New Scientist

WEEKLY 24 January 2026

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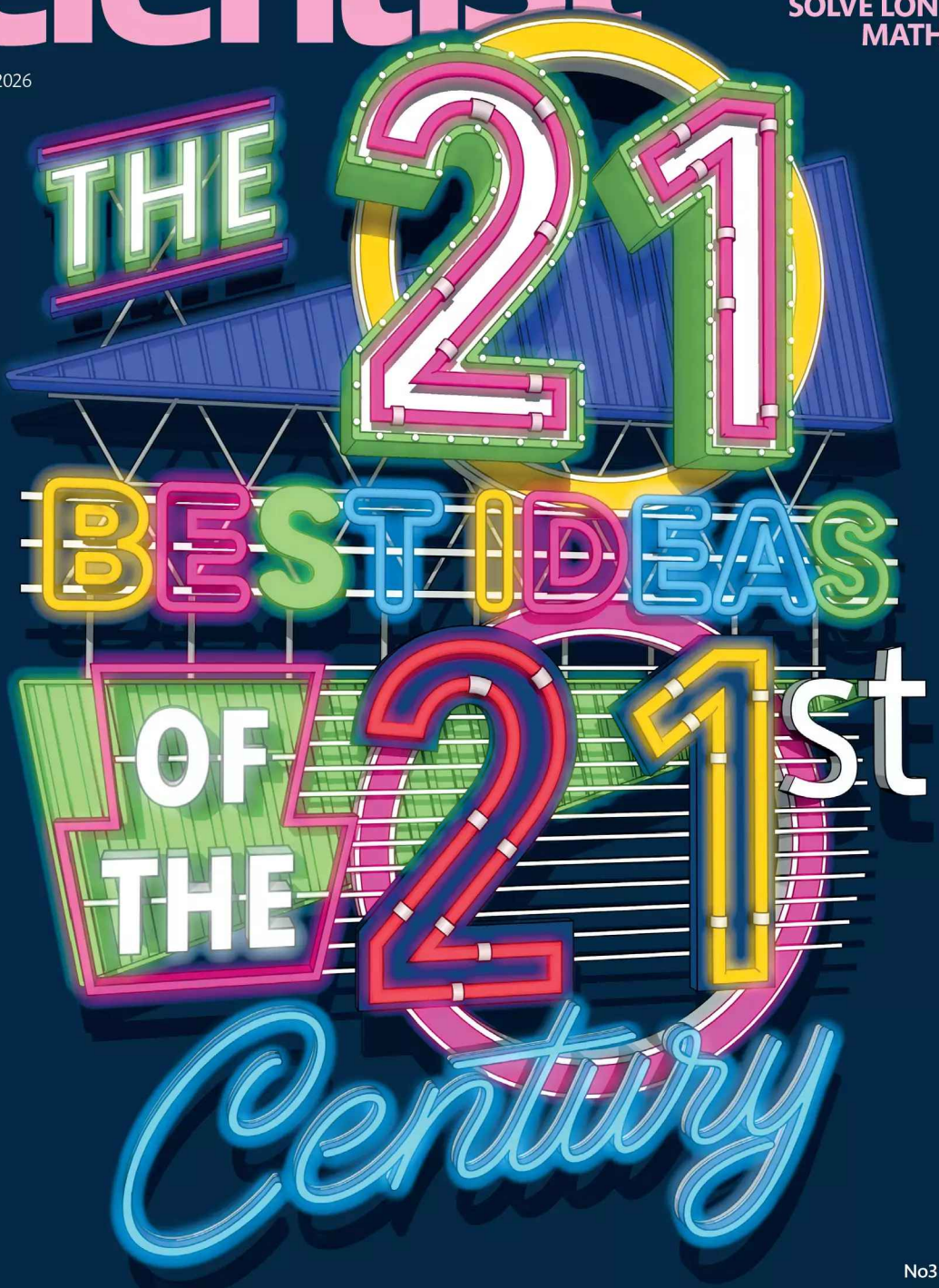

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This week's issue

On the cover

Vol 269 No 3579
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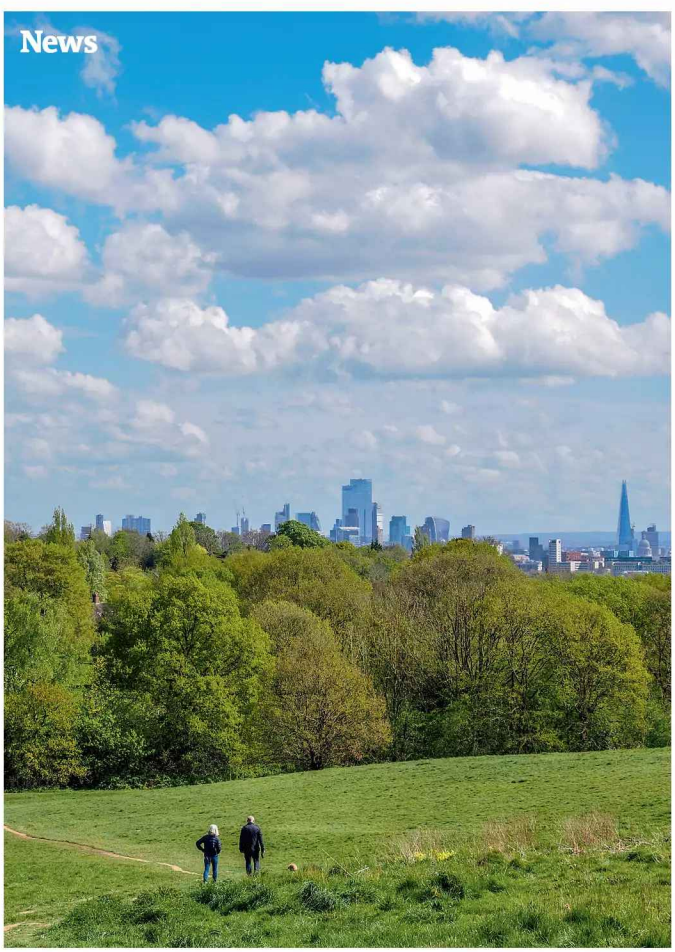
"The 1.5°C target has created a sense of urgency"

News

Views



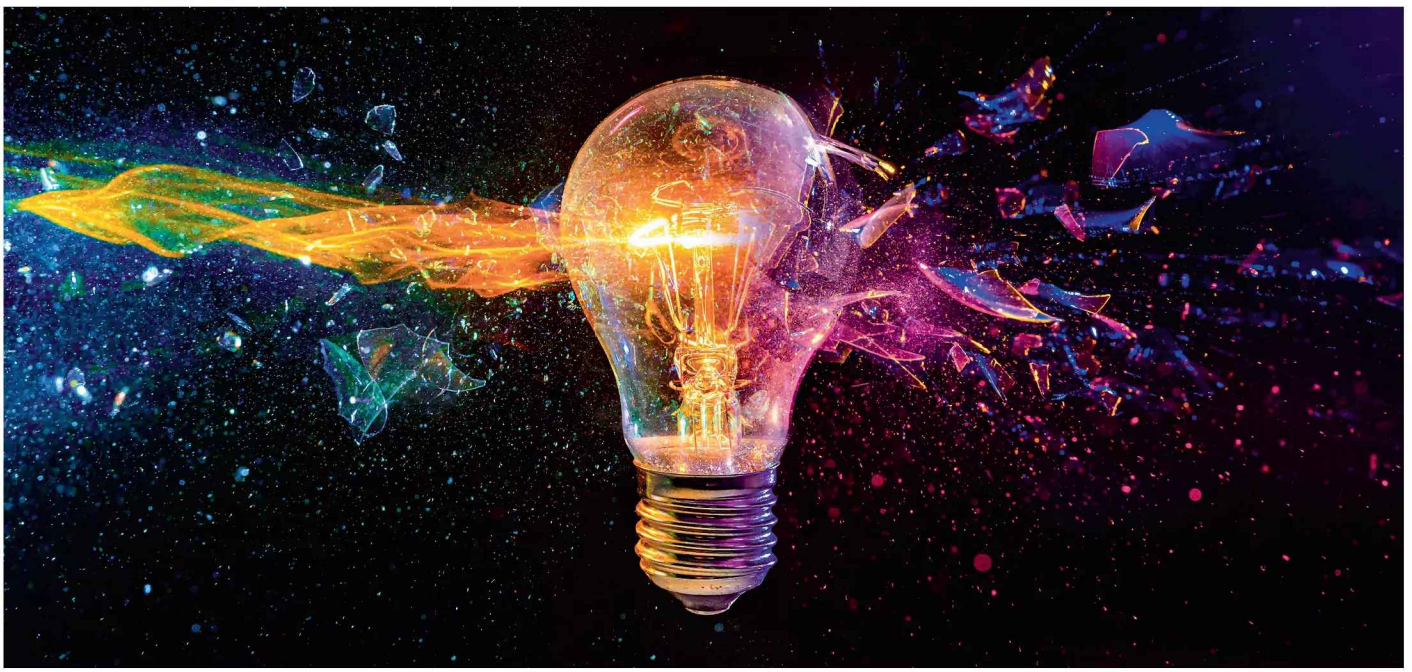
DYLAN GARCIA/ALAMY

Features

The back pages

What an idea!

Looking back on the best (and worst) ideas of the past 25 years



GUALTIERO BOFFI/ALAMY

WHAT separates a good idea from a bad one? It isn't always easy to tell. Take the invention of vaccination, for example. Drawing pus from a woman infected with cowpox and injecting it into an 8-year-old boy seems utterly reckless, but in doing so, 18th-century physician Edward Jenner found a way to fight the deadly scourge of smallpox.

It is only with hindsight that we can see Jenner was on to something: a principle that has now saved millions of lives. That is why, a quarter of the way into this century, we have decided to look back and celebrate the ideas that have really mattered in the past 25 years – the ones that are already transforming the way we behave, think or understand what's around us.

In coming up with our list of the 21 best ideas of the 21st century, there was plenty of heated debate within the editorial team. Our first hurdle was the unexpectedly puzzling question of whether the first quarter of the 21st century concluded at the start of 2025 or the end of it. To be safe, we chose the end. Then it was onto the ideas themselves and further discussion of what should really count, from whether the microbiome is actually a 21st-century concept (we decided it is, see page 28) to whether social media was a good or a bad idea (after some back and forth, we decided on bad, see page 37). What makes a good or a bad idea is, after all, subjective.

In the end, we devised a rigorous set of criteria. To make the list, a concept must have already had a transformative impact – whether on our understanding of ourselves, our health or the wider universe. It must have an idea at the heart of it, even if it was backed up by scientific discoveries. And finally, it must have happened in the past 25 years.

"Rather than trying to forecast the future, it is worth taking the time to reflect on the past"

You might think that last criterion would be easy to administer, but there were lots of suggestions that didn't quite make it. Gravitational waves were discovered in the 21st century, bringing us a whole new way of viewing the cosmos, but they were first predicted by Albert Einstein 100 years earlier. Other ideas like weight-loss drugs, personalised medicine and mRNA vaccines hold much promise, but haven't quite had their time to shine yet. Perhaps they'll make it into our 2050 list.

In coming up with our picks, we couldn't ignore the many ideas that sounded great at first, but turned into flops. That's why we have also compiled a list of the five worst ideas of the century so far. Sometimes, the line between best and worst is surprisingly hard to draw, which is why a few of our choices on the best list might seem controversial – like smartphones, for instance (see page 29), which many people would rather see removed from the planet, but on balance we see as a positive. Or the 1.5°C global warming target, which could be seen as a failure: a new report has found that the three-year average of global temperatures has just passed 1.5°C for the first time (see page 12). Despite this, we argue that changing the threshold down from 2°C remains one of the century's best ideas, setting the benchmark for global climate ambitions (see page 39).

Getting on with actually transitioning away from fossil fuels is certainly a good idea, and one perhaps surprising hero we have recognised in this area is Elon Musk. In 2016, before he began dabbling in social media and politics, Musk's car company Tesla opened its first "gigafactory" in Nevada, marking a turning point in the energy transition by using economies of scale to electrify our transport

and energy systems (see page 34). Other attempts to battle climate change, like alternative fuels and carbon offsets, have made our naughty list for doing more harm than good.

One thing we learned in putting our selection together is the extent to which ideas come about by chance. For most of us, finding a working plug socket on a long train journey enables little more than a few extra minutes of smartphone scrolling. But for two physicists back in 2005, it changed the world's entire decarbonisation strategy (see page 31). Similarly, it was a eureka discovery that revealed the origins of our most complex thought processes. We learned that brain regions don't work alone, but coordinate amongst themselves, creating a powerful and complex web. Since then, these neural networks have transformed our understanding of the brain, as well as how we diagnose and treat its problems (see page 35).

Looking back a quarter of a century, we find that the world was a very different place. We had avoided the millennium bug, the first draft of the human genome had just been completed and the first crew had arrived at the International Space Station. We didn't know what a Denisovan was and the word "microbiome" wasn't in our vocabulary. In the pages of *New Scientist*, we were celebrating new technologies like wireless communication, marvelling at the computer chip no bigger than an aspirin tablet that would let it happen. "Its heart is a device called a Bluetooth chip," we wrote, "and pundits are tipping it as The Next Big Thing". A reasonable guess, but headphones that you don't have to plug in are more of a nice-to-have than a world-changer, so we called that one wrong.

This reflects the fact that while predictions can be appealing, they are all too often wrong and left forgotten in our hurry to move on to the next shiny thing. Rather than trying to forecast the future, this exercise has taught us that it is worth taking the time to reflect on the past. Advances in health, technology and environmentalism have undoubtedly made the world a better place this century, and let us hope – if not predict – that they will continue to do so. ▮

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How play builds creative minds

A growing body of evidence suggests play is a deep-seated biological mechanism that allows young brains to practice curiosity, manage uncertainty and build critical thinking skills

Play develops crucial skills

"ALL we had to do was to construct a set of molecular models and begin to play." When James Watson and Francis Crick set out to solve DNA's structure, they drew inspiration from chemist Linus Pauling, who had recently cracked one aspect of protein structure by tinkering with toy-like physical models. The pair spent hours fiddling with wire and cardboard representations of DNA's components. By trial and error, following their curiosity and investigating different possibilities, they deduced the structure of the double helix.

Emergent breakthrough

It's an example of how scientific breakthroughs can emerge from something that looks remarkably like play, a word that conjures up images of something easy or trivial. "It has a definite overtone of frivolous or unserious or not important," says Paul Ramchandani, LEGO Professor of Play in Education, Development and Learning at the University of Cambridge. But nothing could be further from the truth. A growing body of evidence is showing that play is a vital activity, associated with the development of a raft of cognitive and emotional skills, such as critical thinking, problem-solving and resilience, as well as the ability to form strong relationships and navigate social situations.

For all its importance, it's hard to define exactly what we mean by "play". Researchers tend to adapt their definitions of play to the particular contexts they are investigating, such as adventurous or risky play, says Ramchandani. But one key feature unites them all: "It's an activity that is joyful and enjoyable to children," he says. Children devote a vast amount of time and energy to play. "It's the majority of their world, particularly when they're very young."

Play is not unique to humans; some young animals, such as rats, spend a lot of time playing. But why such a behaviour evolved that distracts young animals from important tasks such as seeking food is still debated. One idea is that it helps animals practise important physical skills, another that it helps develop social bonds, says Ramchandani.

Human play is much richer and changes as a child develops. "Children are thrown into a world of uncertainty and the unknown when they're born," says Bo Stjerne Thomsen, Head of Educational Impact at LEGO Education. "And the main mechanism to deal with that uncertainty is to play, to sense, and try and experiment with things around you. This is how children learn through play."

It begins in infants with parent-child bonding that builds relationships and early learning, later incorporating social elements with peers and siblings, and goes on to include pretend play, physical play and risky play. But young humans also seem to have a distinctive form of play that involves deliberately creating problems for themselves. One theory is that this is how humans practice curiosity-driven thinking, by inventing problems that force us to come up with creative solutions.

Testing ideas

Ethically, we can't deprive children of play to test all these ideas, says Ramchandani. But you can study what happens when you expand opportunities for play. "Increasing play of various kinds is correlated with positive outcomes across almost every aspect of development," he says.

Evidence is also emerging from experimental studies that certain kinds of play can help children learn as well as, or in some cases better than, formal instruction. In 2022, Ramchandani and his team at the Play in Education, Development and Learning (PEDAL) Centre at the University of Cambridge analysed 39 studies of "guided" play in children aged three to eight. Unlike "free" play, where children decide what to do, guided play involves a playful educational task where children have some freedom of choice, but are gently steered towards a learning goal by an adult.

The study found that guided play was as effective as conventional teaching for developing key skills such as literacy, numeracy, social skills and thinking skills. For developing some maths skills, namely understanding shapes, guided play was superior. This may be because guided play lets children explore shape in a range of different ways. The joyful aspect is also key. "If children are enjoying themselves, they're going to engage for longer," says Ramchandani.

Hands-on play with objects such as blocks and puzzles may also help children develop scientific reasoning skills. In 2023, Ramchandani, Thomsen and their colleagues

WUNDERVISUAL/ISTOCKPHOTO

'The study found that guided play was as effective as conventional teaching for developing key skills such as literacy, numeracy, social skills and thinking skills'

analysed 102 studies of the use of objects in learning, mainly of early primary-aged children and found that there were benefits to children's spatial, literacy and science skills, with the strongest evidence for benefits in developing mathematical skills.

Creative links

There are links, too, between play and creativity, a central pillar of the scientific endeavour. "You're creating, you are experimenting, you are buzzing ideas together," says Ramchandani. "There is an obvious parallel with playing imaginatively or playing with friends." So what looked like child's play with wire and cardboard turns out to be anything but trivial—it won Watson and Crick a Nobel Prize and unlocked one of biology's greatest mysteries.

BUILD, SOLVE, INVENT

Right, kids. You've built a LEGO spaceship but it keeps crashing. Now what? This is the kind of challenge posed by LEGO Education's new at home STEM sets, whose new "build-solve-invent" play loop is based on research into how children develop scientific skills.

The new sets incorporate both free play with LEGO bricks and guided play, following building instructions. Children are presented first with a guided build showing them what to make.

But the LEGO designers have included a challenge that the child has to solve, such as a spaceship that crash-lands because it is unbalanced.

Experiencing this frustration and being able to repeatedly try and fail is key to building resilience and confidence, as well as problem-solving skills, says Andrew Snape, a learning designer at LEGO Education.

PHOTOS USED WITH PERMISSION. ©2025 THE LEGO GROUP

Having solved the problem, the child is then invited to think creatively and invent something new with another set of bricks, such as a building a capsule that can ferry food to Mars. "We wanted something on the end, saying, 'All right, now you've solved the problem. Be a bit creative now and think about what a future problem could be or how you could take this a step further'," says Snape.

Problem solvers

It also allows parents to step back from their usual role as problem-fixers. One of the most common parent reactions during product testing was, "I just didn't realise that they were this good," says Snape. "I didn't realise they could do this."

Find out more about LEGO's new at home STEM sets at: www.LEGO.com

News

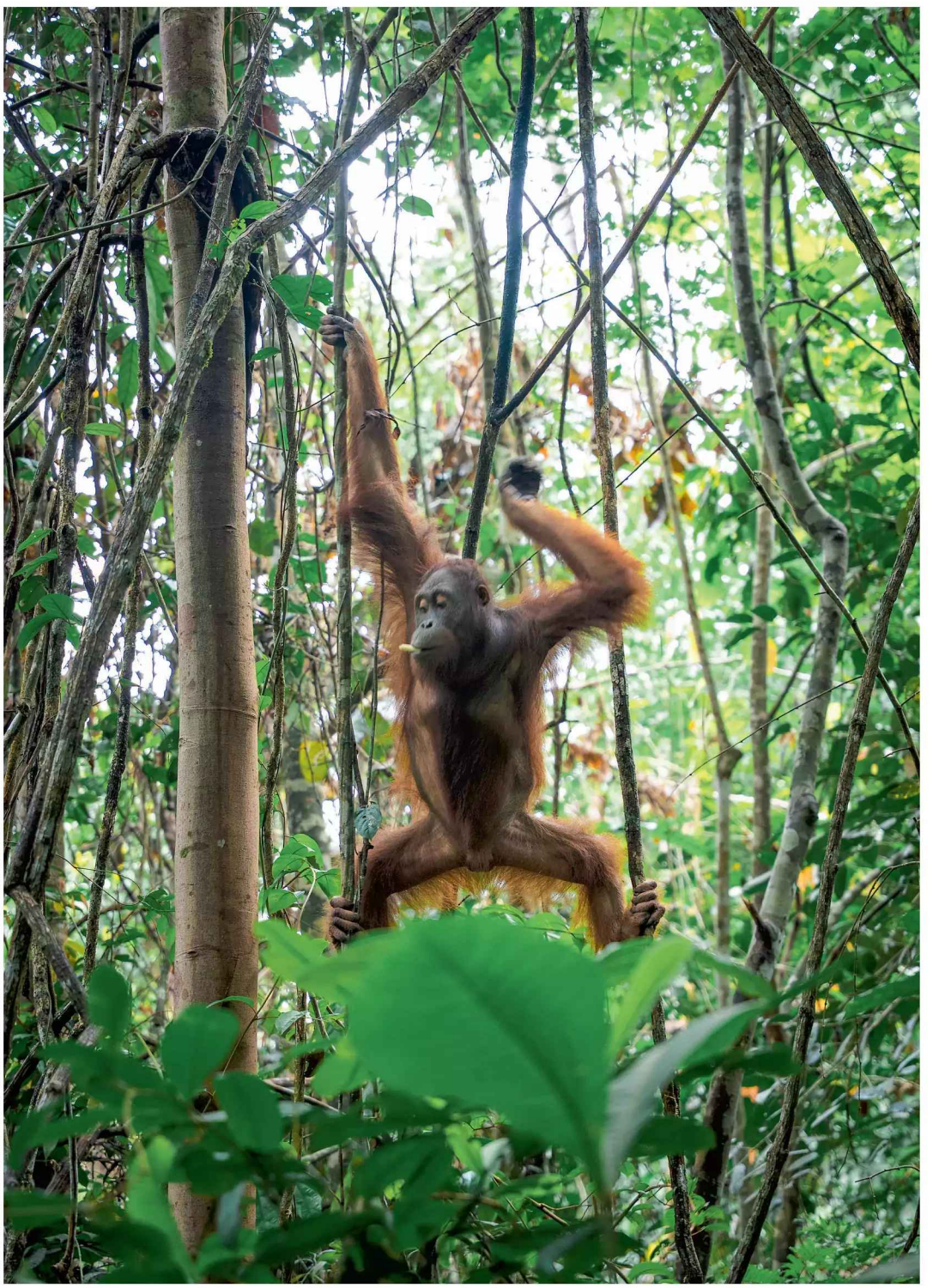
Baby black holes
We may have solved the mystery of the "little red dots" p13

DNA discovery
Woolly rhino genome holds clues to its demise p14

Cosmic dawn
Earliest supernova sheds light on the first stars p14

Take a dip
The ancient Romans cleaned up Pompeii's public baths p17

Staying alive
Greenland sharks seem unaffected by diseased hearts p17



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Zoology

Back where she belongs

This Bornean orangutan (*Pongo pygmaeus*) is enjoying her new-found freedom after being released into Bukit Baka Bukit Raya National Park in Indonesia. Called Koras, she is one of three orangutans to have recently been returned to the wild, after a stay at a rescue and rehabilitation centre, where she was treated for a skin infection. Koras was brought there after being saved from the illegal wildlife trade.

Climate change

World faces era of 'water bankruptcy'

Countries have spent beyond their sustainable water budgets, which could have huge economic, social and environmental costs, finds **Alec Luhn**

OVER-CONSUMPTION of water and the effects of global warming mean 3 in 4 people are living in countries that face water shortages, water contamination or drought.

That's the conclusion of a United Nations report that has found most regions are overdrawing their annual income of rainwater and snowmelt and dipping into their savings of groundwater, which can take thousands of years to replenish (*Water Resources Management*, doi.org/qnmq). Seventy per cent of major aquifers are declining and many of these changes are irreversible.

Two key drivers are agriculture and cities expanding into arid areas, which are getting even drier due to climate change. Almost 700 sinkholes have appeared in Turkey due to groundwater pumping, while dust storms from desertification have killed hundreds in Beijing.

"Our checking account, the surface water... is now empty," says the report's author, Kaveh Madani at the UN University Institute for Water, Environment and Health. "The savings account that we inherited from our ancestors, the groundwater, glaciers and so on... they're also drained now. We are seeing symptoms around the world... of water bankruptcy."

MORTEZA NIKOUBAZL/NURPHOTO VIA GETTY IMAGES

People walk along the dried-up Zayandeh Rud river in Isfahan, Iran

About 4 billion people experience water scarcity at least one month a year, fuelling migration, conflicts and unrest. Madani, who was formerly deputy head of Iran's Department of Environment, says water shortages contributed to the recent bloody protests there, although a currency collapse was the immediate trigger.

Iran had its driest autumn in 50 years, while a rash of dams and wells for farming have almost totally dried up Lake Urmia – once the largest lake in the Middle East – and depleted most of the country's groundwater. The government has mooted evacuating Tehran and is trying to induce rainfall through cloud seeding.

In the US, the flow of the Colorado river, which provides water to much of the western US, has decreased by an estimated 20 per cent over 20 years, largely due to lower precipitation and increased evaporation. But it is also being overly diverted to grow feed for beef and dairy cattle, all while cities like Los Angeles rely on it for drinking water. As with a rising number of rivers, it no longer reaches the sea.

The river's two major reservoirs are at about 30 per cent capacity and could hit "dead pool" levels at 10 to 15 per cent of capacity as soon as 2027, according to Bradley Udall at Colorado State University. Talks over how much each state drawing from it would cut consumption broke down last year.

Increasing the efficiency of agricultural water use has been shown to boost water consumption, since drip or sprinkler irrigation allows water to be gradually absorbed by plants, whereas the flooding of fields results in more water running back into the river. So it needs to be coupled with cuts in water consumption, according to Udall.

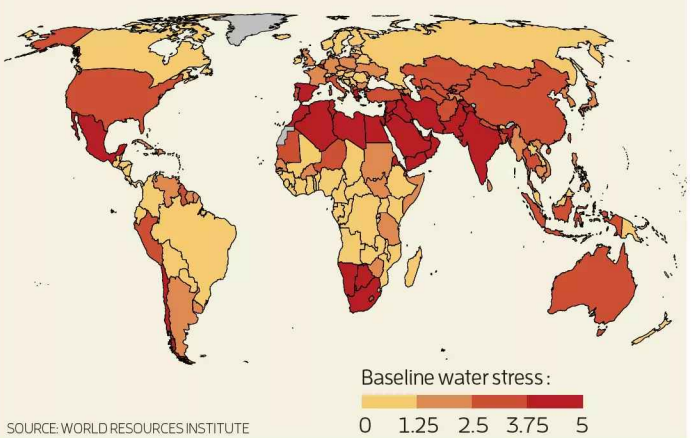
"Most countries need to simply start accounting for their water sources and consumption"

"The solution is going to have to come from agriculture primarily because they use 70 per cent of the water," he says. "Ag cutbacks, that's what we're talking about, and that's true worldwide."

Half of all food production is in areas with declining water storage. But reducing agriculture's water use will also require economic diversification, since it is the livelihood of more than 1 billion people. Most of them are in lower-income countries, which often export food to the

Our demand for water is exceeding supply

A large proportion of the global population faces high water stress – when freshwater demand exceeds supply from rain and snowmelt



SOURCE: WORLD RESOURCES INSTITUTE

River deltas at risk

Our demand for water (see main story) has many knock-on effects, including the sinking of important river deltas, which is putting millions of people at risk of flooding.

Manoochehr Shirzaei at Virginia Tech and his colleagues attempted to determine the rate at which 40 river deltas around the world are sinking, including the Mekong, Mississippi, Amazon, Zambezi, Yangtze and Nile.

The researchers used data from 2014 to 2023 obtained by the European Space Agency's Sentinel 1 satellite radar, which can measure changes in the distance between the satellite and the ground to an accuracy within 0.5 millimetres. In all 40 deltas, more than a third of each area is sinking, while in 38 of them, more than half of the area is (*Nature*, doi.org/qnmm).

They also looked at data on three major human pressures – groundwater extraction, sediment alteration and urban expansion – to determine which is having the greatest impact on subsidence of the deltas.

Groundwater extraction is having the strongest overall influence, but some deltas are more influenced by sediment changes and urban expansion.

James Woodford

service economies of higher-income nations.

"Water plays a major role in economies... because it puts people [in] jobs," says Madani. "If they lose their jobs, what happens is what you see in Iran today."

Even in rainy places, more water is being sucked up by data centres or polluted by industry, sewage, fertilisers or manure. Wetlands covering an area the size of the European Union have been lost, mostly due to conversion to agriculture, costing the world an estimated $5.1 trillion in ecosystem services like flood buffering, food production and carbon storage.

Learning to live with less

In Bangladesh, about half the country has well water that is contaminated by arsenic due to sea level rise and saltwater intrusion. Meanwhile, the tap water and the "dead river" in the capital Dhaka have been poisoned by chemicals from the production of fast fashion for sale in Europe and North America.

"Every person knows that the rivers are being polluted because of the garment industry," says Sonia Hoque at the University of Oxford. "But they know that stringent regulation, if applied, would... scare away the buyers."

In many cases, rivers, lakes, wetlands and aquifers will never return to their previous state. Moreover, many glaciers have melted, shrinking water supplies to hundreds of millions of people.

Humanity will have to learn to live with less water, according to Madani. With better water management, that's possible.

First, however, most countries need to simply start accounting for their water sources and consumption, starting with water meters in homes, wells and diversion canals.

"You're thinking about launching a [cloud-seeding] rocket to get water, but you don't even know how much water you have in your system," says Madani. "We cannot manage what we do not measure." ▮

Palaeontology

T. rex took 40 years to become fully grown

James Woodford

THE largest-ever analysis of *Tyrannosaurus rex* fossils suggests that the fierce Cretaceous predator was a late bloomer, taking 35 to 40 years to reach maturity.

The findings further the debate about whether there were several *T. rex* species and whether smaller specimens, once thought to be juveniles, are in fact a more diminutive species called *Nanotyrannus*.

Based on studies done two decades ago, it had been thought that *T. rex* reached its maximum weight of 8 tonnes in around two decades and that the animals probably only lived until they were 30 years old.

"The last big *T. rex* growth studies were done in the early 2000s, based on, at most, seven specimens," says Holly Ballard at Oklahoma State University.

This time, Ballard and her team were able to sample the thigh and shin bones of 17 individuals, ranging in age from juvenile to fully grown adults, making it the largest collection of growth data ever assembled on *T. rex*.

They studied bone tissue microstructure, including growth rings that form annually like those in a tree trunk. However, the earliest growth rings are destroyed as the bone marrow cavity gets larger, so the team needed access to as many specimens as possible with overlapping growth stages.

"That's why our sample size and age spread is so important and what makes it different from earlier studies," says Ballard.

The analysis reveals that *T. rex* grew more slowly than thought and its growth rate was variable depending on environmental conditions (*PeerJ*, doi.org/hbjx7f).

However, it isn't possible to determine the maximum age of *T. rex* because once the animals reached maturity, they ceased laying down growth rings. "We can say the most successful *T. rex* lived to about 40, but there were very few that made it to that age – only two specimens in our sample had reached adult size," says Ballard.

Another two specimens grew more slowly than the others, opening the possibility that they may be other species, such as *Nanotyrannus*, or part of a "Tyrannosaurus complex", says Ballard.

Lindsay Zanno at the North Carolina Museum of Natural Sciences says it is the most thorough examination of *Tyrannosaurus* growth yet. Her study of a dinosaur fossil from Montana, published last year, concluded that the specimen was a small tyrannosaur that was fully grown at about 20 years old, tentatively named *Nanotyrannus lancensis*.

"It's exciting to finally have a growth curve for *Tyrannosaurus* that we can feel confident in," says Zanno. ▮

Tyrannosaurus rex seems to have been a late bloomer

SHUTTERSTOCK/DZIUREK

Health

Body fat supports your health in surprisingly complex ways

Linda Geddes

IF YOU thought body fat was just a passive storage depot for calories, think again. Research suggests it plays an important role in our overall health, with two studies shedding light on its complexity.

Fat exists in several forms. For instance, there's white fat, which stores energy and releases hormones that influence metabolism; brown fat, which generates heat; and beige fat, which sits somewhere in between, switching on heat production under certain conditions. Even within these categories, location matters: fat under the skin is generally less harmful, while fat deep inside the abdomen – known as visceral fat – is strongly linked to inflammation and heart disease.

The latest research suggests fat actively helps regulate blood pressure and coordinate immune responses at key locations.

In one of the new studies, Jutta Jalkanen at Karolinska University Hospital in Stockholm, Sweden, and her colleagues mapped the cellular architecture of visceral fat from multiple locations within the abdomen. They found that epiploic fat, which wraps around the large intestine, is unusually rich in immune cells, as well as specialised fat cells that produce inflammatory proteins associated with immune activation (*Cell Metabolism*, doi.org/hbjsz5). Further experiments showed that microbial products originating in the gut trigger these fat cells to activate nearby immune cells.

"Our work shows that fat depots appear to be specialised according to their anatomical location, and those that sit right next to the intestine seem particularly adapted for immune interaction," says Jalkanen.

Although the study involved people with obesity, Jalkanen suspects that epiploic fat serves similar core functions in people of all body weights.

The second study reveals another unexpected role for fat: controlling blood pressure. Mascha Koenen at The Rockefeller University in New York and her colleagues set out to understand why obesity, characterised by excess white fat, is linked to high blood pressure, while brown and beige fat appear to be protective.

"Fat depots that sit right next to the intestine seem particularly adapted for immune interaction"

They focused on perivascular adipose tissue, a fatty layer rich in beige fat cells that surrounds blood vessels. In mice genetically engineered to lose their beige fat, blood vessels became stiffer and overreacted to everyday hormonal signals that constrict arteries, leading to elevated blood pressure.

The team traced this effect to an enzyme called QSOX1, released by dysfunctional fat cells. Blocking it prevented blood vessel damage and normalised blood pressure in mice, regardless of their body weight (*Science*, doi.org/qm8x). "What this nicely shows is that the communication between different organ systems is critical to understand complex diseases such as hypertension and blood pressure regulation," says Koenen.

The findings point to future therapies that focus on preserving or restoring fat's beneficial functions by targeting specific fat depots, modulating immune-fat communication or maintaining healthy beige fat activity. ▮

Space

Giving astronauts tardigrade powers could come at a cost

HOW can we protect space explorers from radiation without encasing spaceships in lead? Some suggest dosing them with the DNA-protecting protein from tardigrades – but it will be harder than we hoped.

Corey Nislow and his colleagues at the University of British Columbia in Vancouver have shown that a tardigrade-produced protein called Dsup, short for damage suppressor, can protect against an even wider range of mutation-inducing chemicals than we knew. But it has a trade-off: it reduces the fitness of cells and can even kill them. "There's a cost for every benefit that we've seen," says Nislow.

Tardigrades are tiny animals famed for their ability to survive stresses, including being exposed to the vacuum of space. When human cells were genetically engineered to produce Dsup, they became more resistant to radiation without any reported downsides.

This led to the idea that people could be protected against radiation and mutagenic chemicals by giving them Dsup. One way to do this would be to inject them with Dsup-encoding mRNAs encased in lipid nanoparticles.

But Nislow and his team has carried out extensive studies of yeast cells modified to produce Dsup. They found very high levels were fatal, and even lower levels impaired cell growth (bioRxiv, doi.org/qm8v).

SHUTTERSTOCK/OLEH LIUBIMTSEV

Tardigrades are famed for their ability to survive in extreme environments

Dsup appears to protect DNA by physically surrounding it, says Nislow, but this also makes it harder for proteins to access DNA to make RNA or to replicate the DNA before cell division. It is also harder for DNA repair proteins to access DNA – the team found that in cells with low levels of repair proteins, Dsup could be fatal, probably because crucial repairs didn't take place.

It may be possible to use Dsup to protect space travellers, says Nislow, but it will be crucial to ensure that Dsup is produced only in the cells where it is needed and at the right levels. ▮

Michael Le Page

Quantum computing

No quantum advantage here

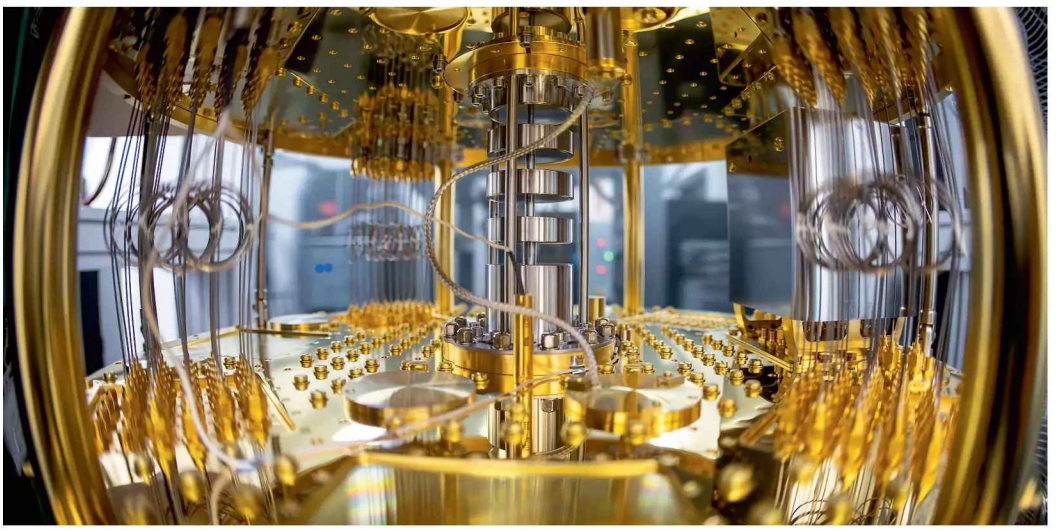
A problem so complex it was thought to require the use of a quantum computer may just have been solved by a conventional supercomputer, reports **Karmela Padavic-Callaghan**

AS QUANTUM computers continue to improve, identifying problems they can solve faster than the world's best conventional computers is increasingly important – but it turns out that a key task held up as a future goal by quantum proponents may not need a quantum computer at all.

The task in question involves a molecule called FeMoco, which plays a vital role in making life on Earth possible. That is because it is part of the process of nitrogen fixation, in which microbes convert atmospheric nitrogen into ammonia, making it biologically accessible to most other living organisms. How exactly FeMoco works during this process is complicated and not fully understood, but if we could crack it and replicate it on an industrial scale, it could drastically cut the energy involved in producing fertilisers, potentially leading to a boost in crop yields.

One key aspect of understanding FeMoco is determining its lowest, or "ground-state", energy, which involves accounting for the behaviour of its many electrons. But electrons are quantum particles that can behave in wave-like ways and occupy many different regions called orbitals. This complexity is why computing lots of FeMoco's properties has, so far, been intractable with conventional computers.

Researchers have had some success using approximation methods, but the accuracy of their energy estimates was limited. On the other hand, mathematical investigations have rigorously proven that quantum computers, which encode this complexity in a fundamentally different manner, could solve the problem without approximations – a well-established example of so-called quantum advantage.



CTK/ALAMY

Quantum computers continue to advance – but may not be needed for everything

But now, Garnet Kin-Lic Chan at the California Institute of Technology and his colleagues have found a conventional computing method that seems to be able to reach the same accuracy as a quantum one. The key metric has been the idea of "chemical accuracy", or the minimal accuracy required to make realistic predictions for chemical processes. Based on their computations, Chan and his colleagues argue that conventional supercomputers can calculate FeMoco's ground-state energy to that accuracy too (arXiv, doi.org/qm8t).

"The researchers estimated that the supercomputer method may even be faster than quantum ones"

FeMoco has many quantum states, each of which has its own energy, and they are arranged on something like a ladder with the ground state at the very bottom. To make reaching that bottom rung more amenable to classical computer algorithms, the team focused on what we know about states that sit on nearby rungs and what their properties imply about what can exist a step or two below. This included, for example, insights about symmetries of electrons' quantum states.

Ultimately, the simplification let the researchers use classical algorithms to calculate upper bounds for FeMoco's ground-state energy, then mathematically extrapolate them to an energy value with an uncertainty that matches chemical accuracy. In other words, their final answer for what the molecule's lowest energy can be ought to be precise enough to use in future studies.

Time will tell

They also estimated that the supercomputer method may even be faster than quantum ones, performing calculations in less than a minute that would take 8 hours on a quantum device – though this estimate assumes an ideal supercomputer performance.

So, does that mean we will soon understand FeMoco well enough to boost agriculture? Not quite – there are still many unanswered questions about, for instance, which parts of the molecule interact with nitrogen the most or what molecules may be produced as intermediate steps in the nitrogen-fixation process.

"The work doesn't really tell us much about the FeMoco system in terms of its function, but as a model to show quantum advantage, it does place the bar even higher for quantum approaches," says David Reichmann at Columbia University in New York.

Dominic Berry at Macquarie University in Sydney, Australia, says classical computers are still only capable of approximation, while quantum methods guarantee the problem can be solved in full.

"This does challenge the argument for using quantum computers for problems like this, but for more complicated systems, it is expected that the computation time for classical methods will increase much faster than that for quantum algorithms," he says.

Climate change

Climate impacts could cost trillions

We may have underestimated the rate of warming, and its effect on the world economy, as the annual rate of emissions continues to increase, discovers **Alec Luhn**

THE impacts of climate change are occurring sooner than expected, but governments and businesses continue to underestimate the risks, which could add up to trillions of dollars in economic losses by 2050.

A report by climate scientists and financial experts has warned that the world may have seriously underestimated the rate of warming and faces "planetary insolvency", where global warming begins to severely damage both the environment and economic growth.

Decision-makers typically focus on the middle-ground estimates of climate impacts. But they should be preparing for the worst-case scenarios instead, the report says, since impacts like short-term precipitation extremes in some regions are happening earlier than anticipated.

"Governments need to agree on a planetary solvency plan quickly," says David King, former top climate adviser to the UK government who contributed to the report. "We are looking at an accelerated rate of temperature rise. We're not sure if that will continue into the future but we can probably assume it's not going to relax backwards."

A first step towards such a plan could be to stop assuming the world economy will keep expanding, says Sandy Trust at UK investment management firm Baillie Gifford, an author of the new report. According to the Network for Greening the Financial System, global GDP could fall by 25 per cent with 2°C of warming by 2050. This would mean up to $25 trillion in economic losses annually due to climate-related impacts, says Trust. But the network says it doesn't foresee a recession, since it expects global economic growth to outpace those damages.

"This is Titanic risk modelling, looking backwards from the deck of the Titanic in April 1912 and predicting a smooth voyage," says Trust. "This fails the first principles of risk management: how to have a best guess about the worst case."

Call to action

The call to plan for the worst comes as a report by the European Union climate body Copernicus finds 2025 was the third-warmest year on record after 2023 and 2024, with an average temperature of 1.47°C above pre-industrial levels. Because 2024 was 1.6°C higher, for the first time, the three-year average was more than 1.5°C above pre-industrial temperatures.

That's another step towards the 20-to-30-year average needed to fail the Paris Agreement goal of keeping warming below the 1.5°C threshold. When the agreement was signed a decade ago, 1.5°C was predicted by 2045. But if the trend over the past 30 years continues, we will breach that threshold by 2030, according to Copernicus.

The rate of warming has been quickening. Many scientists attribute that to the decline in sulphur-containing air pollution from coal power and shipping. As the skies have cleared, more of the sun's heat has been reaching Earth's surface, "unmasking" about 0.5°C of warming.

But the biggest reason we could surpass 1.5°C sooner than expected is because emissions have continued to increase each year, says Samantha Burgess at Copernicus. Fossil fuel emissions set yet another record in 2025.

Every tenth of a degree of warming will result in more frequent and intense extreme weather. Already, the Los Angeles wildfires in January 2025 – potentially the costliest natural disaster in US history – were twice as likely and 25 times larger due to climate change. Hurricane Melissa, the strongest storm to make landfall around the Atlantic Ocean, was associated with wind speeds at least 16 kilometres per hour faster than would be expected without climate change.

"Because this is a global average, the reality is that when we have 1.5 degrees of warming at a global level, that means that heatwaves are often 3 or 4 or even 10 degrees warmer than they otherwise would have been," says Burgess.

The greatest warming is at the poles due to feedback loops like the loss of reflective snow and ice, which allows more of the sun's heat to be absorbed. Last year was the warmest year on record for Antarctica due to a rare stratospheric heating event. Combined sea ice extent in the Arctic and Antarctica reached a record low.

$25tn
Estimated annual economic losses due to climate change by 2050

But in a positive sign, global emissions aren't rising as quickly as they once were, and China's emissions have flatlined.

"Because of this flattening of emissions of CO_2, then we would expect warming to continue but without acceleration, just continue at the same rate," says Timothy Osborn at the University of East Anglia, UK.

Cracking down on methane leaks from infrastructure like gas pipelines and old coal mines could be a quick short-term fix, says King. Cutting methane emissions by 30 per cent this decade could reduce warming at least 0.2°C by 2050.

"We need all the slow fixes as well, but this is a critical part of the pathway," says King. "Because, frankly, the overshoot above 1.5°C is a major challenge to humanity." ▮

To read more about the 1.5°C target, turn to page 39

The 2025 wildfires in Los Angeles were more damaging due to climate change

APU GOMES/GETTY IMAGES

Space

Distant 'little red dot' galaxies may contain baby black holes

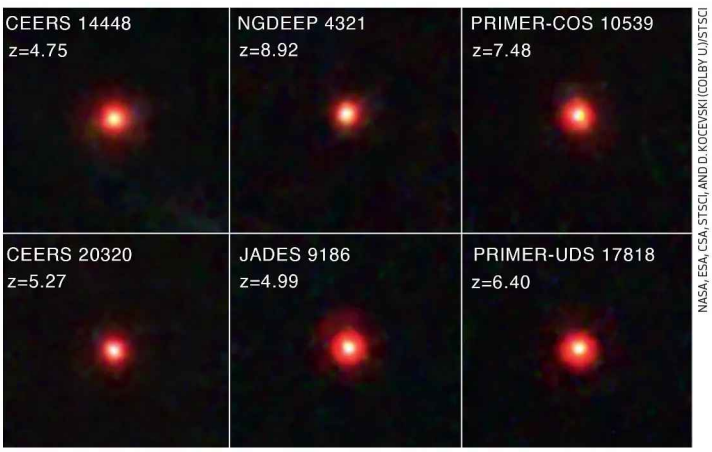
Alex Wilkins

IMPOSSIBLY bright galaxies discovered by the James Webb Space Telescope (JWST) may not be so bright after all. These galaxies once threatened to upend our understanding of the cosmos by suggesting it contained monstrous black holes or far more stars than we had anticipated, but astronomers now think the galaxies might actually contain "baby" black holes instead.

In its first few years scanning the early universe, JWST unexpectedly discovered hundreds of very red and extremely bright galaxies, which astronomers called "little red dots" (LRDs).

The amount of light coming from these galaxies suggested that they contained either a density of stars far greater than any galaxy we know of, or black holes that were far more massive than astronomers thought possible given the size of their host galaxies.

Both of these scenarios would have required significant adjustments to our models of galaxy formation and black hole growth in the early universe.



NASA, ESA, CSA, STScI, AND D. KOCEVSKI (COLBY U./STSCI)

These "little red dots" are all bright galaxies spotted by the James Webb Space Telescope

But these conclusions also rested on the assumption that the LRDs' red colour was due to an abundance of dust, either around the black hole itself or surrounding the stars, because that is what is typically found in the very red galaxies of our local universe. However, recent research found a lack of evidence that LRDs contain dust after all.

Jenny Greene at Princeton University and her colleagues think that this finding means we need to reconceive what LRDs are. "We were sure that we could detect the dust emission, if indeed they were red because of dust, and then we did not find that emission at all," says Greene. "That was the big clue that our assumption that they're dusty is just wrong, that's not why they're red."

Previous observations had inferred the total brightness of LRDs by measuring a specific single frequency of light, associated with the element hydrogen, which can then be used to calculate the total brightness, based on typical models of how dust affects this light.

In a new analysis, Greene and her team directly measured the total light emissions from two LRD galaxies by looking at many different frequencies of light, including X-rays and infrared. They found that for most frequencies, apart from visible light, there was much less light being emitted than for typical galaxies, suggesting that the LRDs were at least 10 times dimmer than initial estimates suggested (*Astrophysical Journal*, doi.org/qm5n).

"If there's actually not as much light there as we thought, the black hole masses are probably much more modest," says Greene.

Because the light emissions suggest the black holes contain relatively little mass compared with standard black holes, team member Rohan Naidu at the Massachusetts Institute of Technology says we can think of them as "baby black holes." He adds that this also fits with an emerging picture that the black holes in the LRDs are actually black hole stars – a special class of black hole surrounded by gas.

"In ordinary black holes, what you actually see with your eyes is the tip of the iceberg of the total energy that is coming out of the system, but the little red dots we now understand should really be thought of as these puffed-up black hole stars," says Naidu.

"If there's not as much light there as we thought, the black hole masses are probably more modest"

But Roberto Maiolino at the University of Cambridge says that we can't be sure about the masses of black holes in the LRDs, because the light being emitted from a black hole tells us about its rate of growth, not about its total mass. ▮

Faint star may be a failed supernova

Black holes come in different sizes (see main story) and can form in different ways. One idea is that a particularly massive star could collapse in on itself to form a black hole, rather than exploding in a supernova, and we might now have seen that process in action.

In 2024, Kishalay De at Columbia University in New York and his colleagues observed an unusually bright star called M31-2014-DS1 in the nearby galaxy Andromeda that was around 20 times as massive as our sun. The star appeared to grow brighter in 2014, before becoming dramatically dimmer between 2017 and 2020.

Now, De and his team have observed this star with the James Webb Space Telescope (JWST) and the Chandra X-ray Observatory, finding a faint, red object where the star once was that is around 8 per cent as bright as the original star and shrouded in a cocoon of dust moving rapidly outwards (arXiv,doi.org/qnmjand). This fits with what astronomers think a failed supernova making a black hole would look like.

But in a separate study, Emma Beasor at Liverpool John Moores University, UK, and her colleagues found the observations could just as easily be the result of two stars merging (arXiv, doi.org/qnmk).
AW

Palaeontology

Woolly rhino genome holds clues to its demise

James Woodford

STOCKTREK IMAGES, INC./ALAMY

A GENOME reconstructed from a tiny piece of flesh found in the stomach of a wolf pup that died 14,400 years ago suggests that woolly rhinos were still genetically healthy even as they faced imminent extinction.

No one will ever know how a young female wolf pup died at a site near what is now the town of Tumat in northern Siberia, Russia. But it is most likely that she and her sister had just been fed the meat of a woolly rhinoceros (*Coelodonta antiquitatis*) by their mother when their den collapsed, entombing the siblings in permafrost.

The first of the puppies was found at the site in 2011 and the second in 2015. A dissection of the stomach contents of one of the puppies yielded a piece of woolly rhino flesh.

Edana Lord at Stockholm University in Sweden, a member of the team that studied the fragment, says it looked "like a piece of jerky with a bit of fluff".

From that, Lord and her colleagues were able to reconstruct the woolly rhino's genome and determined that it was a female with no signs of inbreeding in the DNA (*Genome Biology and Evolution*, doi.org/qm2w).

What caused the extinction of the woolly rhino has long been a source of debate

This finding is very important, she says, because this is the first time that scientists have recovered genetic material from a woolly rhino so close to the date it vanished, just a few centuries later.

It has long been debated what led to the extinction of the woolly rhino – human hunting pressure, climate change or simply that inbreeding meant that the species was no longer thriving.

Another member of the team, Love Dalén, says they compared this woolly rhino genome with two others – one around 18,000 years old and the other at least 49,000 years old – and found no change in genetic diversity or inbreeding levels through time.

"If there had been a population decline, we would have seen lower diversity and higher inbreeding in the 'stomach rhino'," says Dalén.

Instead, the team says the most likely cause of extinction was a rapid period of climatic warming between 14,700 and 12,900 years ago called the Bølling-Allerød interstadial, which would have led to dramatic changes in the woolly rhino's habitat. ▮

Space

Earliest known supernova sheds light on first stars

Alex Wilkins

ASTRONOMERS have caught a massive star exploding just moments after the universe emerged from the cosmic dark ages, illuminating how the first stars were born and died.

When stars run out of fuel and explode, they produce a burst of powerful light called a supernova. Supernovae can look extremely bright in our local universe, but the light from a star exploding in the early universe can take billions of years to reach Earth, by which time it has dimmed.

Because of this, astronomers can typically only see very distant supernovae in special cases, such as type Ic supernovae, which are stellar cores that have lost their outer gas and produce an exceptionally bright burst of gamma rays. Type II supernovae, which are the most common stellar explosions we see in our galaxy and occur when a massive star runs out of fuel, are normally too faint to see.

"We can see this star at a distance where we've never seen an isolated supernova"

Now, David Coulter at Johns Hopkins University in Maryland and his colleagues have spotted a type II supernova called SN Eos from when the universe was just a billion years old, using the James Webb Space Telescope.

The stellar explosion was fortunately placed behind a massive cluster of galaxies, whose powerful gravity magnified its light and made it tens of times brighter than it would normally appear.

The researchers analysed the spectrum of light coming from SN Eos, making it the earliest supernova to be confirmed using spectroscopy. The results clearly show it is a type II supernova, which means it must have come from a massive star (arXiv, doi.org/qm76).

It also shows that the star that produced it had very low amounts of elements other than hydrogen or helium – less than 10 per cent of the amounts in our sun. This is how astronomers think the early universe looked, because there hadn't been much time for multiple generations of stars to form and die and produce heavier elements.

"That tells us immediately about what kind of stellar population [the star] exploded in," says Or Graur at the University of Portsmouth, UK.

When we see light at these distances, it is typically from small galaxies, where you can infer average properties of what stars might be in those galaxies. But studying individual stars at these distances is typically not possible, says Matt Nicholl at Queen's University Belfast, UK.

"We can see this individual star, with beautiful data, at a [distance] where we've never seen an isolated supernova," he says.

This would have been just a few hundred million years after a period in the universe's history known as the epoch of reionisation, says Graur. That was when light from the first stars began to strip electrons from neutral hydrogen gas, which blocks most forms of radiation, and turned it into ionised hydrogen, which is transparent. Before this, the universe was opaque, so SN Eos is effectively as distant a supernova as we might hope to see. ▮

Tiny tweaks may mean a longer life

Getting just a few more minutes of sleep and exercise per day, plus eating an extra half-serving of vegetables, could add a year to your life, finds **Carissa Wong**

IF YOU are hoping to boost your health this year, there is some good news: making even small tweaks to your sleep, diet and exercise habits could have a big impact on your longevity.

"Just around 5 extra minutes of sleep per day, about 2 minutes more of moderate-to-vigorous physical activity – like a brisk walk or taking a flight of stairs – combined with just an extra half-serving of vegetables per day is linked to an additional 1 year longer lifespan," says Nicholas Koemel at the University of Sydney, Australia.

It is no surprise that getting enough sleep, exercising and eating well are crucial to a long life. But it was unknown how very small lifestyle changes affect our lifespan and healthspan, which is the number of years spent in good health.

To fill this gap in our knowledge, Koemel and his colleagues analysed sleep, dietary and physical activity data from nearly 60,000 adults, aged between 40 and 69, from the UK Biobank project. The participants completed surveys that asked them to recall how often they ate various types of food, such as fresh fruit or processed meat, over the past year – with their diets being ranked from poor to healthy on a scale of 0 to 100. A few years later, they wore movement trackers on their wrist for a week to measure their exercise and sleeping habits, and their mortality and health records were tracked over a subsequent follow-up period of eight years.

"When we package lifestyle changes together, we get more bang for our buck"

Using these measurements, the researchers pinpointed the bottom 5 per cent of participants with the least healthy lifestyles: they slept for around 5 hours each day, engaged in about 5 minutes of moderate-to-vigorous physical activity daily and scored about 35 on the dietary scale, on average.

The researchers then used a statistical model to estimate that, compared with these least-healthy participants, those who slept for about 5 minutes more each day, engaged in moderate-to-vigorous exercise for about 2 minutes longer and ate the equivalent of an extra half-portion of vegetables daily lived for a year longer, on average (*The Lancet, eClinicalMedicine*, doi.org/qm2s).

This combination of small lifestyle changes had the same effect as making larger shifts in only one aspect of lifestyle – for instance, sleeping for 25 minutes longer without altering exercise or diet, says Koemel. "When we package lifestyle changes together, we get more bang for our buck and we reduce the overall requirement from any one behaviour."

The findings support a second study published this week, which analysed mortality and exercise data – measured via movement trackers – from more than 40,000 people, aged 64, on average, across Norway, Sweden and the US. Ulf Ekelund at the Norwegian School of Sport Sciences in Oslo and his colleagues fed this data into a statistical model and predicted that, if the vast majority of the population in those countries – except for the most active 20 per cent of people – engaged in an extra 5 minutes of moderate-to-vigorous exercise per day, about 10 per cent of deaths could be prevented in the following eight years, on average (*The Lancet*, doi.org/qm2t).

But both studies have some limitations. For instance, dietary recall surveys are prone to error because people forget what they have eaten, and it is impossible to know whether a week of physical activity or sleep data is really representative of someone's general habits over longer periods, says Alan Cohen at Columbia University in New York.

KRISTINA BLOKHIN/ALAMY

Moderate exercise – like walking up a flight of stairs – can have a big impact

Eating meat could help people reach 100

Your diet can affect your longevity (see main story), and a study in China has revealed that most centenarians there eat meat, which may be particularly helpful for those who are underweight.

To better understand the link between diet and longevity, Kaiyue Wang at Fudan University in Shanghai and her colleagues gathered data from a centralised Chinese health database on people older than 65.

They investigated the database's 5203 participants, who were at least 80 years old in 1998 and free of cardiovascular disease, diabetes and cancer. Of these, about 80 per cent said they were meat-eaters, while the others ate plant-based diets.

Of the vegetarians who had a body mass index below 18.5 (defined as being underweight) in 1998, 24 per cent reached 100, compared with nearly 30 per cent of the underweight meat eaters, with the odds seeming to rise further if they reported eating meat every day (*The American Journal of Clinical Nutrition*, doi.org/qm8k).

A meat-rich diet has been linked to obesity, but research supports animal proteins for building stronger muscles and bones, which may be helpful for people who are underweight, says Wang.

Christa Lesté-Lasserre

Mathematics

AI solves historical maths problems

ChatGPT has helped people untangle problems that previously eluded professional mathematicians, potentially changing the entire field, reports **Alex Wilkins**

AMATEUR mathematicians are using artificial intelligence chatbots to solve long-standing problems, in a move that has taken professionals by surprise. While the problems in question aren't the most advanced in the mathematical canon, the success of AI models in tackling them shows their mathematical performance has passed a significant threshold, say researchers, and could change the way we do mathematics.

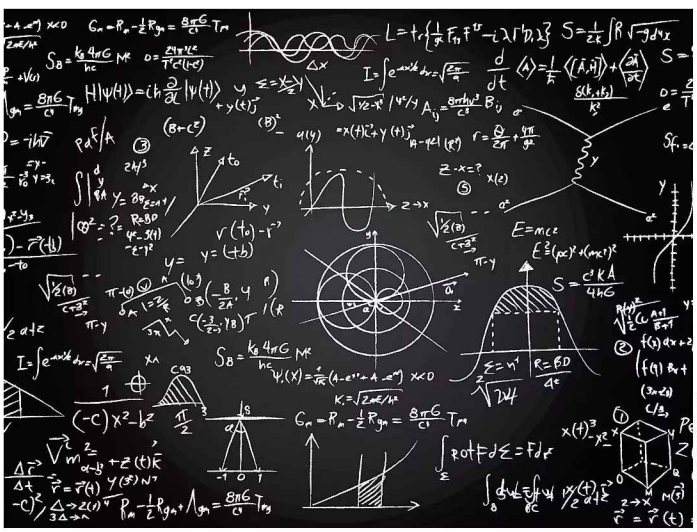
The questions being solved by AI originate from the mathematician Paul Erdős, who was famous for his ability to pose useful but difficult questions during a career that spanned over six decades. "The questions tended to be very simple, but very hard," says Thomas Bloom at the University of Manchester, UK.

By his death in 1996, there were more than 1000 of these unsolved Erdős problems, covering a wide range of mathematical disciplines, from combinatorics (the study of combinations) to number theory. Today, they are seen as signposts for progress in these fields, says Bloom, who runs a website that catalogues the problems and tracks mathematicians' progress in solving them.

Because Erdős problems are often simple to state, mathematicians began experimenting with feeding them to AI tools like ChatGPT. Bloom says that in October last year, he began seeing people use AI models to find relevant references in the mathematical literature that helped with their solutions.

Soon after, AI tools began finding partial improvements to results, some of which had been found in past papers, while others appeared new.

Inspired by this progress, Kevin Barreto, an undergraduate mathematics student at Cambridge University, and Liam Price, an amateur mathematician, began looking for simple and understudied Erdős problems that they might solve with AI. After finding one such problem, number 728, a conjecture in number theory, they fed it to ChatGPT-5.2 Pro to solve it.



ANDRESR/GETTY IMAGES

Could we soon see mathematicians swap chalkboards for chatbots?

Show your working

"I looked at the statement, and thought, 'This one might be able to get solved by ChatGPT, so let's try it,'" says Barreto. "Sure enough, it comes back with an argument that's quite nice and that a lot of people would actually agree was rather sophisticated."

After ChatGPT produced a proof, Barreto and Price used another AI tool called Aristotle, created by the AI company Harmonic, to verify their work. Aristotle converts the conventional language proof into one written in Lean, a mathematical programming language. It can then be instantly checked by a computer for correctness. This is an important step, says Bloom, as it saves the limited time researchers have to check whether a result is correct.

As of mid-January, six Erdős problems have been fully solved by AI tools, though subsequent scrutiny by professional mathematicians revealed that five of these problems had previously been solved in the mathematical literature. Only one problem, number 205, has been fully solved by Barreto and Price with no pre-existing solution. AI tools have also enabled small improvements and partial solutions to seven other problems that don't appear to be pre-existing in the literature.

As a result, there is an ongoing debate about whether these tools

> **"I looked at the statement, and thought, 'This one might be able to get solved by ChatGPT'"**

are really proving new ideas, or merely digging out old and forgotten solutions.

Another question is just how far this approach can go. All of these problems aren't the most demanding in mathematics, and could perhaps be accomplished by a first-year PhD student, but that is still impressive, says Bloom. "To me, it's incredible that AI is capable of that, because this takes non-trivial effort."

Barreto also says that the problems being solved are relatively straightforward, even when compared with more difficult Erdős problems, which current AI models fall short of solving. "Once [AI] gets through the low-hanging-fruit problems, a lot of them are going to need more capable models," he says. Some of the hardest problems have prize money set aside for anyone who can solve them, but Barreto thinks that is unlikely to happen soon: "Some people are trying to do bounty problems, and to me that's kind of nuts. I don't think the models are there yet."

Solving Erdős problems using AI is promising progress, says Kevin Buzzard at Imperial College London, but because most of the problems it is solving are either relatively straightforward or have had little attention, it makes it hard to gauge whether it is a significant achievement – or something that should concern professionals. "That is progress, but mathematicians aren't going to be looking over their shoulders just yet," says Buzzard. "It's green shoots."

But even if the models' capability stays static, their ability to handle relatively complex mathematics could fundamentally change how researchers research and write proofs, says Bloom, because it will allow mathematicians who have limited knowledge of areas outside their particular discipline to draw on other fields. ▮

Archaeology

You wouldn't want to use Pompeii's public baths before the Romans arrived

Colin Barras

A TRIP to Pompeii's public baths meant taking a dip in water contaminated with sweat and urine – until the Romans took over and sanitation improved.

For a large chunk of its history, Pompeii was occupied by the Samnite people. It only became a Roman colony after 80 BC,

"Contamination must have taken place from sweat, oily sebum produced by the skin and even urine"

about 160 years before the eruption of Mount Vesuvius.

Like the Romans, the Samnites seem to have been keen on bathing. They built at least two public baths – now known as the Stabian Baths and the Republican Baths – sometime after 130 BC.

Gül Sürmelihindi at the University of Mainz in Germany and her colleagues have now analysed mineral deposits in the bathhouses to gain a clearer insight into the quality of the water that once filled their bathing pools.

It turns out that the water quality could have been better. "Water in the hot pool of the Republican Baths had low stable carbon isotope values, indicating the presence of abundant organic matter," says Sürmelihindi.

Significantly, when the team analysed mineral deposits in the 40-metre-deep wells that fed the pools, they found little sign of organic matter. "It means that the contamination must have taken place in the pools," says Sürmelihindi – almost certainly from sweat, oily sebum produced by the skin and even urine.

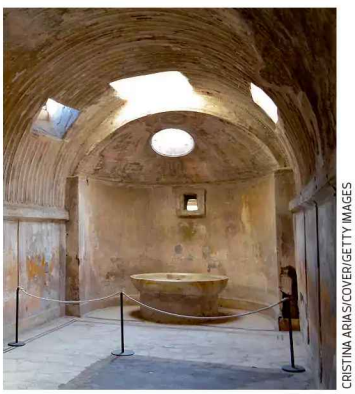
Pulling water from the deep wells using a system of buckets was slow work. The researchers estimate that only between 900 and 5000 litres could have been drawn each hour. This was enough to replenish the water in the baths just once or twice per day.

But within a few decades, the Romans had built an aqueduct to supply Pompeii with water from natural springs about 35 kilometres to the north-east of the city.

The researchers estimate the aqueduct supplied Pompeii with 167,000 litres of water each hour – enough to replenish the baths far more frequently (*PNAS*, doi.org/hbjss8).

However, this doesn't necessarily mean that Pompeiians enjoyed a health boost from the aqueduct. Before its construction, most people drank rainwater collected in tanks connected to the roofs of the city's buildings. Later, many got their drinking water from the aqueduct via a network of lead pipes that ran throughout the city. Lead, a poison that can damage the brain, could then leach from the pipes and into the water.

The contamination should have lessened over time, as mineral deposits coated the inside of the pipes so water was no longer in contact with the lead. But some think that when sections of the city's plumbing were repaired with fresh piping, contamination would spike.



CRISTINA ARIAS/COVER/GETTY IMAGES

Inside what remains of one of Pompeii's public baths

"Pompeii's elite were probably better off, since they lived in houses with large atria with inward-sloping roofs that funnelled rainwater into a cistern," says Duncan Keenan-Jones at the University of Manchester, UK. "Poor people who may have lived in their shops were more reliant on the lead-contaminated water."

Marine biology

Long-living sharks seem unaffected by diseased hearts

GREENLAND sharks are thought to live between 250 and 500 years – but their hearts show signs of severe age-related disease even when the sharks are just 150 years old.

Some parts of the shark's body, such as the eyes, seem impervious to ageing and to cancer, which might have suggested the marine predator's heart is also protected from age-related decline. But an analysis has found that Greenland sharks (*Somniosus microcephalus*) actually show signs of serious heart disease – and yet there is no apparent loss of function or reduction in the species' lifespan (bioRxiv, doi.org/qm2m).

DOUG PERRINE/NATUREPL.COM

Some parts of the Greenland shark's body appear to withstand ageing

Alessandro Cellerino at Scuola Normale Superiore in Pisa, Italy, a member of the research team, says he found the results of the analysis of six Greenland sharks – four females and two males, all over 3 metres long – "truly astonishing".

Based on their length, the team estimates that all six specimens were between 100 and 150 years of age. The team ran a range of microscopy tests on the animals' hearts, including high-resolution fluorescence and electron microscopy.

"We discovered that the Greenland shark heart is highly fibrotic, and full of the ageing markers lipofuscin and nitrotyrosine," says Cellerino.

In a human, a high level of fibrosis, or scarring of the heart tissue, is a common indicator of age-related heart diseases and potential heart failure.

However, says Cellerino, "massive accumulation" of lipofuscin linked to damage to cell mitochondria appears to be benign and doesn't impair the shark's lifespan.

The presence of high levels of nitrotyrosine, another heart disease indicator signifying inflammation and oxidative stress, suggests the shark may have evolved strategies to tolerate chronic oxidative damage "rather than simply minimising it".

James Woodford

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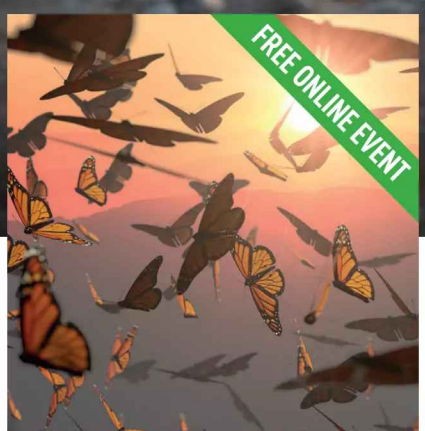

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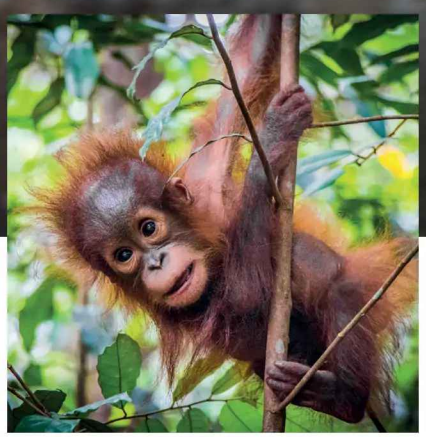

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24 August 2026

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Views

Comment

Changing direction

We thought we could "nudge" people into making the world a better place. We were wrong, say **Nick Chater** and **George Loewenstein**

OUR environmental and social problems are pressing and, in many countries, money is short and politics deadlocked. Wouldn't it be wonderful if there turned out to be a new way of making real progress cheaply and without getting enmeshed in party politics?

About two decades ago, along with many of our colleagues in the behavioural sciences, we thought there might be. The idea was elegant: social problems often arise from people making the "wrong" choices, either for themselves (eating unhealthily, smoking, gambling – the list goes on!) or for others (by, for example, damaging the environment by dropping litter). The old-fashioned approach to bad choices is to tax them or ban them. But the new strategy aimed for a gentler, more psychologically subtle approach: to redesign the way options are presented so the "right" choice becomes easy, natural and appealing. The bad choices are still available, but the clever policy ensures they are picked less often.

Such "nudges" seemed to offer the hope of addressing big social problems through small changes to reshape individual behaviour. Worried about rising obesity? Try smaller portion and plate sizes, and move the salad bar to the front of the cafeteria. Concerned about climate change? Put homeowners on "green energy" by default.

For a while, it appeared that a nudge revolution might be on the cards. An army of researchers (including us) searched for small tweaks to "choice architecture" that could drive changes in individual behaviour and make a big difference for society. Now was our chance to use psychological insights for a better world.

ADRIÀ VOLTÀ

If only. Nearly 20 years on, the results have been few and disappointing: even where nudges work, their effects are small, fade quickly and typically don't scale up. And it turns out that by reinforcing the idea that social problems should be seen through the lens of individual behaviour, researchers have inadvertently provided ammunition for powerful business interests that oppose the old-fashioned (but effective) policy tools of tax and legislation that fundamentally change the system of rules and incentives that shape society – and could threaten their bottom line.

With hindsight, none of this should have surprised us (though it did). The social problems we face have arisen not from changes at the individual level, given human psychology is surely largely constant over history. Instead, they have resulted from seismic systemic changes, such as mechanisation and electrification powered by coal, oil and gas over two centuries, or the rise of ultra-processed foods over the past 40 years. These shifts aren't the responsibility of individuals – and individuals, however well they may be nudged, can't alone fix the problems of carbon emissions or unhealthy diets. Indeed, there is a real danger that the individual focus is a distraction, misleading policy-makers and citizens alike into thinking there is a viable alternative to those laws and taxes.

If we are right, we might expect corporations fighting regulation to be particularly active in inventing ineffective but plausible-sounding individual-level solutions. But wait – this has already happened. Consider the personal "carbon footprint", to help us track our individual damage to the planet. Where did this idea come from? The UN? Greenpeace? No, it came from a huge ad campaign in the early 2000s from one of the world's largest fossil fuel companies, BP.

Whatever the social or environmental problem, opponents of systemic change want to push that problem back to the individual. As behavioural scientists, we have fallen into the trap. No longer. ▮

Behavioural scientists Nick Chater and George Loewenstein's new book is *It's On You*, out on 27 January

This changes everything

The lonely internet crowd

Almost 80 years ago, sociologists identified a new personality type that is particularly sensitive to loneliness. It's even more relevant today, says **Annalee Newitz**

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

Annalee's week

What I'm reading
Notes From a Regicide, *by Isaac Fellman, a fantastical tale of rebellion and family drama.*

What I'm watching
Heated Rivalry, *because I know how to have fun.*

What I'm working on
Researching Sogdiana, my favourite ancient diaspora culture.

This column appears monthly

RIGHT now, I'm glued to my phone. Like most people in the US, I get my news from various apps – social posts, podcasts, newsletters – and when things are blowing up (literally) I can't look away. People in Minneapolis are posting video updates from protests; experts are publishing essays about international law and the US attack on Venezuela. I have to consume them all! The weirdest part, though, is that the more I watch and read what other people are saying, the lonelier I feel.

This is hardly a new or unique experience. Sociologists have been talking about it for nearly 80 years. In 1950, scholars David Riesman, Nathan Glazer and Reuel Denney published a book called *The Lonely Crowd*, in which they argued that the rise of consumerism and mass media had led to a new kind of personality type that is deeply sensitive to loneliness. They called this personality "other-directed", and their descriptions feel startlingly prescient in our era of social media and AI chatbots.

Other-directed people are constantly attuned to what everyone around them is doing, using the preferences of their peer groups to decide what to buy, wear and think. Because their values come from peers, rather than elders or ancestors, they tend to be present-oriented and unconcerned with history. Riesman and his colleagues warned that other-directed people are obsessed with conforming, anxious to be "part of a crowd" and "having fun". What other-directed people fear more than anything is being alone.

All of these personality traits are immediately recognisable to people dealing with social media, with its peer pressure, parasocial relationships with influencers and – especially these days – surveillance capabilities. We are always watching each other and being watched. And because we fear being alone, companies produce apps designed to fool us into thinking we aren't. That's one of the insidious things about AI chatbots, some of which are designed to act like friends.

There's a paradox in every other-directed person's heart. As much as we may want to conform, to be part of the group chat, we also want to feel like we are unique. Riesman and his colleagues explained that consumerism itself assuages this other-directed anxiety by offering "false personalisation". You experience this when you find yourself choosing between six virtually identical polo shirts at the store. Picking one might make you feel that there's a special brand out there just for you, but, fundamentally, all those shirts are the same. You wind up wearing a polo shirt just like everybody else.

> "When we cobble ourselves together out of what we think other people want, we hide from something crucial"

This kind of false personalisation shows up all the time in the algorithms that shape our experiences online. TikTok and other apps have a "for you" feed full of videos that feel tailor-made for your specific tastes. And yet it is shaped by an algorithm that you don't control, whose purpose is largely to keep your eyeballs glued to the same app that everyone else is glued to. It is "for you" in the service of conformity.

As other-directed people, we are invited to express ourselves mainly by participating in peer groups or by "joining the conversation", as so many ads suggest. We turn ourselves into internet content, adding our words and videos to the morass of others online. Be yourself by showing that you are doing what everybody else is doing!

And yet we still feel lonely. Partly that's because in-person friendships and communities are fundamentally different from online ones. But something else is going on here, and I think it has to do with the personality shifts chronicled in *The Lonely Crowd*. When we cobble ourselves together out of what we think other people want, we hide from something crucial: our own truly personal, messy, eccentric, non-conformist desires. We can't connect with other people in a genuine way if we don't know ourselves.

Riesman and his co-authors suggested two solutions to this other-directed problem. First, we need to take back our leisure hours from the hyper-consumerist sphere of media. All that effort we put into paying attention to our peers is too much like work, they argued, and we need more free play. Which brings me to their second suggestion, which is that people – and especially kids – should test out new identities and experiences. Figure out what you enjoy when nobody is telling you what "fun" is supposed to be. Do something you have never done before. Wear something dramatic or silly. Strike up a conversation with a neighbour you have never met. Surprise yourself. And see how it feels to just... experiment.

You won't figure out who you are from a "for you" feed or a chatbot. So get off your phone, do something unexpected and be yourself for a while. ▮

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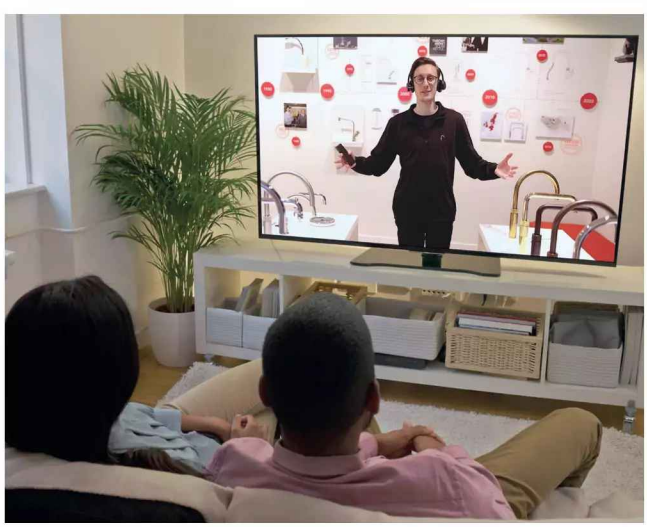

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Monkey magic

Photographer Frédéric Noy
Agency Panos Pictures

A YOUNG yellow baboon (main image) looks out over the Udzungwa Mountains National Park in Tanzania. The Udzungwa mountains are covered by very rich rainforests, but their remoteness means the area was relatively unexplored by biologists until recently.

There are six species of primate living in the park, and for two – the Udzungwa red colobus and the Sanje crested mangabey – the park is their last refuge. Another animal found here, the kipunji monkey, was only recognised as a new species in 2003 – the first new monkey species discovered in Africa since the 1980s.

"To me, it was kind of magic," says photographer Frédéric Noy, who has taken a series of images of the region. It's not so surprising that we are still discovering new species of fish in the deep sea or tiny insects on land, he says. "But mammals, wow!"

On one side of the mountains, native trees are being planted in deforested areas as part of a project known as the Udzungwa Corridor. The aim is to link the Udzungwa Mountains National Park to another reserve nearby.

The work is being funded by selling carbon credits, allowing local people to earn money if they agree to plant trees on their land. The top photo, near left, shows part of one of the nurseries raising trees for the project, alongside some other plants.

Many people around Udzungwa maintain beehives (below). The main reason is to provide extra income, but the hives are thought to deter elephants. There are no elephants living in the park itself, says Noy, but they do sometimes wander in from nearby areas.

Michael Le Page

The wildest of rides

An enthralling book reveals how genetics has rewritten the intertwined story of horses and humans, finds **Christa Lesté-Lasserre**

Book

Horses

Ludovic Orlando (translated by Teresa Lavender Fagan)

Princeton University Press

IT IS in the epilogue of his latest book that equine geneticist Ludovic Orlando delivers one of his biggest take-home messages: "[T]he horse," he writes, "remains what it has been for almost our entire history, a vector for bringing people together."

It is both a beautiful statement and a major theme in *Horses: A 4000-year genetic journey across the world*. In this translation from the French, we see how human civilisation evolved alongside the domesticated horse. With Orlando, we follow a scientific journey that explains the mysteries of this impressive, influential animal across its 4200 years beside humans.

But the statement in reverse – as Orlando's text reveals – is true as well: humans, across history, have also brought horses together.

When our ancestors first fenced in, milked, harnessed, drove and eventually rode horses more than four millennia ago, they became unwitting masters of genetics, mixing and matching individuals in ways that would produce chariot horses, racehorses, desert endurance horses, plough horses, war mounts and today's leisure-riding ponies. We know this not only from the hundreds of specialised breeds alive today, but, more deeply, through their DNA.

That's where Orlando's brilliance shines. Over the past decade, his sequencing work has overturned so much of what the world thought it knew about horses: domestication, where it happened and how horses evolved afterwards – and even how horse lineages stretched back tens of millions of years. This is all told with vivid detail and captivating storytelling, built on mysteries teased apart through unravelled double helixes.

I interviewed Orlando nearly 13 years ago, early in his career, just after he and his colleagues had sequenced the DNA from a 700,000-year-old fossilised horse bone found in Thistle Creek in the Canadian Yukon – then the oldest fully sequenced genome of any organism. At the time, Orlando was driven by the age of the specimen, not its species. Neither of us knew that he would become a leading authority on the horse genome.

> **"Orlando's sequencing work has overturned so much of what the world thought it knew about horses"**

Now, in this book, we follow him as he traces clues across millennia, cultures and continents in search of the true history of humanity's other best friend. Ancient DNA from bones and hair forms the foundation, but he fits the findings into broader frameworks from archaeology, ancient art, historical texts, even linguistics – tracking when and where horse-related words emerged.

Each chapter opens with rich anecdotes that spill into enthralling myth-busting. Medieval warhorses weren't the giants we imagined. Mustangs racing across the Western plains of the US aren't native to North America, but are descendants of horses brought from Europe after the 15th century. Przewalski's horses aren't truly wild, but are descendants of an early, abandoned domestication attempt. And those spectacular Arabian horses – think elegant white steeds in Bedouin tents – aren't the foundation of all fine riding horses worldwide.

In fact – spoiler alert – save for the Przewalski, every horse today comes from a single domestication event 4200 years ago in what is now south-west Russia, as Orlando's comparisons of ancient and modern genomes reveal.

In page after page, he shows us the limitations of what we thought we knew – and how genomic sequencing has added nuance to that picture. Readers meet communities on the Asian steppes and Indigenous people in the US, and study artefacts alongside scientists, in the service of understanding how horse and human came together – and how that reshaped the world.

While it's a wild ride, horse-savvy readers may stumble over small slips in language – such as describing ancient DNA linked to spotted horses as "dappling" or calling Thoroughbreds racing in Kentucky or Melbourne "English".

Still, *Horses* is a thundering read, reminding us that the long, tangled history of humans and horses isn't just written in bones and genomes, but also in the enduring ways we continue to shape one another. ▮

Arabian horses race in the Liwa International Festival, Abu Dhabi

KARIM SAHIB/AFP VIA GETTY IMAGES

Christa Lesté-Lasserre is a science journalist specialising in animal health and behaviour based in Greater Paris

Breaking the rules

Finding order in what looks like chaos is seductive in science and daily life, but is the price too high? **Alex Wilkins** explores

Book

The Score

C. Thi Nguyen

Allen Lane

FG TRADE/GETTY IMAGES

Rule-based cooking is very appealing because it produces highly replicable results

THIS time last year, I wrote an article for *New Scientist* about the perfect way to cook the classic pasta dish cacio e pepe, according to physicists. The meal's smooth, glossy emulsion of black pepper, pecorino cheese and water is hard to make lump-free. Ivan Di Terlizzi at the Max Planck Institute for the Physics of Complex Systems in Germany and his colleagues cooked cacio e pepe hundreds of times until they produced an exacting and foolproof method.

The story proved popular with readers. When I caught up with one of the scientists involved recently and asked him why, he told me it may have been because the research seemed to find order in a "world that looks like a mess if you don't look very closely with the eyes of rigour and mathematics".

Seeing the world this way can be seductive, but it can also be dangerous, argues C. Thi Nguyen in his book *The Score: How to stop playing somebody else's game*. Nguyen, a former food writer and now a philosophy professor at the University of Utah in Salt Lake City, uses recipes guaranteed to produce the perfect outcome as a warning.

Hidden behind their apparent authority, he writes, they are in fact making a value judgement, "an exercise of taste and preferences" about how food should be. They use scientific rigour, with precise measurements and sequences, to produce replicable results. But in doing so, they reduce the diversity of possible outcomes, and the inherent human messiness that can make food such fun.

Cooking is only one example of how the modern drive to categorise, score and impose order on a chaotic reality, often led by homogenising nation states and centralised bureaucracies, can result in less than ideal outcomes. Nguyen paints a picture of a world that is bursting with them.

Take his own academic career, where he has had to grapple with university and journal rankings. In philosophy, those rankings are determined by websites that order departments according to metrics, such as the prestige of the journals in which their academics publish, which are, in turn, dependent on how well they answer "fairly arcane technical questions", he writes.

This was the opposite of the "wild, unmanageable questions" that had attracted Nguyen to the field in the first place, but he began to feel the ranking system getting under his skin. He had experienced what he calls "value capture", where metrics designed to be helpful end up ruling us instead.

One way to cope with the abundance of rules-based systems today is to actively choose to play by the rules, in the form of games, argues Nguyen, an avid hobbyist and games player. The book is full of his extensive experience with play, from *Dungeons & Dragons* and rock climbing to yoga and yo-yoing.

Nguyen convincingly shows why choosing to abide by the rules in the artificial sandbox of games can help us explore, be open and get exposure to life's richness, acting as a sort of "spiritual vaccine" for institutional scoring systems that we grudgingly accept in everyday life, such as school exam marks. The idea that games can save us may be a tall order, and it is certainly an unabashedly optimistic and personal world view. But, overall, Nguyen makes a good case for it.

Many of the ideas in his book aren't new, as Nguyen readily admits, referencing many of the philosophers and academics that shaped his intellectual journey. Their work includes *Prisoners of Geography* by Tim Marshall, which delves into the "geo" in geopolitics, and *Seeing Like a State* by James C. Scott, which looks at why scientifically planned societies so often fail.

Nguyen's playful framing of the arguments, in keeping with the central thesis of his book, makes the debate feel fresh, however. This is a good place to start. ▮

New Scientist *recommends*

Bethan Ackerley
Subeditor
London

Nobody makes blockbusters like James Cameron. **Avatar: Fire and Ash**, his third film set on the verdant moon Pandora, is bombastic and beautiful. And from interspecies war to family feuds, there's also an awful lot going on.

Some 15 years after ex-Marine Jake Sully was adopted by the Indigenous Na'vi, after helping to drive back the human military and fusing with a Na'vi body, he has made a life on Pandora with his partner Neytiri and their children.

But now they are grieving the loss of their eldest son, Neteyam. And their old enemy, Colonel Quaritch, has joined forces with a powerful

volcano-dwelling clan of Na'vi, led by Varang (pictured above).

Shakespeare this isn't (the dialogue is crass, to put it politely), but there is no denying the draw of this meticulously crafted world.

Come for the visuals, stay for Payakan, a member of an intelligent whale-like species called the tulkun and the real heart of the film.

20TH CENTURY STUDIOS

The sci-fi column

Fresh fields Peter F. Hamilton's latest epic, *A Hole in the Sky*, is set on a troubled ark ship hundreds of years into its voyage, with fantastic plot twists and turns. I'm a big Hamilton fan, but it's a little too teenage for me, says **Emily H. Wilson**

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

ADAM SERBA/ALAMY

***A Hole in the Sky* is told through the eyes of 16-year-old Hazel**

Book

A Hole in the Sky

Peter F. Hamilton

Angry Robot

Emily also recommends...

Book

Pandora's Star

Peter F. Hamilton

Pan Macmillan

If you have never tried Hamilton's classic works, there are many possible entrance points to the different universes he has created, but I suggest Pandora's Star *and its follow-up* Judas Unchained *(they make up the* Commonwealth Saga *duology) as a good route in. If you find the phrase "epic space opera" has a nice ring to it, these are probably for you.*

I AM a dyed-in-the-wool Peter F. Hamilton fan, so I was really looking forward to his new book, *A Hole in the Sky*, especially as I always love an ark ship story.

This ship is hundreds of years into its voyage, and its inhabitants have regressed to something like medieval peasantry, living in villages beneath the high-tech towers their ancestors inhabited. We learn about the issues they have faced – a problem with the first planet they were meant to land on, then a mutiny on board – which have left them in dire straits. At the age of 65, every individual must be recycled for the good of the ship. I loved every single thing about this set-up.

All this is told from the first-person perspective of Hazel, a 16-year-old girl. She is getting terrible headaches because there is a literal hole in the hull of the ship (hence the book's title) and she quickly becomes embroiled in a dramatic chain of events. But there is also time for her to worry quite a lot about boys and clothes, which I found myself not quite buying. Would a girl or woman of any age worry about her outfit when the lives of everyone on her spaceship were at stake and she had a constant headache?

As you may already know, Hamilton is a genius who has made his name writing *big* sci-fi. My favourites (probably his *Void* and *Night's Dawn* trilogies, plus his *Commonwealth Saga* duology)

> **"If I were a film or TV scout, I could imagine *A Hole in the Sky* transferring brilliantly to the screen"**

are wild, ludicrously inventive, complicated and mind-blowing. I don't always totally understand them, but I love the ride.

I wasn't so keen on Hamilton's recent book *Exodus: Archimedes Engine*, tied to the upcoming video game Exodus, because I felt there were sequences included only for the game, rather than readers' enjoyment, but I do appreciate that wasn't aimed at me. I also get that a master writer might want new challenges. (The second in the series, for those not averse to video game tie-ins, is out later this year. The game arrives in 2027.)

All of which brings me back to *A Hole in the Sky*. I was halfway through when I noticed it was a bit, for want of a better word, childish. Investigating further, I found that the book first came out as an audio-only novel in 2021 – and that it is generally categorised as "young adult", which means aimed at teenagers.

In an interview in 2020, Hamilton is quoted as saying: "Having a teenager as the main protagonist defines the publishing category, but I'm hopeful that it will appeal to readers of any age." Personally, I think a young protagonist doesn't rule out a book being aimed at adults. (I am writing this as someone who has written novels with teenage protagonists.) But will people of any age enjoy this particular book?

The set-up and the plot twists are fantastic, as you would expect from Hamilton. But I wish he had held off from what I think are meant to be "teenage" elements. When my hero is running for her life, I don't need interludes in which she is thrilled to hold her boyfriend's hand. I found myself wishing the main character was 65 and about to be recycled – that would have had some heft.

Maybe Hamilton will find a fresh audience with this. If I were a film or TV scout, for example, I could imagine it transferring brilliantly to the screen. *A Hole in the Sky* is part of a trilogy, with follow-ups due in June and December. As I wrote in my preview of 2026's new sci-fi books, this rapid schedule is unusual, and I will be intrigued to see how it fares. ▮

Editor's pick

Why sci-fi tends to put humans front and centre

27 December 2025, p 16

From Joel Garreau, Broad Run, Virginia, US

I'm a fanboy of Annalee Newitz and hesitate to question anything they say about science fiction. But one aspect of their recent column has me scratching my head. Can they really be mystified by why humans are far more interested in anything a member of their species does in space than anything a robot does?

I don't think people are fascinated by going into space themselves because of sci-fi stories. It's the other way around: sci-fi stories are focused on humans (and humanoids) because they were created by master storytellers – like Newitz. They know what readers want. The US paid a significant percentage of its federal budget on the Apollo programme because it grabbed the imagination of the entire planet.

Sci-fi isn't primarily read because of the science. It's about humans – who we are, how we got that way and where we're headed. For untold aeons, humans have been seeking out new territory. It's in our DNA. Humans want to boldly go where no one has gone before.

Musings on our relationship with nature

10 January, p 19

From James Hardy, Belfast, UK

Richard Smyth says the growing trend of seeing our relationship with nature as a spiritual thing is a mistake. But "existential" or "mysterious" are surely better words to describe it than "spiritual". Bertrand Russell, the great atheist philosopher, famously said: "We know very little, and yet it is astonishing that we know so much, and still more astonishing that so little knowledge can give us so much power." A sense of awe and mystery is shared by all human observers of nature.

From Andrew Whiteley, Consett, County Durham, UK

Smyth is absolutely right that there are no lessons to be learned from nature. Morality and meaning cannot be obtained from nature or its study; their true source is elsewhere. It is hard not to feel that the deification of nature is a substitute for traditional religious belief. The fundamental question is: is nature – the material universe – all there is?

Here's a design for an improved solar panel

Letters, 10 January

From Eric Kvaalen, Les Essarts-le-Roi, France

Paul Whiteley points out that 75 per cent of the sunlight hitting solar panels is lost as heat, but roof-top solar water heaters convert 95 per cent into hot water. So let's combine the two! Have a layer of water between the solar panel and a glass plate, as in a solar water heater. The sunlight passes through the glass and water, and some 20 per cent of it is turned into electricity. The rest becomes heat, most of which is captured by the water. Install enough of these versions to provide your hot water, plus some normal panels to obtain more electricity if needed.

The odds of alien life are better than you think

Letters, 3 January

From Ernest Ager, Whaley Bridge, Derbyshire, UK

Bryn Glover gives a negative assessment of the likelihood of life elsewhere in the universe. This is based on a *New Scientist* article stating the odds of the formation of the last universal common ancestor from a soup of chemicals as "less than 1 in a billion".

Of course, we cannot be absolutely certain that a soup of chemicals is required, that DNA is necessary, that life must be protoplasmic, etc. All of these theoretical possibilities must raise the likelihood by offering other pathways. However, using the same argument, an estimated total of 1 septillion stars divided by the quoted odds of less than 1 billion still provides much room for optimism!

From Andrew Shead, Tulsa, Oklahoma, US

Decades ago, *New Scientist* ran a feature about Rupert Sheldrake's hypothesis of morphic resonance, which posits that once something comes into being, recurrence becomes easier. He used crystallisation as an example: once accomplished, it becomes subsequently easier to do. We are in the universe; the universe is in us. All is one. As far as we know, the universe is vast. Chances are that life happens in more than one place. It is just that instances of life aren't within our hailing distance.

Trying to solve the meteorite mystery

3 January, p 32

From Bill Courtney, Altrincham, Cheshire, UK

After reading Alex Wilkins's article on the mystery of the missing meteorite, I asked Google's AI assistant whether you can make a pigment for painting rocks using iron meteorites, and whether iron objects look shinier in low morning or midday light. Its answer to both questions was yes. If accurate, this may indicate that Gaston Ripert was honest when he claimed that, after travelling all night, he had seen a large metallic rock in the desert that local people referred to as the "iron of God". But, far from being metallic, the rock was only coated with iron-based paint. This would explain the lack of success by later investigators, who attempted to find the rock using magnetometers.

From Jon Hinwood, Melbourne, Australia

Regretfully, I must strongly assert that there is no giant "iron of God" meteorite. If ever there had been, there would be widespread legends about it, artefacts made from it and religious rituals or taboos involving it. If we accept that Ripert was an honest observer and truly saw something, consider that desert mirages are a common phenomenon and often involve what seem like reflective, shiny pools of water that are sometimes greatly enlarged, usually with inverted scenery.

A reminder of the importance of rocks

6 December 2025, p 17

From Susan Stocklmayer, Perth, Western Australia

In the article "Rapa Nui statues may have been built by small groups", the important materials utilised for the construction of these numerous and impressive stone statues are referred to only as having originated from "one quarry supplying the rock".

Perhaps this is of no concern to most readers, but to a geologist, the significance of the specific physical attributes of the rocks is clear. Not many other rock types could have retained the carved details of the figures, lots of which originally faced towards the open ocean and did so for hundreds of years. Omitting this detail is rather like eating the cake without enquiring about a piquant ingredient! ▮

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For the record

▮ **The record X-ray pulse produced by LCLS-II in 2024 carried a terawatt of power (10 January, p 15).**

The 21 Best IDEAS of the 21st century

We are now a quarter of the way into this century, and science has already reshaped our understanding of ourselves, the universe and our place within it. But what are the ideas that have helped guide this progress? Over the next 14 pages, discover *New Scientist*'s pick of the most transformative ideas in science and technology since the turn of the millennium.

1 MICROBIOME

"THE gut microbiome has transformed our understanding of human health," says Tim Spector at King's College London, co-founder of the Zoe nutrition app. "We now know our microbes influence everything from metabolism and immunity to mental well-being."

While this understanding has accelerated over the past 25 years, humans have long used microbes to influence health. While they didn't realise what they were doing, the Romans used bacterial-derived remedies to "guard the stomach", for instance.

In the 17th century, microbiologist Antonie van Leeuwenhoek first described the parasite *Giardia*, from his own stool. Yet it took another two centuries for scientists to validate his findings, and until the 21st century to appreciate how deeply the microbes that line our guts and skin affect our well-being.

By the 1970s, researchers were making headway, realising that gut microbes could influence how drugs are broken down, altering their efficacy. Experiments with faecal transplants hinted at how microbial communities might restore health. But it was only in the 2000s, with rapid advances in genetic sequencing and computing, that the field was truly transformed. Early genome sequencing revealed that each person carries a unique microbial "fingerprint", which includes viruses, fungi and archaea.

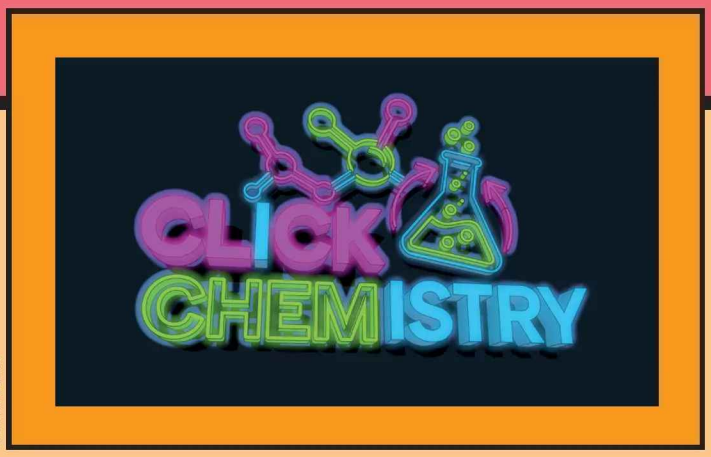
In the early 2000s, several landmark studies showed that our microbiome and immune system communicate directly. This symbiotic relationship reframed the microbiome as an active participant in our wellness, and it was soon found to influence numerous systems, from the pancreas to the brain.

Striking discoveries followed: faecal transplants could cure *Clostridium difficile* infections; microbes from mice with obesity could make lean mice gain weight; specific populations of bacteria could reverse autism-like symptoms in mice. More recently, there have even been signs that microbial dysfunction can trigger diabetes and Parkinson's disease. "Recent discoveries about the human microbiome reveal its influence far beyond the gut," says Lindsay Hall at the University of Birmingham, UK.

Today, researchers are getting a clearer picture of how microbial diversity underpins good health and how boosting it can help treat conditions like irritable bowel syndrome, depression and even some cancers. Studies are also exploring how to seed a healthy microbiome early in life, which Hall says could have "profound, lasting impacts on health".

In just a few decades, the microbiome has gone from obscurity to being considered in all areas of medicine. Now, we need careful trials to separate overhyped products from those that have the potential to reshape how we diagnose, prevent and treat disease.

Helen Thomson



STEPHAN WALTER

2

CHEMISTRY can be a sluggish business, frequently involving cocktails of chemicals in round-bottomed flasks that must later be painstakingly separated. But in 2001, K. Barry Sharpless and his colleagues outlined an idea they called click chemistry that broke the mould. The snappy name, which was Sharpless's wife Janet Dueser's idea, summed it up well: a new set of reactions that worked quickly, cleanly and consistently.

If it seems like a simple idea, it is – and therein lies its brilliance. Sharpless and his colleagues Hartmuth C. Kolb and M. G. Finn described their new reactions as "spring-loaded". The idea was that you could apply them to different starting chemicals, snapping them together almost like Lego bricks, and so quickly build a huge range of new and useful molecules – it was medicines that Sharpless mostly had in mind.

The unifying thought behind these reactions was that they shied away from forming carbon-carbon bonds, as was the orthodoxy among chemists at the time, and instead formed bonds between carbon and what chemists call "heteroatoms", principally oxygen and nitrogen. The best-known click reaction snaps together two reactants to form a triazole, a ring of carbon and nitrogen atoms. This chemical motif tends to be good at sticking to large biological molecules like proteins, making it useful in creating drug molecules. Sharpless unveiled this particular reaction independently, but at the same time as chemist Morten Meldal at the University of Copenhagen, and it has since been used to make, among other things, the anticonvulsant drug rufinamide.

This reaction, says chemist Tom Brown at the University of Oxford, was easy, highly specific and worked in almost any solvent. "I think you can say this was just a great idea," he says.

A few years later, chemist Carolyn Bertozzi at Stanford University in California developed a click-style reaction that works without any toxic catalysts, meaning it could be used inside cells without disrupting them.

For chemist Alison Hulme at the University of Edinburgh, UK, it was this work that elevated click chemistry from a good idea to a great one. It enabled biologists to peg together proteins and other bits of biological machinery at will, and to label them with fluorescent tags to investigate what happened. "It's just so simple and straightforward," says Hulme. "It brought small molecule chemistry to biologists in a way that doesn't require a chemistry degree."

Bertozzi, Meldal and Sharpless shared the 2022 Nobel prize in chemistry for their work – to the surprise of no one.

Joshua Howgego

3

"THE SMART-PHONE HAS PROVIDED AN ADDITIONAL PLACE WITHIN WHICH WE LIVE"

"EVERY once in a while, a revolutionary product comes along that changes everything," said Steve Jobs at an Apple launch in 2007. Tech executives aren't exactly shy about hyping their products, but, for once, this wasn't an exaggeration: the iPhone's release brought apps into common parlance and placed tiny yet powerful PCs into people's pockets.

Not all of the consequences have been desirable. At any moment, we can disappear inside our phones, like a snail retreating into its shell, raising fears of social disconnect. This, combined with safety concerns, has led many countries to ban phones in schools, while in December 2025, Australia imposed a blanket social media ban for under 16s. And depending on a single device for so much, which is always online, has other insidious effects, says data scientist Mar Hicks at the University of Virginia. "It's a device that has accustomed users to have far less privacy – not only in public, but wherever we are, even in our own homes."

The smartphone clearly isn't just a phone, says anthropologist Daniel Miller at University College London. "It's provided an additional place within which we live," he says. These portable digital homes can instantly transport us into the digital houses of our friends and family, too, so that we spend our lives switching between physical and digital realities, he says.

Yet we can't ignore the broader impact of smartphones around the world. Seven in ›

10 people worldwide now own a smartphone, according to the GSMA, a mobile operator trade body. Smartphones are so ubiquitous that they have allowed people in many lower-income countries to bypass the desktop computer altogether. Smartphone-based fintech platforms now broker payments for 70 million users across more than 170 countries, removing the need for traditional, centralised banks. Other smartphone apps are used by farmers to monitor crops and by hospital doctors to circumvent the need for expensive machinery.

What's more, the influence of smartphones extends far beyond the devices. Electrical components such as cameras, transistors and motion sensors were rapidly miniaturised to cram in more processing power and place new features at our fingertips. This helped kick-start several other 21st-century tech innovations: versatile drones, smart wearables, virtual-reality headsets and smaller medical implants.

Chris Stokel-Walker

4

"TRANSIENT ASTRONOMY IS TRANSFORMING THE WAY WE DEPICT THE UNIVERSE"

STEP back 1000 years, look up at the night sky and you might notice some extra dots of light compared with today. Back then, Chinese astronomers called these "guest stars" and believed them to be harbingers of great change.

We now know these were likely to have been supernovae – explosions borne from dying stars – and they are one of many happy accidents caught when astronomers were looking at the right spot at the right time.

But at the turn of this century, looking for these "transient" events became a tactic in its own right, and it is changing the way we do astronomy altogether. We have since found a myriad of intermittent events throughout the cosmos, lasting from nanoseconds to longer than a human lifetime.

"You think the universe has a different range of spatial scales, but it also has these ranges of time scales, and they're incredibly poorly explored in astronomy," says Jason Hessels at the University of Amsterdam in the Netherlands.

Relying on chance to capture these events risks missing much of the action, so astronomers have now automated the process of serendipity, with surveys like the Palomar Transient Factory, which ran from 2009 to 2012, coordinating telescopes as one well-oiled machine. The main telescope in San Diego, California, would see an interesting flash and another would investigate further. "It was really set up like a conveyor belt," says Hessels.

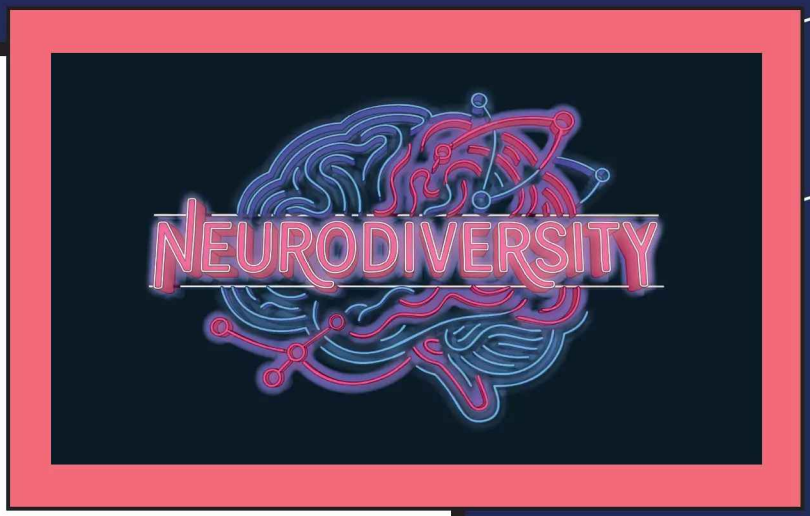
Many more telescopes whose purpose is to search in time, rather than space, have followed. These include the Zwicky Transient Facility, Palomar's successor, and the Pan-STARRS survey, which has collected the largest volume of astronomical data of all time, at 1.6 petabytes, from its perch in Hawaii.

These telescopes and others have produced a torrent of data that has unveiled the universe's blinks and flashes: gamma-ray bursts, fast radio bursts, gravitational waves and stars exploding either of their own accord or because they are being torn apart by black holes.

Transient astronomy is transforming the way we depict the universe. "We started with drawings, and then we had photographs, and then we had something like stop-motion film," says Hessels. Now, we are getting closer to a full movie, he says. "It seems like every time we tweak the way we look at the sky, we fill in more and more of the movie."

Alex Wilkins

5



ONCE upon a time, science worked on the assumption that there was such a thing as a "normal" brain that neatly conformed to society. Those who were different might be diagnosed with an illness or mental health condition, and were treated as though something was wrong with them. Over the decades, scientists honed the concept that neurodevelopmental conditions such as autism, ADHD, dyslexia and dyspraxia should be considered distinct and were reflective of sharply different brains.

Then, in the late 1990s, a new idea started to emerge. What if these "disorders" were better understood as natural variation in the way human brains can be wired? What if, instead of a hard line between normal and abnormal function, human traits and abilities existed on a spectrum along which we all fit somewhere? And while people towards the extremes experience challenges, their unusual brains also come with unique strengths. When seen this way, diverse brains aren't a problem to be solved, but an asset that, if properly supported, could benefit everyone.

The concept of neurodiversity grew out of discussions in online autism advocacy groups, but it wasn't long before there was scientific evidence to support it. By 2013, the Diagnostic and Statistical Manual of Mental Disorders did away with the diagnosis of Asperger's as a "higher-functioning" form of autism, instead recognising one condition, autism spectrum disorder, on a scale from level one to level three, depending on the amount of support required. The notion of neurodivergence as a spectrum was firmly embedded in medical literature.

Studies from the early 2000s onwards have reported that autistic people are more likely to have above-average skills in mathematical reasoning and attention to detail. People with ADHD score higher on tests of creativity, as do people with dyslexia, who also excel at pattern recognition and big-picture thinking. People with dyspraxia have also been found to be more creative as they develop sophisticated coping methods.

These kinds of findings led many scientists to believe that neurodiverse conditions are no evolutionary accident. They exist because our ancestors benefitted from having a few visionary thinkers, creative types and detail-driven perfectionists in the group. With a handful of brains wired with different specialist skills, the group would be better able to explore, adapt and survive. Some researchers are beginning to rethink the autism spectrum along these lines, too, suggesting that there may be distinct subtypes of the condition with different clusters of challenges and abilities.

Some researchers warn that reframing neurodivergent conditions as "superpowers" may not always be helpful. "By being too positive, we risk undermining how serious it can be, particularly if unsupported," says Jessica Eccles, a psychiatrist and neurodiversity researcher at Brighton and Sussex Medical School in the UK. Nevertheless, "now that we have a vocabulary for it, we have opened the door to understanding both its strengths and challenges so that people can move more easily through the world", she says.

Caroline Williams

"NEURODIVERSE CONDITIONS MAY EXIST BECAUSE OUR ANCESTORS BENEFITTED FROM HAVING A FEW VISIONARY THINKERS"

6

NET ZERO

IN 2005, physicists David Frame and Myles Allen were on their way to a scientific conference in Exeter, UK, and had been, in Frame's words, "fiddling about" with a climate model to prepare for their presentation.

At the time, most research focused on stabilising the number of greenhouse gas molecules in the atmosphere to prevent dangerous climate change. But scientists were struggling to figure out how much the world would warm at a fixed level of greenhouse gas concentration.

Frame and Allen turned the problem on its head. Rather than focusing on atmospheric concentrations, they turned to emissions. What if humanity shut off human-caused carbon dioxide emissions? The duo tested the idea out on their climate model right there on the train. The result? Global temperatures remained stable at their new level. In short, the ›

world would stop warming once humanity reached "net-zero" carbon emissions. "It was quite cool sitting on the train looking at these figures for the first time and thinking: 'Wow, that's a big deal,'" Frame remembers.

That presentation – and the subsequent *Nature* paper published in 2009 detailing their findings – kicked off a new way of thinking in the climate community. Before the advent of net zero, it was widely believed humans could still emit a fair chunk of emissions, around 2.5 gigatonnes per year – about 6 per cent of annual global emissions today – while holding global temperatures stable. But now, it was clear emissions would have to reach net zero to stabilise the climate, with any human-made emissions balanced by equivalent removals from the atmosphere.

The idea of a global need to eventually reach net-zero CO_2 emissions quickly caught on, becoming a headline conclusion of an Intergovernmental Panel on Climate Change report in 2014. The next question was timing: when would we have to get to net zero? With research uncovering the dangers of surpassing 1.5°C of warming, the world decided in Paris in 2015 to aim to keep warming as close as possible to that threshold (see page 39). That meant achieving net-zero emissions by roughly mid-century.

Almost immediately, governments around the world came under intense pressure to set net-zero goals. Hundreds did so, along with thousands of companies and financial institutions, which saw the economic opportunities a clean-energy transition promised. This net-zero fever has led to some dubious pledges that rely far too heavily on using the world's forests and swamps as sponges for human pollution, but it has also changed the trajectory of the century. Three-quarters of global emissions are now covered under a net-zero pledge, and projections for warming this century have fallen from around 3.7°C–4.8°C before Paris to 2.4°C–2.6°C under current climate promises.

Madeleine Cuff

7

IN THE 1920s, Albert Einstein thought he had found a fundamental flaw in quantum physics. This set off a chain of investigations that, over several decades, showed he had instead discovered a crucial feature of quantum theory – and one of its oddest.

This property, now called Bell non-locality, which involves quantum objects maintaining coordinated behaviours even across cosmically large distances, has been unkind to our intuition. Yet embracing it in the 21st century has turned out to be a fantastic idea.

The issue can be set out with the help of two hypothetical experimenters, Alice and Bob, who each have one of a pair of "entangled" particles. Entanglement allows the particles to exhibit correlations even if they are so far apart that no signal could ever pass between them quickly enough to make a difference. Yet, for those correlations to become obvious, each experimenter must interact with their particle. Do the particles "know" they are correlated before Alice or Bob interacts with them, or is there something spooky going on between them?

Einstein, working with Nathan Rosen and Boris Podolsky, rejected spookiness. He proposed that there must be "local hidden variables" that researchers could measure to work out how the particles were always in the know. This would make quantum physics more like our daily experience, where objects only influence each other when they are nearby.

In the 1960s, physicist John Stewart Bell outlined a way to test the trio's idea. After decades of attempts, in 2015, several experiments turned Bell's test into reality in an unprecedentedly rigorous way, earning three of the physicists involved a Nobel prize in 2022. "That was the final nail to the coffin of all those ideas," says Marek Żukowski at the University of Gdańsk in Poland. Hidden variables couldn't save locality in quantum physics, says Jacob Barandes at Harvard University. "You can't escape non-locality."

And there are real benefits if we stop trying to escape non-locality and embrace it instead. For Ronald Hanson at Delft University of Technology in the Netherlands, who led one of the experiments, the issue was never about spookiness. Rather, he conceived of the experiment as a feat of "quantum advantage" – something beyond the abilities of any conventional computer. His intuition bore out: some of the machinery necessary for "Bell tests" became a foundation for unprecedentedly secure quantum cryptography.

Hanson now builds quantum communication networks, leveraging entangled particles to develop a nearly unhackable future internet. Quantum computing researchers similarly use entangled particles to make computations more effective. Physicists haven't yet fully unravelled the meaning of entanglement and are continuing to examine the assumptions that underlie Bell's work, but entangling quantum objects reliably has become a technological resource, a stunning second act for a key player in the debate about our world's quantumness.

Karmela Padavic-Callaghan

8

AT THE dawn of the millennium, the number of genes in our genome was still up for discussion. When we finally got our first official estimate, the number was so far below expectations that it helped turbocharge a movement to rethink the evolutionary process.

In 2001, the Human Genome Project announced we have no more than 40,000 protein-coding genes – a figure that has since been revised down to about 20,000. We needed other mechanisms to explain the complexity of our biology and evolution. It was epigenetics' time to shine.

Epigenetics is a catch-all term to describe how a wide variety of molecules interact with DNA or RNA to influence the activity of genes without changing the underlying genetic code. Two cells with identical genomes but different epigenetic markers can look and behave very differently.

Epigenetics offers a way to squeeze more complexity out of the genome, through things like environmental factors. And some biologists are convinced it can do more, potentially even influencing the evolutionary process.

We know how this might happen. In a 2019 study in which yeast was exposed to a toxic chemical, the toxin killed the yeast by interacting with a protein produced by one of its genes. But yeast cells with the capacity to silence that gene, through an epigenetic pathway, survived. After several generations, some yeast cells in the thriving population developed genetic mutations that reinforced the silencing of the vulnerable gene. The yeast had evolved, its genetic code had changed – but those genetic changes began with epigenetic modifications.

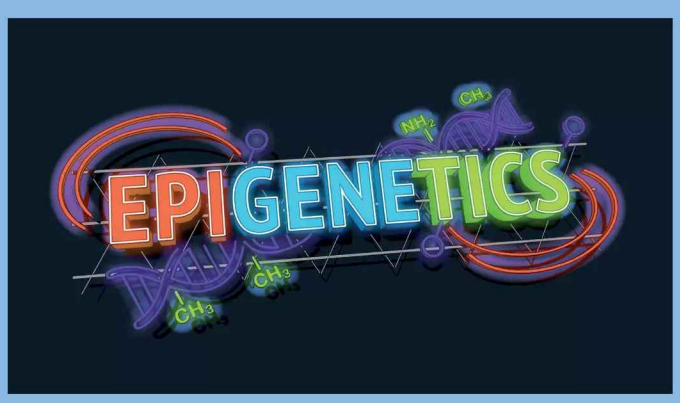
Epigenetics has become a cornerstone of a drive to extend and expand evolutionary theory. But despite evidence that epigenetics can influence the evolution of plants and microbes, there isn't universal acceptance that this applies more broadly.

"I am sceptical," says Adrian Bird, who researches genetics at the University of Edinburgh, UK. In a paper last year, he argued there is no obvious way for environmental factors, such as drought and famine, to influence the mammalian genome. What's more, epigenetic markers can be passed from parent to offspring, but many are removed early in mammalian embryo development.

Others brush off these concerns. "Epigenetic inheritance is common in both plants and animals," says Kevin Lala, an evolutionary biologist at the University of St Andrews, UK. In a book published last year, Lala and his colleagues offered a long list of studies that suggest epigenetics affects evolution across life's tree.

Why are opinions so strongly divided? Perhaps it's a question of timing. "Epigenetic inheritance is a very fast-moving field," says Lala. Although it has been on the biological radar for 80 years, it is only within the past 25 years that epigenetics has become a central focus of evolutionary research – and big ideas take time to assess.

Colin Barras



"EPIGENETICS HAS BECOME A CORNERSTONE OF A DRIVE TO EXTEND AND EXPAND EVOLUTIONARY THEORY"

9

OUR NEW FAMILY TREE

WHAT has happened in the field of human evolution over the past 25 years can be summed up in one word: "more". Archaeologists have found many more fossils, species and artefacts, in more places – from diminutive "hobbits" who lived on an Indonesian island to the mysterious *Homo naledi* known only from a single deep cave in South Africa. In parallel, researchers have developed more and better techniques for analysing all these remains. There is, quite simply, a huge amount of information about our origins and extinct cousins.

Two major lessons have emerged from this blizzard of discoveries. First, since 2000, the hominin fossil record has been extended much further back in time. In the late 1990s, the oldest known hominin was the 4.4-million-year-old *Ardipithecus*. But in 2000 and 2001, researchers found an even older *Ardipithecus*, *Orrorin tugenensis* from 6 million years ago and *Sahelanthropus tchadensis* from 7 million years ago. A second *Orrorin* species, *Orrorin praegens*, was quietly described in 2022; it seems to be a little more recent than *O. tugenensis*.

The discovery of these early hominins was "one of the big revolutions", says Clément ›

Zanolli at the University of Bordeaux in France.

Second, the story of our own species' emergence from the hominin pack has become far richer. By 2000, genetic evidence had demonstrated that all non-African people are descended from African ancestors who lived about 60,000 years ago. The implication was that modern humans evolved in Africa and then expanded from there, replacing all the other hominin species.

However, in 2010, researchers sequenced the first Neanderthal genome, and DNA from many other ancient humans has followed. The DNA revealed that our species interbred with Neanderthals, Denisovans and possibly others – and that other groups were also sometimes mixing.

Researchers who study skeletons had long suspected interbreeding, because many fossils don't neatly fit species categories, says Sheela Athreya at Texas A&M University in College Station. A jawbone from Peştera cu Oase in Romania was described by Erik Trinkaus and his colleagues in 2003 as a human-Neanderthal hybrid, based on its shape. "[Trinkaus] was called a crackpot," says Athreya. Then, in 2015, genetics revealed that the Oase individual had a Neanderthal ancestor four to six generations previously.

Our species didn't simply expand out of Africa, then. Instead, our population absorbed the genetic heritage of Neanderthals and Denisovans along the way. Genetically, we are a patchwork: the stitched-together remains of millions of years of diverse forms of humanity.

Michael Marshall

"THE STORY OF OUR OWN SPECIES' EMERGENCE FROM THE HOMININ PACK HAS BECOME FAR RICHER"

10

BATTERIES and the harnessing of solar energy have been around in one form or another for centuries, but only in 2016 did these technologies, arguably, become world-changing. This was when Elon Musk, before his controversial political career began, opened the first "gigafactory" in Nevada, producing advanced battery technology, electric motors and solar cells on a massive scale – giga meaning 1 billion, or "giant".

You could fairly describe the amount of renewable energy – in the form of solar, wind and hydropower – available to extract on Earth as gigantic too. In just a few days, the sun delivers more energy to our planet than is in all the reserves of fossil fuels we have ever discovered.

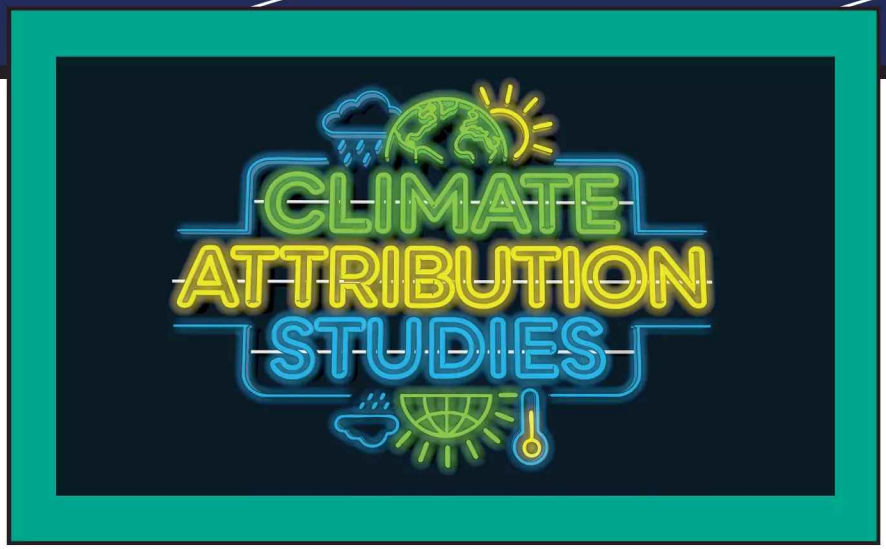
Reliably harnessing that power is another matter. Even though the photovoltaic effect, where light energy produces electrical current, was discovered in 1839 by Edmond Becquerel, and the first practical solar panels were made in the 1950s, it wasn't until the 2010s that technology had advanced enough for solar electricity to become competitive with fossil fuels. Parallel to this, the invention of lithium-ion batteries in the 1980s provided somewhere to store this energy.

The gigafactory certainly helped advance these solar cell and battery technologies too. Yet its impact was less down to any specific invention and more in how it brought all the parts of electric car production under one roof. This supply-chain integration reflects what Henry Ford did a century earlier – just populating the planet with Teslas instead of fossil fuel-powered Model Ts. "It gave us dispatchable solar thanks to batteries, and it gave us electric vehicles," says Dave Jones at Ember, an energy think tank in the UK.

The economies of scale unleashed by the gigafactory had knock-on effects beyond electric cars, too. "That battery unlocks all kinds of new things: the phone, the computer and the ability to have relatively low-cost, high amounts of energy you carry around," says Sara Hastings-Simon at the University of Calgary in Canada.

In fact, in recent years, the cost of these technologies has plummeted so much that many experts say electrification of our energy systems is inevitable. In California and Australia, solar energy is so plentiful that grid operators give it to people for free. Commensurate with that, batteries are getting closer to storing energy as densely as fossil fuels do, so we can start to build solar airplanes, ships and long-haul trucks – and completely detach our transport and energy systems from their centuries-long dependence on fossil fuels.

Chris Stokel-Walker



11

IN JANUARY 2003, physicist Myles Allen watched as floodwaters from the Thames river threatened to seep into his home in Oxford, UK. He wanted to know why meteorologists at the time were refusing to blame climate change for the event.

Later that year, Peter Stott, a climate scientist at the UK's Met Office, arrived in Italy for a summer holiday. But instead of a week of ice cream and beach reads, Stott found himself trapped in one of the longest, deadliest heatwaves in European history. "For me, that was a really striking experience, because I'd never experienced 40°C heat before," he says.

Both Allen and Stott wanted to pin down the role of climate change in driving the extreme weather they had experienced. Stott realised existing climate models could be used to run an experiment simulating two model worlds in which the European heatwave occurred: one mirroring the 2003 climate and one without human-caused warming.

Together, Stott and Allen ran the model for both worlds thousands of times and concluded, in a groundbreaking 2004 paper in *Nature*, that human activities had at least doubled the risk of the 2003 heatwave striking.

It was the start of a whole new field of climate science, for the first time identifying our influence on a specific extreme weather event. Soon, attribution analysis was being performed on all kinds of extreme events, from heatwaves to severe droughts and rainstorms.

But there was still a hitch. It took months, sometimes years, after an extreme weather event for researchers to produce the analysis to declare the influence of climate change.

A group of researchers, including Friederike Otto at Imperial College London, decided to change that with the launch of World Weather Attribution in 2014. The team performs rapid analysis of extreme weather events to quantify the possible influence of climate change, often getting the results out to the public and media within days of the extreme weather hitting.

The result was a huge shift in how such events around the world are communicated, with contemporary news reports now able to directly blame climate change for deadly weather, driving home the real-world impact of rising emissions.

"When we started doing this 10 years ago, every scientist and every journalist was saying, 'you can't attribute an individual weather event to climate change', and that has dramatically changed," says Otto.

It has even paved the way for climate lawsuits, with attribution studies acting as evidence in dozens of cases against polluters around the world. It has also opened the door to climate change reparation payments, with a new international loss and damage fund established by the United Nations in 2022.

Writing in 2003, Allen asked: "Will it ever be possible to sue anyone for damaging the climate?" The answer, thanks to the advancement of attribution science, is now a resounding "yes".

Madeleine Cuff

BRAIN NETWORKS

12

YOU HAVE probably heard the parable of the blind men and the elephant. One feels the trunk and says it's a snake, another feels a leg and claims it's a tree. It warns of how focusing on single parts can obscure the whole.

Neuroscience made the same mistake for decades, viewing the brain as a collection of specialised regions, each working on a distinct function. Our understanding of what each region did often stemmed from accidents, like the case of Phineas Gage, a 19th-century railway worker who survived having an iron rod blown through his brain. His personality change was blamed on frontal lobe damage. More recently, we have gained insights from brain stimulation studies that tied the amygdala to emotions, the occipital lobe to vision, and so on.

Brain regions do specialise, but that isn't the whole picture. Advances in imaging technologies in the late 1990s and early 2000s allowed scientists to observe the whole brain in action. What they found transformed neuroscience. Brain regions don't operate alone – instead, behaviours emerge from synchronised activity across multiple, overlapping networks.

"The mapping of brain networks has played a major role in shifting neuroscientific thinking," says Luiz Pessoa at the University of Maryland.

The shift began in 2001 when Marcus Raichle, now at Washington University in St. Louis, Missouri, described the default mode network (DMN), a system of interconnected regions that lights up when your mind disengages from a task.

Two years later, Kristen McKiernan, then at the Medical ›

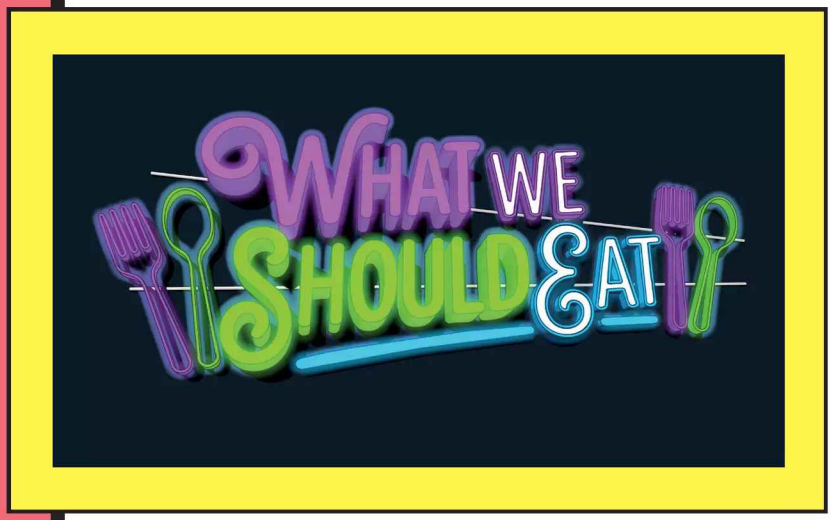
College of Wisconsin, and her colleagues showed that the DMN increased in activity during easier and familiar tasks, such as daydreaming and self-reflection.

Suddenly, researchers had a "resting state" baseline against which to measure all brain activity. They also began to link the DMN with complex behaviours such as emotional intelligence and theory of mind. Meanwhile, the discovery of other networks – for attention, language, emotion, memory and planning – reshaped thinking about mental health and neurodiversity. Network differences are now associated with many conditions, including Parkinson's disease, depression, anxiety and PTSD. It is also linked to ADHD.

Network science has become a field in its own right, improving our understanding of everything from autism – which is increasingly being characterised as a difference within the social salience network, a brain system that detects and prioritises relevant social cues to help us produce appropriate responses – to Alzheimer's disease, where new research suggests abnormal proteins may spread along network pathways. We even have it to thank for inspiring the development of artificial neural networks in AI systems like ChatGPT.

Neural networks have transformed how we understand the brain, as well as how we diagnose and treat the problems affecting it. We may not yet be viewing the whole elephant, but the picture is certainly coming into focus.

Helen Thomson



13

"THERE HAS BEEN A REVOLUTION IN OUR UNDERSTANDING OF DIETS"

THE Mediterranean diet is the crème de la crème of healthy eating. Filled with fibre, vegetables, legumes, fruit, nuts, some fish and minimal meat and dairy, it brings a smorgasbord of health – and planetary – benefits, all while being utterly delicious. "It's not only healthy, it's also extremely tasty," says Luigi Fontana at the University of Sydney in Australia.

Unlike certain dietary fads, the Mediterranean diet is backed up by decades of evidence. But it is only in the 21st century that a series of randomised controlled trials established it as the scientific gold standard.

In the 1940s, physiologist Ancel Keys was among the first to argue that the diet cuts the risk of heart disease thanks to low levels of saturated fat – found in meat and dairy – which increases the presence of artery-clogging cholesterol.

Keys and his wife Margaret, a nutritionist, conducted a study comparing people's diet and heart health across seven countries, finding that the Mediterranean diet was linked to a lower risk of heart disease. But they didn't account for other factors, such as participants' income levels, that may have influenced the association.

Stronger evidence came in 1999 when scientists randomly assigned people who had previously had a heart attack to follow either a Mediterranean diet or a low-fat one. This showed that the Mediterranean diet does seem to reduce the risk of stroke and heart attack.

The finding paved the way for a revolution in our understanding of the diet over the next 25 years. After 2000, several randomised controlled trials confirmed the cardiovascular benefits. They also revealed that the diet cuts the risk of type 2 diabetes. That's not all: subsequent studies have linked it to a reduced risk of breast cancer, slower cognitive decline and a greater chance of successful IVF, although more evidence is needed to confirm all this. "By eating a Mediterranean diet, you decrease your risk of developing multiple chronic diseases," says Fontana.

We are also gaining insights into why the diet is so good for us: fibre and extra virgin olive oil seem to be crucial. Both are thought to boost "good" gut bacteria (see page 28) that reduce harmful inflammation. "A lot of chronic diseases are driven by inflammation, so that's one reason why eating [the] Mediterranean diet is so beneficial," says Richard Hoffman at the University of Hertfordshire, UK.

Eating this diet also helps the environment, because producing meat and dairy accounts for about 15 per cent of global greenhouse gas emissions, while legumes and vegetables have a much lower impact. As the world heats up, we need to brush away the fads and embrace the diet that has been there all along.

Carissa Wong

THE WORST IDEAS

Some of the biggest ideas of the century started off promising, but soon turned sour

Bitcoin
The blockchain-backed currency has many supporters, but its outsized environmental impact is difficult to ignore.

Social media
While it began as a way for people to build communities, social media has created unique social problems nobody foresaw.

Carbon offsets
The practice of offsetting carbon emissions is so complicated and, for many reasons, fails to deliver on its promises.

Alternative fuels
Not only has the push to switch from fossil fuels to things like biofuels failed to reduce emissions, it has also had some nasty side effects.

Effective altruism
The movement says we should work out the most impactful way to give charitably. That sounds like a great idea, so how did it go so wrong?

For the full story on each, visit newscientist.com/5worstideas

14

CRISPR GENE EDITING

"THE pain was like being struck by lightning and hit by a freight train all at the same time," Victoria Gray told *New Scientist* in 2023. "Now everything is different for me."

Gray used to experience severe episodes of sickle cell disease, but in 2019 she was effectively cured by a revolutionary technique that enables changes to be made to specific bits of our DNA: CRISPR gene editing. In 2023, that experimental treatment became the first approved CRISPR therapy.

There are hundreds of clinical trials of CRISPR-based treatments now under way, and this is just the start. CRISPR could help treat all kinds of diseases, not just genetic conditions. For instance, a single dose of CRISPR could reduce your risk of heart attacks and strokes by permanently lowering your cholesterol levels.

And while it isn't yet safe enough to attempt, it does seem likely that in the future, CRISPR will be routinely used to alter our children's genomes to reduce their risk of common diseases.

CRISPR is also starting to transform farming by making it much easier to develop crops and livestock that are disease-resistant, adapted to warmer conditions or better for eating.

Given all this, there is no doubt that CRISPR is one of the very best ideas of the 21st century. Its power lies in its ability to correct "spelling mistakes" in DNA.

There are two parts to this: first, you have to get your gene-editing tool to the right place in the genome, like moving your cursor to the right spot in a long document on a computer. Next, you make the change.

Microbes use this mechanism in their battle with other microbes and, prior to 2012, biologists had discovered many natural gene-editing proteins. However, each one targeted just one location, or sequence, in the genome. To edit a different spot, the only option was to redesign the part of the protein that binds to DNA to target another sequence, a laborious process that took years.

But it turns out that bacteria have evolved a big family of gene-editing proteins that don't bind to DNA directly. Instead, they hook up with a piece of RNA – a cousin of DNA – and search for sequences that match the RNA. And making RNA takes days, not years.

In 2012, Jennifer Doudna at the University of California, Berkeley, and her colleague Emmanuelle Charpentier at the Max Planck Institute for Infection Biology in Berlin, Germany, showed how one of these gene-editing proteins, called CRISPR Cas9, could be made to target any desired sequence by adding the right form of "guide RNA".

There are now thousands of variants of CRISPR being used for many purposes, but all rely on guide-RNA targeting. It is a world-changing technology, for which Doudna and Charpentier, were awarded a Nobel prize in 2020.

Michael Le Page

15

WIKIPEDIA

HOSTILITY and discord are hallmarks of the internet more so than collaboration and cooperation. So the fact that a public encyclopaedia, editable by anyone, has become one of the most useful repositories of knowledge in the world is, frankly, unbelievable. "Thank God it works in practice, because it would never work in theory," says Anusha Alikhan at the Wikimedia Foundation, the non-profit that runs Wikipedia.

The website was set up in 2001 by Jimmy Wales, who remains involved today, and Larry Sanger, who left the project the following year – but continues to criticise it from afar. He recently wrote that the site had been "hijacked by ideologues".

Needless to say, Sanger's view isn't shared by most. Every month, Wikipedia's 64 million articles in more than 300 languages receive 15 billion visits. At the time of writing, it is the ninth-most visited website in the world. "The fact that it is now one of the most trusted resources on the web is not something that anyone could have ›

contemplated, but we're here," says Alikhan.

Fostering trust on a mass scale is no mean feat. The internet may have given billions of people access to the sum total of human knowledge, but it has done so largely in ways that are fragmented, unverified, unreliable and limited in scope. Wikipedia bucks the trend by allowing anyone to create or edit entries on the site. There are now around 260,000 volunteers around the world, with 342 edits made every single minute. A clever system then grants wider editing powers to volunteers once they have built a history of responsible changes. Trust fosters engagement and commitment so that strangers on the internet are willing to work together.

In some cases, Wikipedia encourages special interest groups to create and edit pages. For instance, a group called Women in Red works to address gender imbalance. Other groups work to spread information on climate change and African history. These articles are held to the same standards of accuracy, but this hasn't stopped critics, including Sanger, of accusing the site of bias.

Wikipedia is a deeply unusual website in that, to avoid influence and bias, it runs no advertising, has no shareholders and makes no profit. It is an outlier in the technology world, and things have gone surprisingly well for more than 20 years.

Yet artificial intelligence is poised to change all this: it can rapidly pump out misleading or harmful entries, consumes resources as bots scrape the site for training data and reduces the number of visitors – and therefore potential donors – by creating AI-generated search summaries.

Matthew Sparkes

"WIKIPEDIA IS A DEEPLY UNUSUAL WEBSITE. IT IS AN OUTLIER IN THE TECHNOLOGY WORLD"

16

WHEN wolves were reintroduced to Yellowstone National Park in 1995, the effects were dramatic. Among other things, elk numbers fell far more than expected.

It turns out that the mere fear of wolves was having a big impact. In places where elk thought wolves might be present, they spent much more time looking out for them, leaving less time to feed. In a paper published in 2001, biologist John Laundré, who died in 2021, used the term "landscape of fear" to describe this effect.

The idea wasn't entirely new. Previous lab experiments had shown that fear of predators alone can affect prey. Yet the prevailing view at the time was that predators affect wild prey populations only through direct predation. Laundré and others' observations suggested this was wrong, but they didn't demonstrate causality.

That's what Liana Zanette at Western University in Ontario, Canada, has done through a series of experiments over the past two decades. In British Columbia, Zanette and her colleagues played recordings of predators near wild song sparrows. Fewer eggs were laid, fewer hatched and fewer hatchlings survived. Overall, less than half as many lived compared with those played non-predator sounds. In other words, fear can have an even bigger impact than direct predation.

It is all about food, says Zanette. In addition to spending more time looking out for predators, prey animals will just completely avoid some areas, she says, "even though it might be the best food in town".

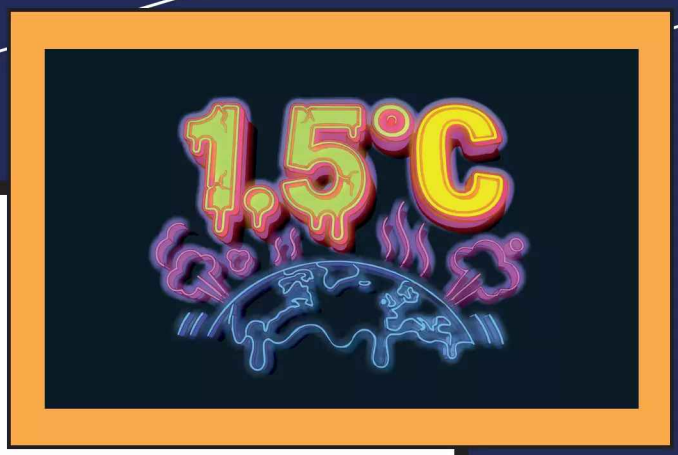
This landscape-of-fear concept is hugely important because of knock-on effects on ecosystems. In many places on the west coast of Canada, for instance, humans have eliminated the bears, cougars and wolves that prey on raccoons. These raccoons now spend a lot of time on the shore looking for food such as crabs.

When Zanette's team visited and played recordings of dogs barking, the raccoons mostly avoided going to the seashore and, when they did, spent much more time looking for predators. This led to a dramatic rebound in the abundance of the shore animals the raccoons feed on. Where the team played recordings of seals barking, by contrast, these effects weren't seen.

Landscape of fear is key to fully understanding humans' impact on wildlife. In one study, Zanette and her team used camera traps to film how wildlife responded to sounds in the Kruger National Park in South Africa. "Fear of lions should be maximal there," she says, "but we found that humans were two times more frightening."

Michael Le Page

17



"THE 1.5°C TARGET HAS CREATED A SENSE OF URGENCY"

IN THE first decade of the 21st century, most scientists and policy-makers were focused on 2°C as being the highest "safe" threshold for warming above pre-industrial levels. But emerging research was beginning to suggest that even this was too severe, threatening sea level rise that would wipe out low-lying islands. In response, some scientists began to investigate the benefits of keeping any temperature rise closer to 1.5°C.

Armed with this research, the Alliance of Small Island States (AOSIS), a United Nations negotiating bloc, called for the adoption of a global target to limit warming to 1.5°C, warning that a 2°C warming limit "would devastate many small island developing countries".

James Fletcher, a UN negotiator for the AOSIS bloc at the 2015 UN COP climate summit in Paris, says it was an uphill battle to convince other countries to adopt this much tougher global goal. He recalls the head of a lower-income nation's delegation cornering him at the end of a meeting in Paris: "He was wagging his finger in my face and saying, 'You small island states will get 1.5°C over my dead body'. That's how incensed they were about this."

With the help of pressure from the European Union, tacit support from the US and even an intervention from Pope Francis, 1.5°C made it into the hugely influential 2015 Paris Agreement. Yet, with no formal assessment of what 1.5°C of warming would really mean for the planet, the world's climate scientists set to work.

In 2018, the Intergovernmental Panel on Climate Change published its report on the 1.5°C goal, confirming the relative advantages of holding warming to the lower level and crystallising a new global target to reach net-zero emissions by 2050 (see page 31), in line with a 1.5°C trajectory.

Both goals quickly became a rallying cry for governments and companies around the world, and some countries, including the UK, upgraded their national climate goals to be in line with the new, more stringent target.

Piers Forster at the University of Leeds, UK, credits the 1.5°C target for helping to push nations to commit to much tougher climate targets than they would have previously countenanced. "I think it has created a sense of urgency," he says.

The target's legacy is mixed. Despite the fanfare, global temperatures are still rising, and the world has delivered nothing like the emissions cuts needed to deliver on the 1.5°C promise. The best scientific assessments now assume the world will cross that warming threshold in just a few years' time.

Nevertheless, 1.5°C remains the central climate goal against which global progress in reducing emissions is measured. The public and policy-makers are now much more focused on each fraction of a degree of temperature rise. "Overshooting" beyond 1.5°C is widely viewed as a risky future, and the idea that 2°C was ever seen as a "safe" threshold for warming seems laughable.

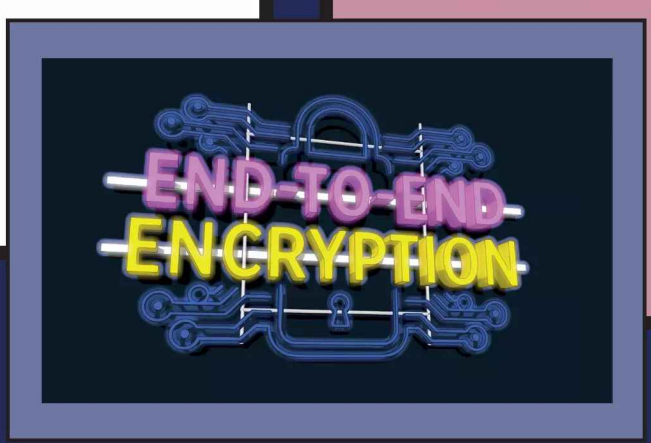
Madeleine Cuff

18

WE ALL keep secrets. Whether you are trying to protect messages to loved ones, company accounts or vital state intelligence, the technology that allows you peace of mind in our increasingly online world is end-to-end encryption (ETEE).

ETEE means that whoever provides your internet connection, or runs your messenger or video-conference app, cannot see your communications. That's because they are encrypted on your device, then decrypted on the recipient's. During transmission, they are a meaningless string of impenetrable gibberish, so no police force, spy agency or criminally minded company insider could demand, blackmail or threaten their way in.

Digital encryption doesn't ›



depend on promises, but on immutable mathematics. The first useful form of encryption was made possible by the RSA algorithm, publicly described in 1977, which hinges on how difficult it is to find the two prime factors that must be multiplied to create a particular extremely large number. Since then, other algorithms have used all manner of obscure mathematics to create other hard-to-crack encryption codes.

But ETEE's power is less about exactly how it is implemented and more about how internet secrecy supports democracy and human rights around the world. "There are people in very dangerous parts of the world who literally rely on [encryption] to save their lives," says Matthew Feeney at UK-based privacy campaign group Big Brother Watch. What's more, even if you live somewhere you consider to be a liberal democracy, those liberties can be rolled back. "Those who say, 'I'm a law-abiding citizen, I've done nothing wrong [and I've nothing to hide],' should pick up a history book and proceed with caution," says Feeney.

Some governments may well hate ETEE because it impedes them from snooping in the same way that postal services and telephone networks allow. Indeed, successive UK governments have sought to ban it, unsuccessfully – most recently, in August last year, Prime Minister Keir Starmer announced an embarrassing U-turn after his government's demands for Apple to install a backdoor were leaked.

We can't say for sure that nobody has a way to break through ETEE, because intelligence agencies aren't in the business of boasting about their abilities, says Feeney. One looming threat is that quantum computers, which harness principles from quantum mechanics to solve problems that classical computers struggle with, may soon crack the algorithms on which ETEE currently depends. Yet encryption has always been a game of cat-and-mouse, with new mathematical innovations cropping up as previous algorithms are weakened. "Governments are powerful institutions, but they have yet to outlaw the laws of mathematics," says Feeney.

Matthew Sparkes

19

THE FIRST few exoplanets were discovered in the early 1990s. But it wasn't until the early 2000s, when astronomers began carrying out large-scale, long-term surveys of other stars, that we started to get the first hints that our solar system – with its neat arrangement of four rocky planets, then four gassy giants – might be unique.

For decades, the High Accuracy Radial Velocity Planetary Searcher in Chile and the California Legacy Survey watched for telltale orbital wobbles that exoplanets might induce in other stars. Though these surveys didn't discover as many exoplanets as later telescopes like Kepler and TESS, they did find signs of just how unusual our solar system is.

Our sun, for instance, is larger than 90 per cent of other stars. It is also alone, unlike other stars that have at least one or two close neighbours. Our planets, too, are rare: only around 1 in 10 stars have a Jupiter-sized planet, and when they do, these worlds are often on very different trajectories to Jupiter's neat, round orbit.

We are also missing planets common to most other star systems – those known as super-Earths or sub-Neptunes, of between about 2 and 10 Earth masses. What's more, even after finding thousands of exoplanets, we have yet to spot an Earth-like planet around a sun-like star, not to mention alien life.

"The weird things are both what we have and what we don't have. Putting those together, we're definitely weird," says Sean Raymond at the University of Bordeaux in France. "It's not clear yet whether we're weird at the 1 per cent level, which is a little bit weird, or whether it's really at the 1 in a million level."

These discoveries also raised questions about how our solar system formed, such as why Jupiter is so far out, at around 700 million kilometres from the sun, rather than a fifth of that distance as we see for Jupiter-sized planets in most other planetary systems. The strange orbits of certain exoplanets made astronomers rethink our system's history, such as with the Nice model, first suggested in 2001, which posits that a dramatic rearrangement occurred not long after the solar system initially formed, kicking Jupiter out to the periphery and flinging many of the asteroids and moons we see today into new orbits.

"The idea that that could have happened at all came straight from exoplanets," says Raymond. "Nine out of every 10 giant exoplanet systems underwent an instability, and what we see is the aftermath... People saw that and connected the dots and said, 'Well, if it happened out there, could that have happened here?'"

Alex Wilkins

20

HIV IS one of the world's biggest killers. The virus has claimed more than 44 million lives, sparking fears around sex and immense stigma towards those most at risk, particularly men who have sex with men. But drugs that prevent the sexually transmitted infection have drastically cut this threat.

The virus spreads via sex when infected bodily fluids enter the blood of someone who is HIV-free, but it can also be transmitted by sharing needles or breastfeeding. If left untreated, HIV wreaks havoc on the immune system, leading to acquired immunodeficiency syndrome, or AIDS.

Early on in the HIV epidemic, it became clear that condoms provide protection. But these can fail and they make sex less pleasurable, meaning many prefer not to use them, says Benjamin Weil at The Love Tank, a not-for-profit organisation in London that promotes the sexual well-being of communities underserved by the healthcare system.

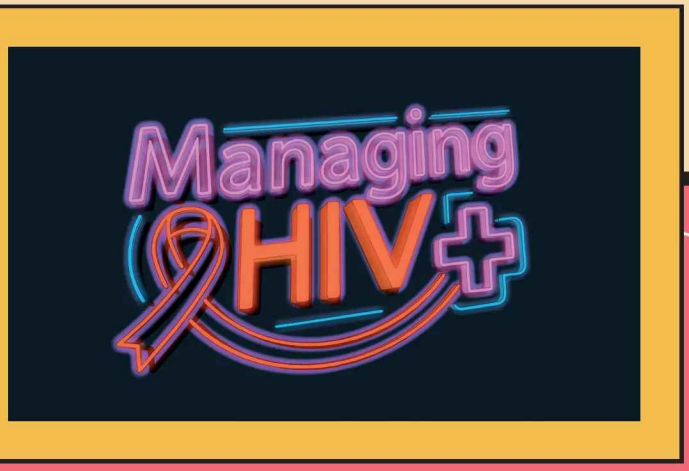
It wasn't until 2010 that a landmark trial revealed the power of pre-exposure prophylaxis, or PrEP, for HIV prevention. People who took a daily antiviral pill were substantially less likely to catch HIV than those taking a placebo. Two years later, the US Food and Drug Administration approved PrEP for HIV.

Soon after, a slew of studies showed that, when used correctly, PrEP cuts the risk of HIV transmission by more than 90 per cent. The World Health Organization recommended PrEP in 2015 and, in the following years, more than 150 countries adopted the approach. "The advent of PrEP really was an enormous revelation for lots of people because it allowed them to have the kind of sex they wanted to have, where bodily fluids could be exchanged and you could actually feel the contact of another's skin," says Weil. In 2023 alone, more than 3.5 million people worldwide took PrEP at least once.

Together with antiretroviral therapy, or ART – drugs that suppress the virus to undetectable levels in infected people, so they can't transmit the virus – PrEP has slashed HIV rates. In 2024, there were 1.3 million new cases of HIV, a 61 per cent reduction compared with the peak of 3.4 million seen in 1996. "Those two things together certainly have played the lion's share in reducing HIV rates," says Weil.

Today, PrEP comes in many forms. Oral pills can be taken just before and after sex, while injectable drugs provide longer-lasting protection. Yet HIV rates are still rising in certain groups, such as Black African and Asian populations in the UK, partly due to stigma and poor healthcare access. Ironing out such inequalities will be crucial to unlocking the true potential of PrEP – and eliminating HIV entirely.

Carissa Wong



TRANSFORMER ARCHITECTURES

21

TODAY'S most powerful AI tools – the ones that can summarise documents, generate artwork or predict how complex proteins fold – all stand on the shoulders of the "transformer". This neural network architecture, first announced in 2017, enables machines to process information in a way that reflects how humans think.

Previously, most state-of-the-art AI models relied on a technique called a recurrent neural network. This worked by reading text in tight windows, left to right, remembering only what came just before. That set-up worked well enough for short phrases. But in longer, more tangled sentences, the models had to squeeze too much context into their limited memory, causing crucial details to be lost. The ambiguity stumped them.

Transformers embraced a more radical approach: self-attention.

It's surprisingly intuitive. We humans certainly don't read and interpret text by scanning word by word in a strict order. We skim, we double back, we make guesses and corrections by weighing up the context. This kind of mental agility has long been the holy grail of natural language processing: teaching machines not just how to process language, but also how to understand it.

"IT ENABLED MACHINES TO PROCESS INFORMATION IN A WAY THAT REFLECTS HOW HUMANS THINK"

Transformers mimic that mental leap. Their self-attention mechanism allows them to compare every word in a sentence with every other word, all at once, spotting patterns and building meaning from the relationships between them. "You could leverage all this data from the internet or Wikipedia and use it for your task," says AI researcher Sasha Luccioni at Hugging Face. "And that was hugely powerful."

This flexibility isn't limited to text either. Transformers now underpin tools that generate music, render images and even model molecules. AlphaFold, for instance, treats proteins – long strings of amino acids – like sentences. A protein's function depends on how it folds and that, in turn, depends on how its parts relate across long distances. Attention mechanisms let the model weigh those distant relationships with fine-grained precision.

In hindsight, the insight feels almost obvious: intelligence, whether human or artificial, depends on knowing what to focus on and when. The transformer didn't just help machines grasp language. It gave them a way to navigate any structured data – much like humans navigating their own complex worlds. ▮

Jacklin Kwan

Stargazing at home

X marks the spot

Time it right each month, and you can spot two fleeting tricks of light on the lunar surface. **Abigail Beall** is planning ahead

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

THE first time I took a photograph of the moon through my telescope was almost a decade ago. It was a very amateur set-up. I held up my phone camera to the eyepiece and after capturing a dozen fuzzy images, my shaky hands managed to stay steady for long enough that I got a clear picture of the moon's surface. I was so proud of the photo that I posted it online.

I hadn't realised it back then, but I was photographing the moon during a very specific 4-to-6-hour window that comes around each month. It wasn't until someone replied to my post that I realised, by sheer chance, I had captured two fleeting features on the lunar surface known as the lunar X and V.

These marks on the surface of the moon are optical illusions, created by the way sunlight hits the rims of specific craters. And they are only visible during the moon's first quarter phase, when the line between light and shade – known as the terminator – sits at exactly the right spot.

The lunar X (pictured) is, as you might imagine, a bright X shape that appears because light falls on the rims of three craters named La Caille, Blanchinus and Purbach. The V is also bright and comes about because of the way light hits a crated called Ukert and other smaller craters nearby.

To see the lunar X and V, you will need access to a telescope. Other than that, timing is everything. The time to look will always vary depending on where you are in the world – as will the moon's visibility.

THE YOMIURI SHIMBUN VIA AP IMAGES/ALAMY

The next first quarter of the moon will be on 26 January at around 5am GMT, but if you live in the UK, the moon will be below the horizon then, so don't set your alarms. A good place to look from on the night of 25 January into the next morning will be New York, where the first quarter will be around midnight. This means the X and V will be visible from around 10pm to 2am. In other parts of the world, it will be daylight, so the moon won't be visible. From Sydney, for example, the January first quarter will be at around 3pm.

If you hope to see the lunar X and V, your best bet is to find a first quarter moon that falls within a good window for observing the moon from where you live – in other words, when it's dark and the moon is high in the sky. You can use software such as Stellarium to check whether the moon will be visible at a specific time and date, and where it will be in the sky.

The next first quarters are on 24 February, 25 March and 24/25 April. If you live in the UK, like me, 25 March is a good one to aim for, since it falls at around 7pm local time.

Knowing how many factors must align for the lunar X and V to be visible, I feel incredibly lucky that the first time I managed to take a photo of the moon's surface, these two tricks of light happened to be on display. ▮

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Next week
Mathematics of life

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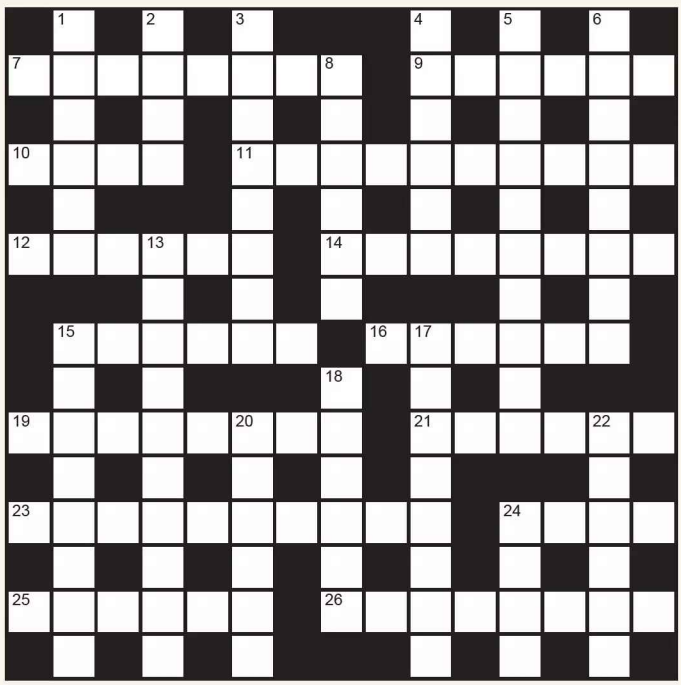
Quick crossword #200 *Set by Richard Smyth*



Scribble zone

Cryptic crossword next week

ACROSS

7 Concerning the chest (8)
9 Diaphragm spasm (6)
10 Metres per second (1/3)
11 Increase in velocity (10)
12 Co (6)
14 Rare (8)
15 Tailbone (6)
16 Chinese social media site (6)
19 Outlines; condenses (6,2)
21 Gain entry to (6)
23 Coming together in a single mass (10)
24 Plant with psychoactive leaves (4)
25 Lessens (6)
26 Type of chemical bond (8)

DOWN

1 Sports therapist, say (6)
2 ___ acid, $C_5H_4N_4O_3$ (4)
3 James ___, US oceanographer (8)
4 ___ acid, $C_{24}H_4OO_5$ (6)
5 Colourless (10)
6 Piping – for ventilation, perhaps (8)
8 Spherical bacterium (6)
13 Increase gradually (10)
15 Units of electric charge (8)
17 Inert (8)
18 In respiratory suspension (6)
20 Neglect (6)
22 Line that intersects a curve at least twice (6)
24 Unemotional (4)

Our games are now playable online
newscientist.com/games

Quick quiz #336
set by Michael Dalton

1 As we recently reported, which frog species has seen its numbers fall by 90 per cent in Chile's Parque Tantauco forests due to the chytrid fungus?

2 Fossils potentially belonging to the last common ancestor of *Homo sapiens*, Neanderthals and Denisovans have been found in which country?

3 Bacteria on which part of a tree have been found to play an overlooked role in controlling greenhouse gas emissions?

4 Which ice dome in northern Greenland was recently found to have completely melted 7000 years ago?

5 What is the acronym for the supercomputer in Germany currently running large-scale simulations of the human brain?

BrainTwister
set by Kirsty Fish

#110 Six, seven

Two terms of a sequence are known – the sixth is 6 and the seventh is 7. It is an arithmetic sequence, meaning each pair of terms is the same distance apart. What is the first term of the sequence?

A different sequence is geometric, where if you divide each term by the next one, the ratio is always the same. If the sixth term is 6 and the seventh is 7, what is the first term?

Another sequence is Fibonacci-like, where each term is the sum of the previous two. If the sixth term is 6 and the seventh is 7, what is the first term?

Answers to this week's puzzles on page 47

Pillow talk

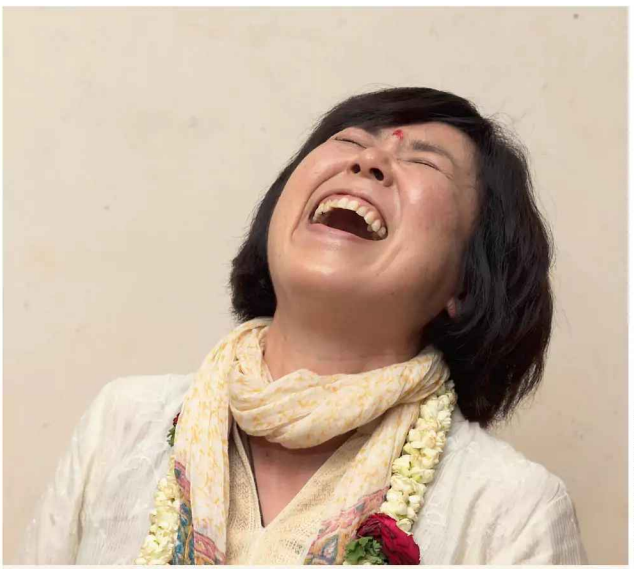
What is it about human physiology that leads us to use pillows, and does anyone know when we first came up with the idea?

Mike Follows
Sutton Coldfield, West Midlands, UK
We likely inherited our habit of using pillows from our ancestors. The great apes build nests in which to sleep. With the exception of those made by gorillas, these nests are usually located in trees, helping the animals to evade predators and biting insects, as well as providing warmth and comfort. Chimpanzees (*Pan troglodytes*), bonobos (*Pan paniscus*) and orangutans (*Pongo sp.*) all construct arboreal sleeping platforms.

Orangutans, in particular, are master architects and have learned to build remarkably strong structures. They deliberately bend and partially break branches, creating what's known as a greenstick fracture. Counterintuitively, this makes the branches stronger, as the only way to break them completely is then to twist them. The apes add loose branches for bedding, including structures that would readily pass for a pillow.

> **"Particularly when lying in the fetal position, having a pillow makes sleep more comfortable for most of us"**

Particularly when lying in the fetal position, having a pillow to support the head makes sleep more comfortable for most of us. Animals that experience more comfortable sleep spend more time in REM (rapid eye movement) sleep, which is crucial for brain development and learning. Nest-building, and the use of a simple pillow, may therefore have been central to the advances made by early hominins.



ALEC SOTH/MAGNUM PHOTOS

Why do we throw our heads backwards when we find something funny?

This week's new questions

Head scratcher **Why do people throw their heads back when experiencing ecstasy, agony, laughter, grief and surprise?**
Rachel Loden*, Palo Alto, California, US*

Signs of life **If the world exploded, what proportion of the rocks floating in space would have evidence of life?**
Tom Frost*, Brisbane, Australia*

Eric Kvaalen
Les Essarts-le-Roi, France
I don't know, but they go back thousands of years. In the Book of Genesis, Jacob is leaving the Land of Canaan to escape the wrath of his brother Esau. He spends the night in the open, and uses a rock for a pillow. He then dreams of seeing a ladder going to heaven, with angels climbing up and down. When he wakes up, he exclaims that the place is full of wonder, the dwelling place of God, and he calls it Bethel, meaning "house of God" (which might be interesting to the question poser, Paul Bethel).

Mike Griffiths
London, UK
In ancient Egypt, people didn't use a pillow, but a solid headrest, with a semicircular top section supported on a pillar. I have no idea how they got a good night's sleep.

Tied in knots

Why do jewellery chains put in a box together become so tightly knotted on themselves, and each other, that it is impossible to unknot them?

David Muir
Edinburgh, UK
A jewellery chain, like everything else in the universe, is subject to the second law of thermodynamics. This states that the entropy (disorder) of an isolated system will increase over time. A box of necklaces, neatly arranged, can only become more disordered (higher entropy) through any random movement of the box, as there are billions of tangled configurations and few ordered configurations (low entropy), and probability is the driver.

As the necklaces become more tangled, there is the likelihood that loose knots can form and, once formed, friction makes it highly improbable that a loose knot will randomly untie itself. Motion in the rest of the necklace is more likely to cause tightening of any knots. It isn't impossible to untie these knots as the correspondent suggests, but to move from a high-entropy situation to a lower-entropy state requires outside input: in this case, human effort, dexterity and patience.

When you start looking, you find that entropy is all-pervasive. The second law of thermodynamics dictates that when you open a bottle of perfume, it is much more probable that the scent molecules will spread throughout the room rather than spontaneously find themselves all back in the bottle. Likewise, glass breaks easily, but shards are unlikely to reform a recognisable article.

Conrad Jones
Llansteffan, Carmarthenshire, UK
The chains are inanimate objects, so they will only become tangled if shaken about in their box, such as in a suitcase put through an airport baggage handling system. Further, even this won't tighten them. My guess is that this happens when their owner is rushing to dress for dinner in their posh holiday hotel, and rashly pulls on one, which tightly tangles on the others. The solution is to send your partner to the hotel bar for two toothpicks (with cocktails if you like) and, maybe using the magnifying app on your mobile phone and with a good amount of patience, use them to gently

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Tom Gauld
for New Scientist

pull the chains apart. Oh, and send for room service, as this will take some time. My next tip would be to use those clever cloth jewellery bags, which at least keep items separate.

Scream if you know the answer

Why do we scream in fear? It doesn't help and makes us more vulnerable to predators (continued)

Ron Dippold
San Diego, California, US
There actually is some small benefit for the screamer. I have been hiking with someone who encountered a brown bear. She screamed. The bear was (apparently) freaked out by the scream and ran away at high speed. I have run into a couple of bears myself without conflict, and you should realise that most predators are not bloodthirsty maneaters. They have far more to fear from humans than vice versa.

But assume you are a neolithic human around the campfire and

"The genes for screaming preserve themselves in our relatives (though sadly, often not in the screamer)"

a bloodthirsty leopard who only wants to feast on human flesh wanders near your camp and runs into you on the periphery. You scream. This has two minor advantages for you: first, it lets your comrades know where to find your body – maybe you won't be quite dead and can be dragged back, or at least they know where your corpse is. But more importantly, you have let your tribe members know there is danger and where it is. Your scream is mostly not for yourself – it's so your relatives can survive.

James V. Stone
Buxton, Derbyshire, UK
When we scream in fear, it does indeed make us more vulnerable to predators. But it makes those around us less vulnerable to them, and if those around us are related to us, then they share some of our genes. Consequently, the genes for screaming preserve themselves in our relatives (though sadly, often not in the screamer).

Thus, our screaming is more likely to benefit the genes for screaming if those around us also possess these genes, and this is more likely if those around us are our close relatives.

The logical endpoint of this kin selection hypothesis is known as Hamilton's rule (1964). This states that altruistic behaviour – in this case, screaming – persists if the fitness cost, C, to the altruistic individual is less than the overall fitness benefit, B, to the recipient, multiplied by the closeness, r, of their relation. Or, $C < Br$.

For example, Belding's ground squirrels make alarm calls most frequently when their close kin are within earshot. So, screaming makes us more vulnerable to predators, but it also helps the genes for screaming in our relatives to survive into the next generation. ▮

Answers

Quick quiz #336

1 The southern Darwin's frog

2 Morocco

3 The bark

4 Prudhoe

5 JUPITER

Quick crossword #200

ACROSS 7 Thoracic, **9** Hiccup, **10** m/sec, **11** Accelerate, **12** Cobalt, **14** Uncommon, **15** Coccyx, **16** TikTok, **19** Summed up, **21** Access, **23** Coalescent, **24** Coca, **25** Abates, **26** Covalent

DOWN 1 Physio, **2** Uric, **3** McCarthy, **4** Cholic, **5** Achromatic, **6** Ductwork, **8** Coccus, **13** Accumulate, **15** Coulombs, **17** Inactive, **18** Apneic, **20** Disuse, **22** Secant, **24** Calm

#110 Six, seven
Solution

If it is an arithmetic sequence, then each term is 1 more than the previous one, so the first term is 1.

If it is a geometric sequence, the ratio between each pair of terms is the same. The ratio between the sixth and seventh terms is 7/6, so each term must be 7/6 of the previous one. The fifth term × 7/6 = 6, so it is 36/7. The fourth term is 216/49 and so on, so the first term is 7776/2401.

The first term is -13. If the sequence is Fibonacci-like, then the seventh term is the sum of the fifth term and the sixth term, which means the fifth term is 1, and so on.

Even stranger things

In common, it seems, with a substantial fraction of the human species, Feedback spent part of our holiday watching the final episodes of *Stranger Things*. We laughed, we cried, we wondered if it would have even more endings than *The Return of the King* (it did).

As is almost inevitable these days, a group of fans vocally disliked the finale, and went so far as to create a conspiracy theory about it. According to "Conformity Gate" (don't blame us, we didn't name it), the finale wasn't the real finale – despite lasting more than 2 hours, costing an enormous amount of money and being shown in cinemas. No, a super-secret final episode was going to air in January, which would reveal the true ending. The evidence for this principally consisted of some minor continuity errors, all supposedly hints that everything we saw was an illusion created by the mind-controlling villain Vecna.

Feedback was confident that this was silly even before the supposed extra episode failed to emerge. Not least because the people critiquing the finale were making the wrong critiques. Who cares about the school's graduation gowns being the wrong colour, when the show's entire set-up defies physics?

For those who didn't watch, *Stranger Things* is set in a town in Indiana, where a government lab has been doing dodgy experiments. This – and there are spoilers ahead, so consider this your warning – has opened gateways to "the Upside Down", a sort of nasty parallel dimension where another version of the town exists, but everything is mouldy. It eventually transpires that the Upside Down is a wormhole: a gateway to yet another dimension called the Abyss.

So if the Upside Down is a wormhole, what is the red wibbly-wobbly swirly thing hovering in the sky? This gets described as a wormhole, and someone says it contains "exotic matter", which is the hypothetical substance that would have to exist to stabilise a real wormhole (and which probably doesn't exist). This is doubly odd, because the passage to the Abyss is in the sky of the Upside Down.

Feedback has been thinking about this for weeks and we cannot work out what the wibbly-wobbly swirly thing is doing there. We also cannot work out why shooting it with a gun causes all nearby matter to liquefy, but blowing it up with explosives destroys the entirety of the Upside Down. And we also cannot work out why destroying this huge wormhole doesn't release enough energy to wipe out most of the eastern seaboard.

Perhaps the Conformity Gate theorists could turn their attention to solving the physics of the Upside Down. A Nobel prize, or at least an Ig Nobel, could be in the offing.

Twisteddoodles *for New Scientist*

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

Sparkle sports

What could be more fun than going to a sports match: being part of a crowd, cheering your players along? Well, what if you were part of a crowd, cheering your players along, while drinking sparkling water? That might be more fun.

Reporter Alice Klein spotted a study about an experiment showing that spectators at a collegiate women's basketball game enjoyed the game more, and felt greater "perceived unity" with the crowd, if they had drunk some sparkling water, as opposed to still water. "Co-consuming sparkling water serves as an alcohol-free, low-burden ritual to enhance social connection during and after live sport events," the authors said.

Alice described this as "ridiculous", to which news editor Jacob Aron retorted: "They studied a whole 40 people, what more do you want?" Readers can make their own judgement as to whether this evidence is convincing. However, Feedback does want to draw readers' attention to the "Competing interests" statement on the paper, on which we will make no comment whatsoever, and which reads as follows:

"This study was funded by the Asahi Soft Drinks Co., Ltd. W.K. and S.M. are employees of Asahi Soft Drinks Co., Ltd. The authors declare that this has not influenced the research design, methodology, analysis, or interpretation of the results of this study. The sponsor had no control over the interpretation, writing, or publication of this work."

Prime bloopers

Reader Peter Brooker wrote in to ask if Feedback could start a new section called "AI Bloopers". He was moved to suggest this after checking a puzzle entry on "a popular search engine", only for its AI tool to confidently inform him that the first six prime numbers were 2, 3, 5, 7, 9 and 11.

Feedback feels that we have been running this section for some time already, just without an official title. In fact (and here we can give you a little glimpse behind the curtain), we have a recurring conversation with our editor about how often to feature AIs messing up like this. We could fill the whole column with AI bloopers every week, but we worry it would get repetitive.

Still, in the spirit of Peter's request, we must tell you that the new chancellor of Ghent University, Petra De Sutter, used a generative AI to write her first speech in the role. It contained quotes from Albert Einstein, which the AI had hallucinated.

To quote *The Brussels Times*: "What's striking is that De Sutter herself referred to the dangers of AI in her speech. She warned that we should 'not blindly trust' the output of AI tools and that AI-generated texts 'are not always easy to distinguish from original works.'"

New Scientist

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