** Extra, **4** Logjam, **5** Sealant, **6** Flint, **7** Petrel, **12** Taping, **13** Unitard, **15** Origami, **16** Sirens, **18** Earth, **19** Edify, **21** Motet

Plus Side *Solution*

12	4	2	6	8	2
18	8	7	3	2	5
12	3	5	8	4	6
14	2	1	7	4	4
11	4	2	3	1	6
	17	10	19	6	15

Don't get it twisted

FEEDBACK is not young. We have been here on the back pages for many years, endlessly pushing a boulder up a hill and trying to take joy in the effort. This means, every so often, we are forced to repeat ourselves – because the world repeats itself.

With a due sense of ennui, we turn our world-weary eyes to the cover of the new 50th anniversary edition of Richard Dawkins's popular science classic *The Selfish Gene*. The title, written in all-caps, takes up most of the cover. The "I" in "SELFISH" has been replaced by a colourful little drawing of a DNA double helix.

Alas, something is awry. Geneticist Simon Fisher pointed it out on Bluesky: "You know a gene is selfish when its DNA twists the wrong way, as demonstrated by the left-handed double-helix proudly adorning the 50th Anniversary Edition of the multimillion copy bestseller on this topic."

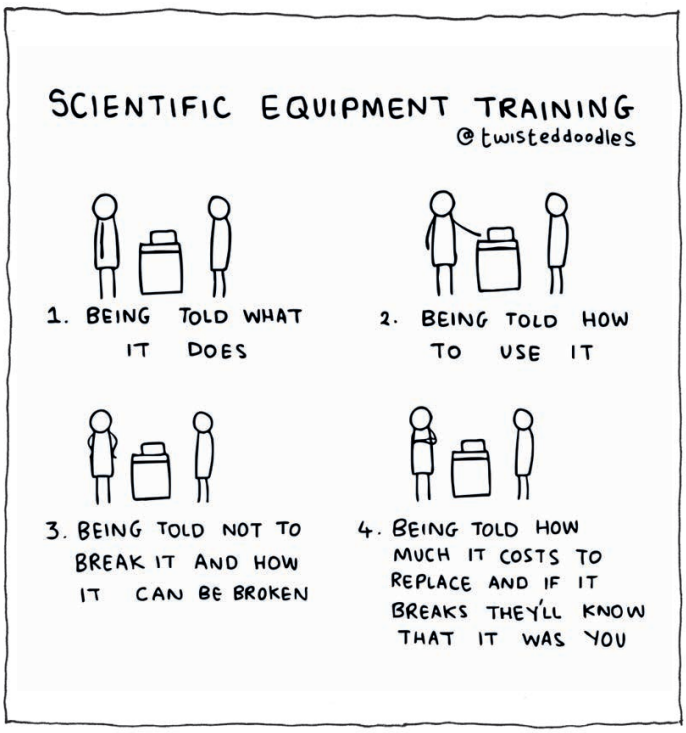
Yes, once again we have an example of a DNA molecule being drawn, essentially, backwards. In reality, it is a right-handed double helix, but the one on the book cover is left-handed. It's twisting the wrong way.

Feedback's mind's eye immediately cast itself back to March 2025, when we covered a Lego model that included many scientific and technological objects, including a sadly left-handed DNA.

It turns out that *The Selfish Gene*'s art has been wrong for at least a decade. Patrick Goymer, an editor at *PLOS One*, shared the cover of the 40th anniversary edition on Bluesky, and it has the same left-handed DNA in place of the "I". Feedback notes that our own copy is the 30th anniversary edition, and the DNA is correct. At some point since 2006, the DNA on the cover has flipped into a mirror universe.

This little mistake would be doubly embarrassing if, say, the Nobel prize in chemistry had recently been awarded for research into these sorts of mirror molecules. Can you imagine?

Twisteddoodles *for New Scientist*



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or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

Coca-Cola faecaloma

Sometimes a scientific paper has a title so vivid, so immediate, that Feedback just has to write about it. Such is the case with a paper published in *Cureus*, titled: "Massive fecaloma dissolved by Coca-Cola: A case report". It was sent to us by Australia reporter Alice Klein, who either has a truly terrible browser history or makes extensive use of a VPN.

A faecaloma, for those not yet blessed with the knowledge, is a large lump of impacted faeces trapped in a person's rectum. In this case report, the faecaloma had a maximum diameter of 12.2 centimetres.

Readers anxious to see a dramatisation of such a condition are advised to try series two, episode five of *The Pitt*, in which one of the patients has impacted faeces that the doctors must manually dislodge. Based on our own personal experience, we do not recommend watching this sequence over dinner.

Back in the real world, the doctors reported that they tried "conservative management", which apparently consisted of "polyethylene glycol, senna, mineral oil, and sodium phosphate enemas". But the faecaloma didn't budge, so they turned to a more drastic solution.

The authors tell us that "isolated case reports have described the use of Coca-Cola enemas for fecaloma dissolution with favorable outcomes". This is because "Classic Coca-Cola acts as a mucolytic agent [it makes mucus less thick and sticky], a source of carbonic acid, and an effervescent solvent". Hence the doctors administered two 1-litre Coca-Cola enemas, which shrank the faecaloma enough to resolve the situation.

Feedback has a number of thoughts, such as: would Pepsi work as well? What if the doctors had first inserted Mentos? We are also not sure we ever want to put Coca-Cola into our mouth ever again: if it can be used to destroy a faecaloma, we dread to think what it might be doing to our teeth.

@2, Brute?

Some weeks ago, Feedback began investigating unfortunate technology-induced truncations and abbreviations. These truncations have gone on for a long time and there is no end in sight.

Stuart Arnold was bemused to find Facebook recommending a post about an obsolete form of aircraft called a Rotodyne, which never made it past the prototype phase. It is best described as "a plane, but stick a set of helicopter rotors on top". Unfortunately, due to the character limit in the Facebook feed, the post was cut off as follows: "designed to take off vertically, then fly faster and fart..." "It's probably a good thing that the program was cancelled," says Stuart.

Secondly, David Smith encountered a related problem: tech-induced rudeness. Because his name is a common one, he has long struggled to find unique identifiers for email addresses and such. Imagine his surprise when he joined a large organisation and found he was only the second person there with that name. This seemed like (minor) good news, but he swiftly discovered a downside to being the second David Smith. "The part of the email address corresponding to '2@' has to be pronounced very carefully," he says.

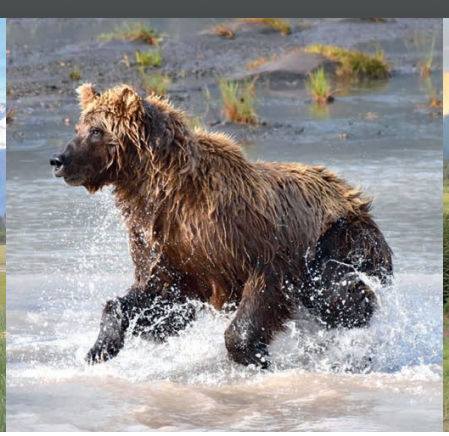
And finally, Andy Howe reminds us that Trinity Hall, one of the Cambridge colleges, "is colloquially abbreviated as Tit". He tells us: "This was particularly unfortunate for an archaeology student who saw his name listed in a society's membership records, followed by the descriptor 'Arch Tit'."

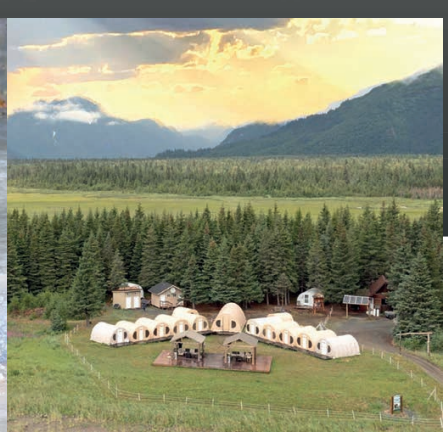
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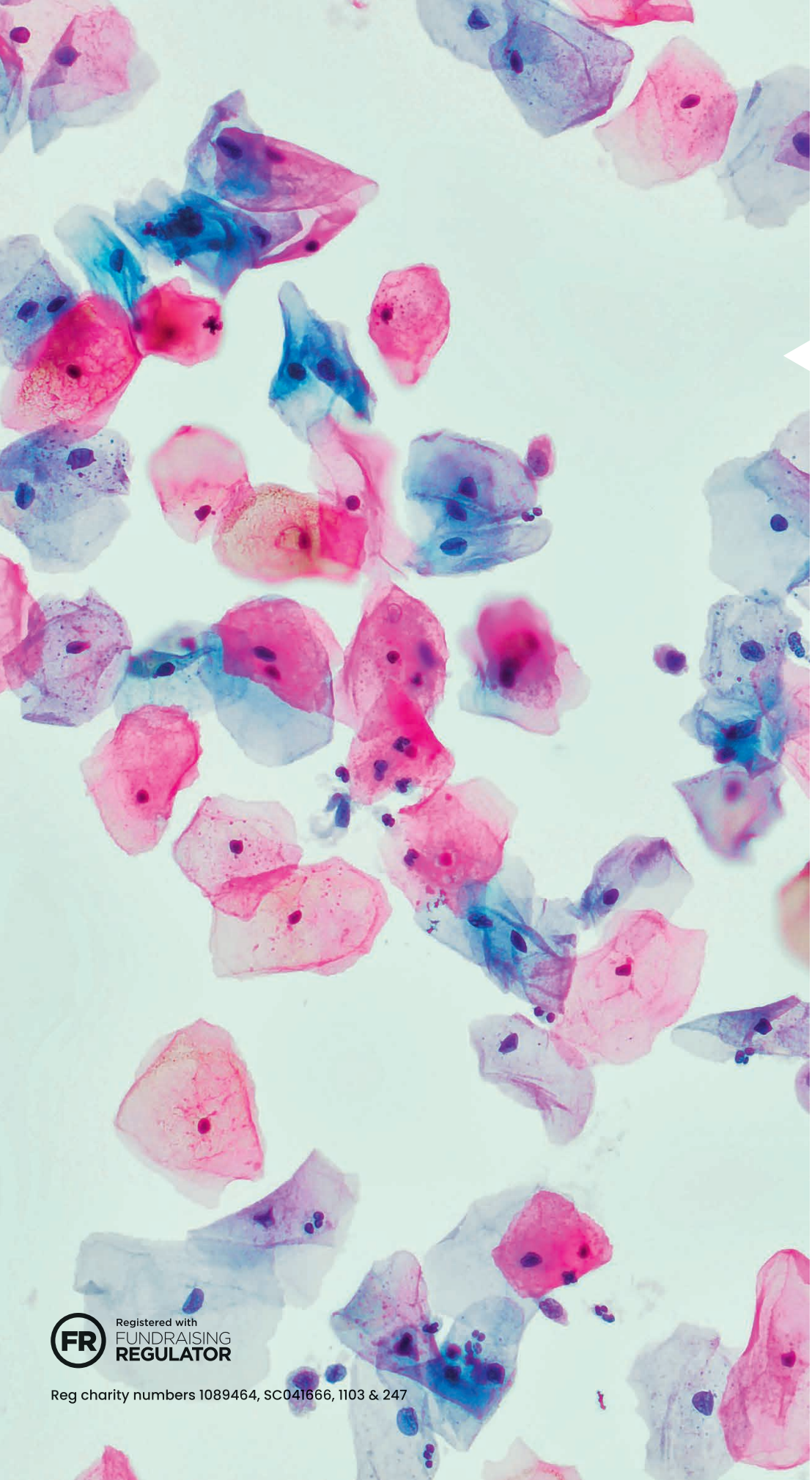
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