New Scientist

FROZEN BRAIN TISSUE BROUGHT BACK TO LIFE

HOW COUNTRIES ARE PREPARING FOR THE COMING DRONE WARS

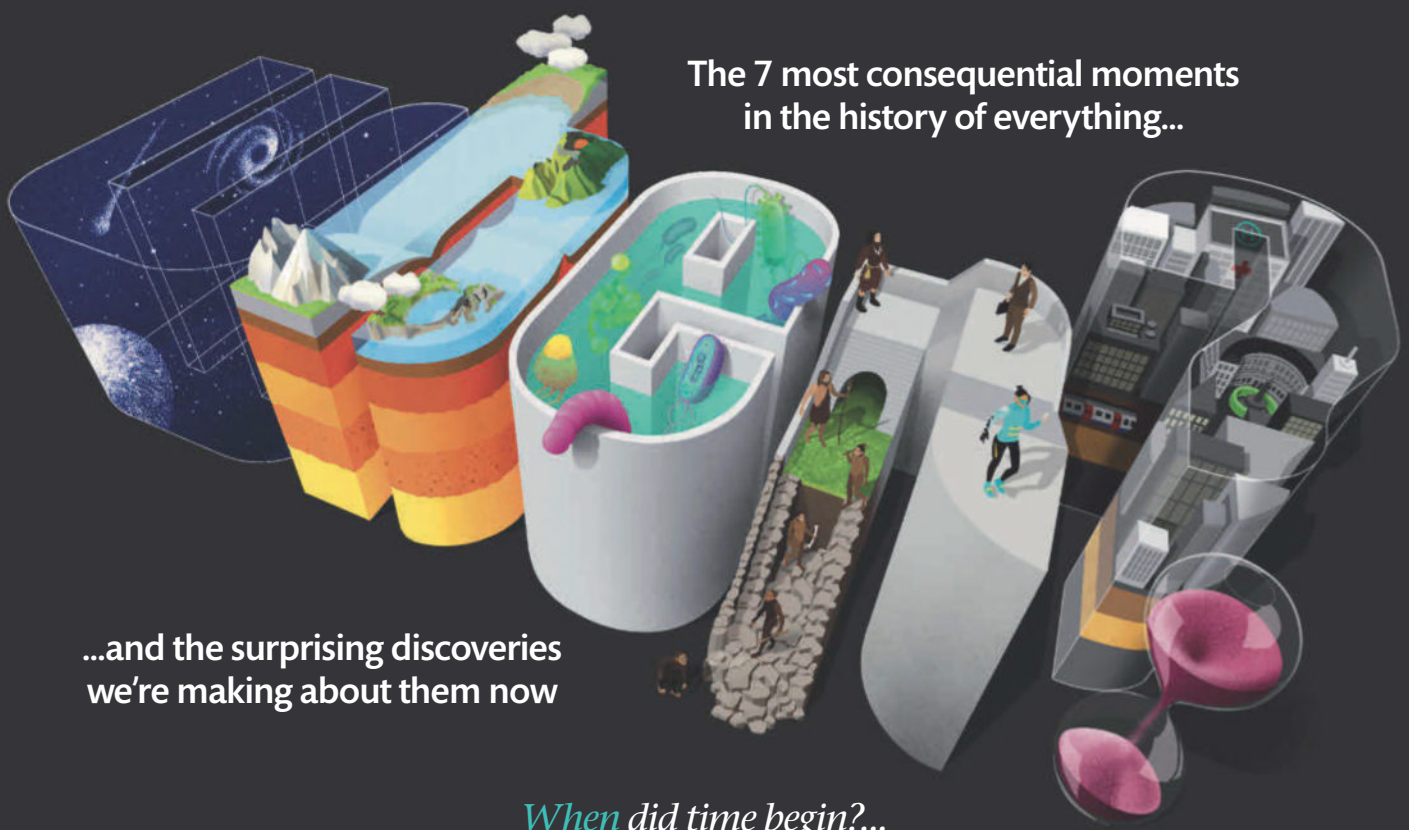
CAN REWILDING DO MORE HARM THAN GOOD?

WEEKLY February 22 - 28, 2025 No3531 US $7.99 Canada CAN$9.99

SPECIAL ISSUE

WHEN?

The 7 most consequential moments in the history of everything...



...and the surprising discoveries we're making about them now

When did time begin?...
When were the first galaxies formed?...
When did plate tectonics start?... When did life emerge?...
When did humans become a distinct species?...
When did civilisation arise?... When did the Anthropocene begin?

PLUS HOW POMPEII BECAME ROMAN
MEGALODON VS MEGALODON
WHY YOU ALWAYS HAVE ROOM FOR DESSERT

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This week's issue

On the cover

30 When?
When did time begin?
When were the first galaxies formed?
When did plate tectonics start?
When did life emerge?
When did humans become a distinct species?
When did civilisation arise?
When did the Anthropocene begin?

Vol 265 No 3531
Cover image: Lex Wilson

News

Views

LIZ BARNEY/GUARDIAN/EYEVINE

Features

The back pages

Elsewhere on New Scientist

Instant Expert

Mind-body connection

Unravel the complex links between our physical and mental worlds, such as the placebo and nocebo effects, and learn how the body is central to the mystery of consciousness. Join six leading experts to discover what this means for our future health and well-being. This Instant Expert event takes place on 26 April at London's Congress Centre.

newscientist.com/events

Tour

Retracing Darwin's travels across Wales

Explore the dramatic landscapes of Eryri (Snowdonia) National Park and examine how the region's geology has been transformed by volcanic and glacial activity over millions of years. Discover the story of Charles Darwin's 1831 and 1842 tours of Wales, and walk in his footsteps from his birthplace of Shrewsbury, England, into Snowdonia. This six-day tour starts on 5 May or 1 September and costs £3445.

newscientist.com/tours

Podcast

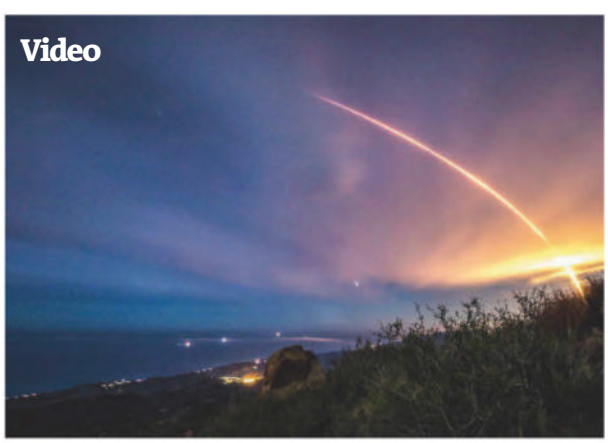
Weekly

The team discuss the asteroid that is currently given a 1-in-43 chance of hitting Earth in 2032. They go to Virginia to investigate a large-scale trail of enhanced weathering to absorb carbon dioxide from the atmosphere. Plus, bits of frozen mouse brain have been revived after being in deep freeze, making cryogenic preservation more plausible.

newscientist.com/nspod

PAWEL BEDNARSKI 303/SHUTTERSTOCK

Origin of evolution Walk Wales as Charles Darwin once did



GEOPIX/ALAMY

Terrestrial life How do rocket launches affect nearby nature?

Video

Space haven

Vandenberg Space Force Base near Lompoc, California, is home to the US Space Force. It is a major SpaceX launch site, but it also contains unique and rare biodiversity across the 99,000-acre site. This includes 17 species that are threatened or endangered, such as the western snowy plover, the California red-legged frog and the vernal pool fairy shrimp.

youtube.com/newscientist

Newsletter

Health Check

Health reporter Carissa Wong looks at the evidence for taking omega-3 supplements. These "good" fats, found in foods such as nuts and some fish, have already been shown to boost our immunity, cognition and heart health. But it was unclear whether omega-3s might slow the pace of biological ageing, too.

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Podcast

"Why would you want to freeze a brain and bring it back to life?"

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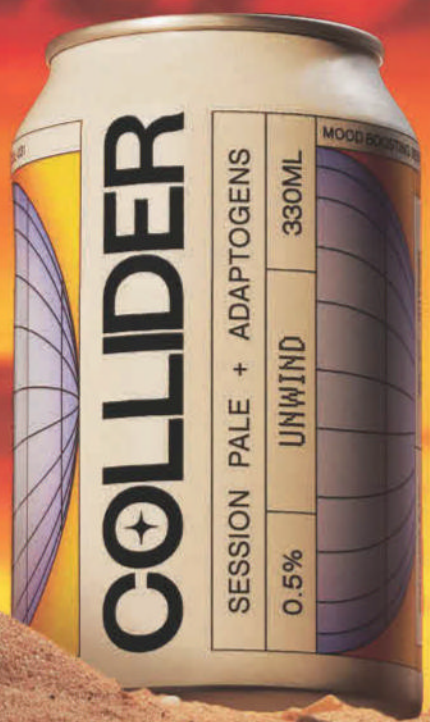

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It's a question of timing

Pinning down dates can completely upend our understanding of events

IF THERE is one word associated with scientific curiosity, it's "why". Why is the universe expanding? Why are cases of cancer rising in young people? Why is the sky blue?

In contrast, it is rare for us to give so much attention to questions that begin with "when". Indeed, it is often written almost in passing that the universe began 13.8 billion years ago, that our planet is 4.5 billion years old or that *Homo sapiens* evolved 300,000 years ago. Yet these confident statements conceal plenty of scientific intrigue, mystery and uncertainty. All of which might make one wonder, well, why? Why don't we focus on "when" a little more?

Asking when forces us to sharpen our thinking, to carefully define our terms and think through what beginnings really look like. It is in this spirit that we tackle seven of the most crucial "when" questions in a special package beginning on page 30. Each piece shows that "when?" can be one of the most interesting questions it is possible to ask.

> "Asking when has already taught us so much about the grand sweep of cosmic history"

To take one example, we have recently begun to find that the first galaxies appeared far earlier than we thought possible. The "when" here dramatically changes our understanding not only of the early universe, but also of how the chemical elements that went on to create life as we know it could have come about. Without "when", there is no "how", and certainly no "why".

Science is increasingly well-equipped to investigate when things happened. We can deduce dates in the distant past using evidence from radioactive isotopes or by extrapolating from known points in history. Our special feature serves as a reminder of how much asking when has already taught us about the grand sweep of cosmic and terrestrial history, from the switching on of the first stars to the first life on this planet.

Asking why is also an important part of scientific curiosity, of course, and something we do often, but let's not give it all the glory. It's time "when" got some of the limelight too, because if not now...

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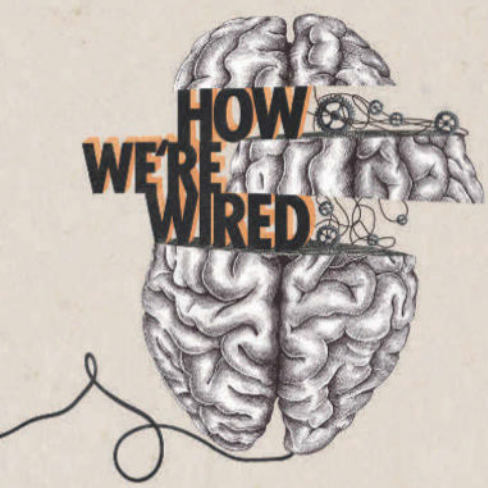

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Geology

Glow of Etna's latest lava flow

A tongue of lava spilling down the side of Mount Etna glows orange on the snow-covered volcano. This image, taken on 12 February by one of the Copernicus Sentinel-2 satellites, shows a river of lava flowing for around 3 kilometres. A smaller flow and plumes of ash can also be seen heading to the right. Etna, in Sicily, Italy, is famously active, and this latest phase began on 8 February.

EUROPEAN UNION, COPERNICUS SENTINEL-2 IMAGERY

Neuroscience

Frozen brain tissue brought back to life

Mouse brain tissue has survived being frozen for a week, in a step towards suspended animation of people, finds **Michael Le Page**

SLICES of mouse brain that were kept at -150°C for up to a week have shown near-normal electrical activity after being warmed up. The results could take us a step closer towards cooling and reviving entire brains for purposes such as putting people in suspended animation for space flights.

"At the moment, it is not possible, but I think there are existing techniques that can be combined to achieve this, and there is room for careful optimism," says Alexander German at the University of Erlangen-Nuremberg in Germany.

The key to cryopreserving living tissues is to avoid the formation of ice crystals. These rip up molecules in cells and even larger structures like blood vessels as they grow, and as the remaining liquid in a tissue becomes more concentrated, that does damage as well.

"I personally do believe that it is possible to cryopreserve a whole human"

Some insects and a few amphibians and reptiles produce cryoprotectants that help control ice crystal formation, such as the brown tree frog (*Litoria ewingii*), allowing them to survive in below-zero temperatures.

In the 1980s, Greg Fahy, now scientific head of California-based company Intervene Immune, and William Rall, then at the Cryobiology Laboratory in Maryland, showed that mammalian cells could be preserved by adding cryoprotectants that result in fluids turning into a so-called amorphous solid when cooled rather than crystallising – a process known as vitrification.

AMELIE-BENOIST/BSIP/ALAMY

Cryopreservation of tissue samples, such as stem cells, involves cooling them using liquid nitrogen

This works by largely replacing the water in cells with cryoprotectants, says German. "For conventional biologists, it's often hard to believe that it is possible to replace the majority of water molecules in the tissue with different polar solvents."

In 2006, Fahy and his colleagues reported reviving slices of a rat brain after cooling them to -130°C for short periods. But the limited test results they described didn't convince neuroscientists that the slices had regained normal activity, says German.

Now, he and his team have gone further. They first experimented with different combinations of cryoprotectants and varying methods for applying them to minimise adverse effects – for instance, cryoprotectants can be toxic at the high concentrations required and they can cause cells to swell or shrink.

DAVE WATTS/ALAMY

The brown tree frog produces natural cryoprotectants to help it survive freezing

The researchers then used their optimised technique to cool slices of the hippocampi of mouse brains to -196°C with liquid nitrogen, before storing them in a freezer at -150°C for up to a week. After reviving them, the team did a battery of tests, including measuring electrical activity. All the results were similar to those seen in non-cryopreserved brain slices (bioRxiv, doi.org/n68v).

Recovered memories?

In particular, there was no damage to the delicate synapses that connect nerve cells to each other. In a whole brain, this degree of recovery should preserve memories. "That would be expected, but this needs to be confirmed," says German.

In 2021, rat hearts were revived after vitrification, he says. This was achieved in rat livers in 2022 and in rat kidneys in 2023.

"And our work now shows that it is also possible to cryopreserve rodent brain tissue slices," says German. "So this is leaving some room for optimism that it would be possible to cryopreserve the whole brain, and also the whole rodent organism, at some point. I personally do believe that it is possible to cryopreserve a whole human and that this could have beneficial applications if done responsibly."

Even if it becomes possible to cryopreserve and revive healthy brains, this doesn't mean people cryopreserved after death with these improved methods could be revived. Significant damage can occur after death, says German.

"It's an exciting piece of research that pushes the boundaries in the fascinating area of brain cryopreservation," says João Pedro de Magalhães at the University of Birmingham in the UK. "Of course, there is still a lot more research needed before we can cryopreserve human organs, including brains, but it is a step in the right direction."

John Baust at Binghamton University in New York state says the work is a step forward, but the findings need to be independently verified. He also isn't convinced that this approach will help with entire brains. "Whole-organ vitrification and long-term functional recovery is an entirely different ballgame," he says.

Even if the improved method works only with slices of brain tissue rather than whole brains, being able to store and revive slices will in itself be a very useful tool, as these usually survive for only 10 or so hours.

For instance, small living slices of human brains are sometimes removed during surgery, says German. If these could be stored and transported, it would greatly increase the opportunities for using them to study brain conditions and test treatments.

"There are immense potential applications of brain slice vitrification for the sharing of valuable materials between different laboratories and for preserving valuable brain samples for later analysis," says Fahy. ▮

Evolution

Surprising fossils suggest early animals could survive out of water

Michael Marshall

ANIMALS living about 500 million years ago spent time on mudflats that were periodically exposed to the air. The finding suggests that some of the earliest animals were able to survive outside of water, if only for a limited time, tens of millions of years before some animals started living permanently on land.

"They must have had mechanisms to cope with some of the stressors of this environment," says Giovanni Mussini at the University of Cambridge. "There was already the genetic toolkit, the physiological toolkit, to make these brief excursions into very landward environments."

Mussini and his colleagues re-examined sedimentary rocks from the Pika Formation in Jasper National Park, Canada. They were originally collected in 1999 but then went largely unexamined for two decades. The rocks are estimated to be about 498 million years old, placing them in the middle of the Cambrian Period (539-487 million years ago), which is when many of the major animal groups originated.

The team found thin layers of shale with telltale cracks,

"There was already the genetic toolkit to make these brief excursions into landward environments"

indicating that the rocks formed from mud that had dried in the sun. Combined with other evidence, this suggested that the mudflats were sometimes exposed to the air.

Mussini emphasises that we can't be sure whether the mudflats were regularly exposed, as in a modern tidal zone, or only intermittently. "All we can tell from the evidence I've seen, at least, is that sometimes this was exposed," he says. "Some of the time, if not most of the time, I would say it was underwater."

Despite this setting, the team found abundant animal fossils (*Palaeontology*, doi.org/n68n). There were annelid worms, which are related to modern earthworms, and marine worms called priapulids. They also found fragments of animals similar to *Wiwaxia*, which Mussini calls a "spiny, slug-like creature with blades covering its body".

These types of animals are known from other Cambrian fossil beds, including the Burgess Shale in British Columbia, also in Canada, which famously preserved many soft-bodied creatures. Most such deposits formed in deep waters, however, suggesting the species preserved in them couldn't survive out of water. The Pika Formation finds indicate that some of them could, at least for a while.

"Animals, by this time, were not confined to these deeper water environments," says Mussini. "Some of them already had physiological tolerances and environmental tolerances that allowed them to edge closer to exposed environments."

"They expanded the ecological ranges for the Cambrian fauna," says Xiaoya Ma at the University of Exeter in the UK.

Spending time out of water requires tolerance for sharp temperature changes and for drying out, says Ma. Modern intertidal organisms, like molluscs on seashores, have similar tolerances. "They can endure quite harsh environments," she says. ▮

Environment

Torrential rain didn't replenish California's deep groundwater

IN 2023, atmospheric conditions brought months of heavy precipitation to much of California, filling reservoirs and raising the snowpack far above average levels. This was a major relief after nearly two decades of drought, but it seems it did little to restore the state's depleted reserves underground.

"There was very limited recovery, compared to the groundwater lost over the recent droughts," says Shujuan Mao at the University of Texas at Austin.

Groundwater supplies between 40 and 60 per cent of California's water. But years of drought and over-pumping, especially for irrigation, has severely depleted the state's aquifers. "People don't really see what's underground, so they tend to think less about groundwater," says Mao.

She and her colleagues used the dense network of seismic sensors around earthquake-prone Los Angeles to see how groundwater changed in the aquifers beneath the city during years of drought and 2023's heavy precipitation, measuring the faint ambient seismic waves generated by human activity and the tides. When these waves pass through an aquifer, they change velocity depending on the water pressure.

SCOTT LONDON/ALAMY

A flooded farm in California's Central valley after heavy rain in 2023

While the precipitation in 2023 largely replenished the shallow aquifers beneath Los Angeles, the team found deeper aquifers only regained 25 per cent of the water they had lost due to pumping during droughts since 2006 (*Science*, doi.org/g842dg). This shows one wet year isn't sufficient to solve California's groundwater crisis.

With the state facing another wet forecast after a year of drought, California is actively trying to capture more of this water underground. This could involve letting water pour out of rivers to flood fields, giving it more time to seep into the soil. The low recovery rate in 2023 suggests there is scope for such efforts to make a difference, says Mao. ▮

James Dinneen

Technology

The coming drone wars

Future conflicts are likely to involve the kind of drone deployment currently being seen in Ukraine, so how are the world's militaries preparing, asks **David Hambling**

UKRAINE and Russia are now three years into what has been called the first drone war: not the first in which they were used, but the first in which they have been a major factor on the battlefield. What lessons have other nations drawn about the shape of future wars?

"Drones are here to stay, and they will be everywhere – on the ground, in the air and at sea – in numbers," says Oleksandra Molloy at the University of New South Wales in Canberra, Australia. "The point of no return was passed in 2022."

Military drones were, of course, in use long before Russia's invasion of Ukraine that year, particularly rising to prominence with the US's employment of Predator drones during the 2000s. However, the technology now being used and the scale at which it is being deployed – Russia and Ukraine each built more than a million military drones in 2024 – are unlike anything we have ever seen. With global tensions rising, other nations are starting to think about how they might fight a drone war on a similar scale.

"We can't predict future developments, but many countries around the world are writing strategies for using drones, acquiring them and introducing in their military training," says Molloy. "These will define objectives and, at the highest level, will guide each country's dos and don'ts."

Low-cost options

For example, the US Department of Defense (DoD) is now working to develop the capacity to rapidly produce large numbers of low-cost drones, rather than small numbers of high-end drones like the Predator at present. In Europe, a coalition of nations led by Latvia is developing a drone-manufacturing base to supply hardware to Ukraine, but will ultimately beef up domestic capacity, while the UK has tasked a Royal Air Force unit with testing drone swarm technology.

KATERYNA KLOCHKO/EPA-EFE/SHUTTERSTOCK

Ukrainian troops have made extensive use of drones

Part of the challenge in setting up these initiatives is that drone technology evolves so fast. Molloy says people in Ukraine talk about a 40-day development cycle, rather than the years usually required to specify, develop, test and get new military hardware onto the battlefield.

"Nothing drives innovation like an existential threat," says Molloy. "Necessity is the mother of invention. War is the catalyst of technological innovations, and you can't progress at the same speed in the peacetime. Our mindset isn't adapted to it."

This rapid evolution means that any huge investments in hardware look speculative. The peacetime procurement cycle means drones might be obsolete before they can be delivered. But there is a growing awareness that nations need to plan for the age of drone warfare.

One concern for militaries is how dependent drone supply chains are on Chinese manufacturers. For example, last year US drone-maker Skydio was sanctioned by China for selling drones to Taiwan, limiting its supply of batteries and disrupting the company's delivery schedule.

> **"Drones are here to stay, and they will be everywhere in large numbers"**

Both Russia and Ukraine have taken steps to make items such as batteries and flight controllers locally, in an effort to remove supply bottlenecks and to avoid the sudden price hikes during shortages. The US is yet to fully tackle this problem, however: the DoD has taken steps to ensure that drones don't contain electronics from China or other nations that could compromise security, but hasn't yet addressed the supply chain issue for more basic components.

"Developing sovereign capability in drones allows a nation to independently design, manufacture and operate drones, providing greater control over their technology," says Molloy. "Domestic production also mitigates vulnerabilities associated with international supply chain disruptions and potential political constraints on foreign procurement."

As for China itself, it is unclear what lessons its armed forces are drawing from the conflict. Publicity videos from the People's Liberation Army show Chinese troops training with small attack drones and robotic dogs, but it isn't known whether these represent experiments, actual integration into infantry units or simply flashy propaganda. Molloy says it is hard to tell how much is real, but US defence analyst Zachary Kallenborn says it seems plausible that China is moving to a drone-enabled force: "The barriers for such integration seem pretty low."

Indeed, the low barriers to entry are what make drones so different to other military technology, as they can be acquired on shoestring budgets. In Ukraine, infantry units have developed their own drone reconnaissance and strike capabilities using hardware donated by well-wishers or bought by the soldiers themselves.

The flip side of this is that nations need to consider the drones that will be deployed

against them, with every future war likely to be a drone war. The problem is that nobody knows what drones will look like even in a few years. "You can't develop counter-drones if you don't know what's coming next," says Molloy.

Emerging technology

That means analysts are keeping a close eye on technologies now emerging in Ukraine, says Molloy, including fibre-optic-controlled drones that can't be jammed and advances in artificial intelligence that allow drones to avoid incoming projectiles. "It gets complicated when you are dealing with large numbers and different types of drones," she says.

For example, the battlefields of Ukraine are now seeing small quadcopters for reconnaissance and attack deployed alongside larger quadcopter bombers and fixed-wing attack drones, like Russia's Lancet, or strategic attack drones with ranges of more than 1000 kilometres. Such attacks may come simultaneously from different speeds and altitudes, requiring multiple countermeasures. The only thing that seems clear is that existing defences aren't adequate.

"We are close to a consensus that expensive missiles are not the solution to small drones at scale," says Kallenborn. Instead, future drone defence will need to be "cheap, sustainable and multi-dimensional", he says, able to counter large high-performance drones as well as swarms of smaller ones. This will involve a layered defence of radars and other sensors, with smart control systems linked to an arsenal of missiles, guns, jammers and interceptor drones that can be rapidly tasked to take down a mixed swarm.

Finally, there is the ultimate question when it comes to drones: can they replace human fighters entirely? Ukraine has been attempting to put uncrewed systems in the frontline and has even carried out an assault on Russian positions using entirely robotic forces backed by drones. But Molloy says the rise of the robots isn't yet complete.

"Drones alone cannot win wars. We still need humans to hold ground. At present, drones are not capable of doing this," she says. "But it is possible this could happen in the next conflict." ▮

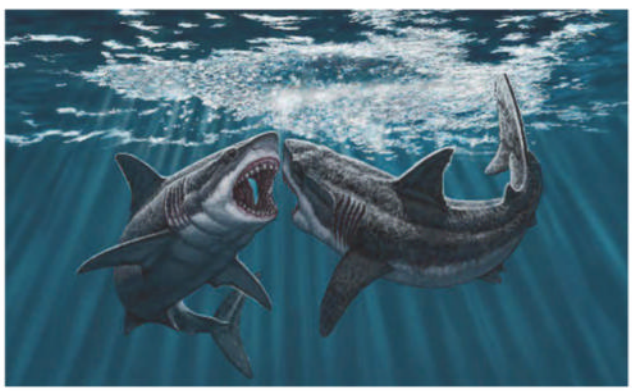
MA JIAN/VCG VIA GETTY IMAGES

Drones coordinating a display for China's Army Day

Palaeontology

Megalodon sharks may have fought with their jaws

Riley Black



CLARENCE "SHOE" SCHUMAKER/CALVERT MARINE MUSEUM

SEVERAL fossil teeth from the giant predatory shark *Otodus megalodon* show scratch marks that could only have been made by members of their own species, suggesting that the largest sharks of all time may have fought by sparring with their jaws.

Between 23 million and 3.6 million years ago, megalodon, which may have grown up to 24 metres long, swam the world's oceans. Now, Stephen Godfrey at the Calvert Marine Museum in Maryland and his colleagues have studied four teeth from fossil sites in North and South Carolina dating to about 12 million years ago.

The giant predatory shark grew up to 24 metres long

"Fossil teeth show scratch marks that could only have been made by their own species"

Each one had parallel scratch marks characteristic of the gouges made by *O. megalodon*'s serrated teeth (*Acta Palaeontologica Polonica*, doi.org/n6zg). "Meg-bitten teeth are exceedingly rare in the fossil record," says Godfrey.

One of the teeth was scratched perpendicular to its length. This damage couldn't have been caused by a shark biting in such a way as to scratch its own teeth, which raises the possibility of combat between two sharks. Alternatively, the megalodon's body may have been scavenged by another megalodon after it died.

It is possible that each tooth was marked in a different way, says Alberto Collareta at the University of Pisa in Italy, who wasn't involved in the study. "Sharks that feed on carrion occasionally leave their teeth embedded in bitten items, where they may receive or record their own bites," he says.

Nevertheless, researchers have found other evidence that megalodons weren't shy about biting predators around the mouth. Prehistoric sperm whale teeth have also been found with *O. megalodon* bite marks.

It is unclear whether the sperm whales or megalodons were alive or carrion when bitten, but either is possible, says Godfrey. "Extant sharks are known to engage in cannibalism and scavenging, and these meg-bitten teeth could have come about because of comparable encounters," he says. ▮

Analysis Conservation

Is rewilding actually bad for global biodiversity?

Conservation projects in wealthy but nature-depleted countries can cause food and timber production to "leak" into poorer, wildlife-abundant nations, finds **Madeleine Cuff**

BETWEEN 1990 and 2014, forests in Europe expanded by 13 million hectares, an area roughly the size of Greece – but that came with a cost. Crops consumed in the European Union had to be grown somewhere, so, in other nations – mainly tropical countries – around 11 million hectares of forest was chopped down to make up for the drop in EU production.

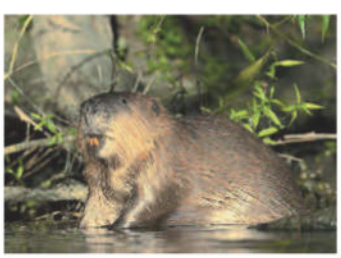
Such biodiversity "leakage" is a major problem with conservation and rewilding projects, particularly schemes in higher-income, industrialised countries that tend to have lower biodiversity, says Andrew Balmford at the University of Cambridge, who is among a group of scientists calling for greater attention to be paid to this issue (*Science*, doi.org/n6x3).

Restoring nature in wealthy but nature-depleted parts of the world can lead to a net loss of biodiversity, he argues, by pushing production of food and other products to more wildlife-abundant regions. The impact of this is rarely tracked, meaning the benefits of conservation actions are probably overestimated.

The UK is one of the world's most nature-depleted countries, with just half of its biodiversity left. Habitats have been destroyed for building or to harvest food and fuel, causing widespread decline in animal populations. This trend is mirrored in other higher-income, industrialised regions, including other parts of Europe and North America.

Conservation groups have been championing rewilding to restore indigenous wildlife to nature-depleted nations. But if this pushes food or fuel production overseas, it is doing more harm than good, says Balmford. For example, if productive arable farmland in a country like the UK is rewilded, this could lead to increased habitat destruction overseas, as more biodiverse nations increase their production of wheat, barley and oilseed rape to make up the shortfall. The upshot would be a net loss of biodiversity, he says.

PAUL GLENDELL/ALAMY; BELOW: DAN KITWOOD/GETTY IMAGES



River and woodland regeneration in the Cairngorms (above) and beaver reintroductions in Kent (left) are two rewilding schemes in the UK

Even projects on low-grade land could have a negative impact, he warns. "In general, rewilding efforts are tending to target lower-yielding farmland, but there is still a yield on farmland very often, so that production will still go overseas," says Balmford. "We're effectively increasing our footprint, our offshoring of the problem, and that seems essentially quite an irresponsible thing to do."

> **"We're effectively increasing our offshoring of the problem, and that seems quite irresponsible"**

It is a problem discussed in conservation circles, but it is "very rarely actually acted upon", he says.

One option is to focus action on the most biodiverse nations. But this brings geopolitical problems, says Steve Carver at the University of Leeds, UK. If we want lower-income, biodiverse nations to protect their ecosystems, higher-income countries have to lead the way, particularly as almost all nations have pledged to meet conservation targets. "If we [in the UK] just ignore our obligations to biodiversity, then we are just offshoring those obligations," says Carver.

Perhaps a better strategy would be to manage the trade-offs internally. If countries like the UK want vast, wild landscapes, there will be a price to pay, says Balmford. "To what extent is it reasonable for us to expect to be able to have nature everywhere in the UK at the expense of people in the rest of the world having a great deal less?" he asks. "It's not unreasonable to at least explore the proposal that we should deal with some of those trade-offs internally, rather than export them and expect other parts of the world to sort them out."

For example, restoring of wild landscapes should happen alongside increased domestic production to prevent leakage effects, he says. That might mean more intense farming methods, heavier logging activities or the conversion of leisure landscapes like golf courses into food production. In Sierra Leone, for example, conservationists enhancing protection for the Gola rainforest are working with farmers to increase yields.

For Alister Scott at The Global Rewilding Alliance in Switzerland, expecting conservationists to take responsibility for land productivity elsewhere risks overburdening a movement that is still largely finding its feet. "You're putting more responsibilities onto nature restoration people when, frankly, I don't see the beef industry and the timber industry taking any kind of responsibility for their leakage effects," he says.

Instead, Scott wants more focus on the drivers of demand for land use. There would be little competition for land if the global food system became more efficient by swapping the most land-hungry foodstuffs – meat and dairy – for plant-based alternatives, he says. With a global change in diet, richer and poorer nations alike could rewild. "We have absolutely no problem feeding the world's population at current and increased levels if we shift the focus of food production," says Scott. ▮

Environment

Microbe dyes could make clothes greener

Michael Le Page

THE colour in our clothing has many serious environmental consequences, from the use of fossil fuel by-products to make dyes to the heavily polluted water left after dyeing. But the UK-based company Colorifix says it can reduce these by using microbes that both make the dyes and help fix them to fabrics.

"We've had considerable interest in this, because consumers are really starting to think about what they wear and how it damages the environment," says Colorifix's chief science officer, Jim Ajioka.

> "Consumers are starting to think about what they wear and how it harms the environment"

Ajioka and Orr Yarkoni founded the company in 2016 to commercialise the process they developed to genetically modify bacteria or yeast to "grow" dyes, instead of making them from chemicals derived from fossil fuels.

Some of the colours made by the microbes are pigments long used for dyeing, such as the indigo that gives denim its colour. Others are novel, such as a reddish pigment found in a mould that can grow in showers.

When textiles are put in the vats where the microbes are growing, the cells attach themselves to the fibres. This means they are producing the dye exactly where it is needed, says Ajioka. "They like going onto surfaces," he says. "That's a real advantage that we have."

In fact, the microbes naturally work their way inside the fibres. In conventional dyeing, fabrics instead have to be heated to up to 130°C (266°F) to open up the fibres so dyes can get inside them. "You waste a lot of energy going up to these very high temperatures to open up the fibres," says Ajioka. The Colorifix process does involve heating to burst open the microbes and release the dyes, but not to such high temperatures.

Conventional dyeing also involves adding chemicals known as mordants that help fix colours to fibres. Chromium is used, but it is toxic. Sodium, potassium and magnesium can also be used as mordants, says Ajioka, and they are naturally found within cells. So the microbes also provide the mordants when they burst open.

According to the company, the process uses about half as much energy and a quarter as much water, with the leftover liquid containing only biodegradable substances. Water authorities in Cambridge gave the company permission to put it straight into sewers after testing, says Ajioka.

One downside is that the microbes are fed nutrients derived from soya, which might lead to an increase in the area of land that is farmed, and thus to more deforestation.

"This innovative, microbe-based dyeing technology offers significant environmental advantages," says Suraj Sharma at the University of Georgia in the US.

The company is one of several aiming to make the dyeing industry greener. At least three – Alchemie, Imogo and NTX – have developed processes that are more like printing than conventional dyeing. Sharma's team, meanwhile, has created a way of dyeing denim that involves attaching indigo to cellulose nanofibres that then bind to the cotton. ▮

Archaeology

Pompeii's streets show switch to Roman rule

Colin Barras

A CLOSE look at Pompeii's roads has shown how traffic through the ancient city changed dramatically after it was incorporated into the Roman world.

Although often seen as a quintessentially Roman place, Pompeii was anything but. For several centuries, it was actually governed by a different people, known as the Samnites – and even after it fell to the Romans in 89 BC, Pompeii retained traces of its Samnite identity right up until its destruction by the eruption of Mount Vesuvius in AD 79.

"If I was visiting Pompeii in AD 78, it would have had a very different character than a city closer to Rome," says David Picker-Kille at Florida State University.

Despite this, life in Pompeii did change after it became a Roman colony, says Picker-Kille. He has concluded that traffic patterns shifted – potentially evidence of local entrepreneurs reorganising their business operations to cater to Rome's vast trade networks.

His conclusion came in part from the fact that the Samnites and Romans had slightly different measurement systems. Crucially, these differences are significant enough that we can tell whether pairs of wheel ruts worn into Pompeii's streets were left by Samnite-style or Roman-style carts.

Based on this, Picker-Kille discovered that ruts in the streets around Pompeii's northern city gate – which faces Vesuvius – were typically left by Samnite-style carts. Ruts in the streets around its southern gate – which faces the Sarno river – were typically left by Roman-style carts .

This doesn't tell us when those different carts were in use – but there are clues from a recent analysis of the city's streets led by Eric Poehler at the University of Massachusetts Amherst. With colleagues, Poehler built up a detailed picture of how Pompeiians repaired their highways in response to the damage caused by carts.

After studying this evidence, Picker-Kille realised it showed that the streets around the northern city gate were most heavily used and repaired in the decades just after Pompeii became a Roman colony. Routes around the southern gate, in contrast, were most heavily used later, shortly before the eruption of Vesuvius (*Journal of Archaeological Science*, doi.org/n6zp). "We're seeing this shift affecting different kinds of vehicles used in different areas of the city," says Picker-Kille.

He suspects this reflects Rome's influence. Under Samnite rule, Pompeiians had traditionally farmed on the fertile land around Vesuvius to the north of Pompeii. After the Romans took over, Pompeiians might have preferred farming on land to the south so as to be nearer to the Sarno river, on which archaeologists suspect there was a port that tapped into Rome's maritime trade network. ▮

Different types of carts carved distinctive ruts into Pompeii's streets

IMAGODENS/SHUTTERSTOCK

Humans

Most Europeans probably had dark skin until 3000 years ago

Michael Le Page

JUSTIN TALLIS/AFP VIA GETTY IMAGES

A model of Cheddar Man, who lived in Britain 10,000 years ago

A STUDY of ancient DNA from people who lived in Europe between 1700 and 45,000 years ago suggests that 63 per cent of them had dark skin and 8 per cent had pale skin, with the rest somewhere in between. It was only around 3000 years ago that individuals with intermediate or pale skin started to become a majority.

Until a few years ago, it was assumed that the modern humans who moved into Europe around 45,000 years ago rapidly evolved paler skin to ensure they got enough vitamin D in weaker sunlight. Cells in the skin can make a precursor of vitamin D when exposed to ultraviolet light, but in darker skin, fewer UV rays reach these cells.

However, this view has changed as it has become possible to sequence DNA from individuals who lived many thousands of years ago and to apply methods developed by forensic scientists to help identify suspects from DNA samples found at crime scenes.

In 2018, for instance, researchers found that Cheddar Man, an individual who lived in Britain 10,000 years ago, probably had very dark skin and blue-green eyes. Such predictions about individuals have been criticised, though, as the genetics of pigmentation aren't fully understood and so we can't be certain about the conclusions.

63%

Percentage of people who lived in Europe between 1700 and 45,000 years ago thought to have had dark skin

Guido Barbujani at the University of Ferrara in Italy and his colleagues have now predicted the skin, eye and hair colour of almost all the ancient Europeans whose genomes have been sequenced so far – 348 individuals in total – to get the most comprehensive picture yet of how these traits changed due to factors such as natural selection, sexual selection, war and migration (bioRxiv, doi.org/n6x2). Gaps in the sequences meant it wasn't possible to predict all three traits in all 348 genomes.

With this large dataset, errors should average out at the group level, so the team's overall conclusion that most ancient Europeans were dark-skinned is more robust than the individual predictions. However, the results should still be treated with caution, as there is no way to check whether predictions based on modern European populations are accurate for ancient people.

"This paper is enormously significant because of the breadth of sampling undertaken and the care and attention given to the analysis of the ancient DNA data," says Nina Jablonski at Pennsylvania State University.

The reason why Europeans seem to have evolved paler skin relatively recently may relate to dietary changes as people started living in bigger settlements, says Jablonski. "Most Palaeolithic hunter-gatherers and most Bronze Age peoples probably did get sufficient vitamin D from dietary sources, including from the meat of wild animals," she says. "This situation doesn't begin to change significantly until settlements get larger."

It is possible that some of the Neanderthal peoples who lived in Europe long before modern humans arrived had pale skin, but there was probably a lot of variation, says Jablonski. "Their skin colours probably varied nearly as much in time and space as those of modern humans." ▮

Health

Modified cells could help prevent clogged arteries

Carissa Wong

GENETICALLY engineered immune cells could help reduce the clogging of arteries, potentially lowering the risk of heart attack or stroke in people who don't respond to common treatments.

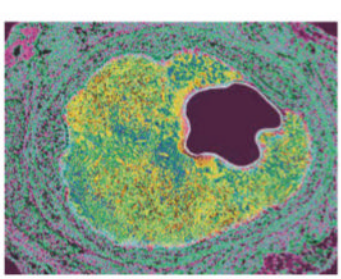
Many cardiovascular conditions are caused by the build-up of fatty deposits called plaques on artery walls, which can restrict blood flow to major organs. Statins and some other drugs work by lowering levels of low-density lipoprotein (LDL), or "bad" cholesterol, a key component of plaques. However, inflammatory immune cells may also play a role in plaque build-up, or atherosclerosis.

To address this, Robert Schwab at the University of Pennsylvania and his colleagues collected immune cells called T-cells from mice and genetically tweaked them to release anti-inflammatory proteins in the presence of LDL cholesterol. Next, the researchers injected two doses of the engineered cells into each of four mice over five weeks, while feeding the animals a high-fat diet that causes atherosclerosis.

After another five weeks, the researchers found that arteries extracted from the mice contained 80 per cent less plaque, on average, than those from controls (bioRxiv, doi.org/n6xz).

"The LDL-targeted T-cells substantially reduced plaque build-up, without major side effects," says Schwab. ▮

Clogged arteries result from the build-up of fatty deposits called plaques



BSIP SA/ALAMY

Geology

Earth's core pulled out of shape

Seismic waves suggest the change happened in the past few decades

James Dinneen

OUR planet's solid inner core appears to have changed shape in the past 20 years or so.

Since the 1990s, models and seismic measurements have indicated that Earth's iron-nickel inner core moves at its own pace. Over decades, the rotation of the inner core speeds up and slows down relative to the rest of the planet, affecting things such as the length of a day.

These changes in rotation are mainly due to magnetic forces generated by convection in Earth's liquid outer core, says John Vidale at the University of Southern California. "That flow is continually torquing the inner core," he says.

Those magnetic forces, or related processes, could change the shape of the inner core as well – in fact, past measurements of seismic waves passing through the planet's centre seem to indicate just that. But uncertainty about the core's rotation made it impossible to distinguish between a change in rotation and a change in shape.

Now, Vidale and his colleagues have analysed seismic waves generated by 128 earthquakes off the coast of South America between 1991 and 2023. The waves

"This is critical to understanding the evolution of Earth's deepest interior"

were all measured by instruments in Alaska after passing through the planet. From these, the researchers identified 168 pairs of seismic waves that passed through or near the same area of the inner core – but years apart. Identifying these matches was only possible due to recent work better constraining the changes in rotation of the inner core, says Vidale.

Both waves in each pair that didn't pass through the inner core shared a similar pattern, suggesting nothing had changed in those areas within our planet between the first and second quake. But the waves in pairs that did intersect with the inner core didn't match, indicating something about the core had changed beyond what could be explained by differences in rotation (*Nature Geoscience*, doi.org/g84k38).

The researchers say this suggests the inner core not only slows down or speeds up its rotation over decades, but it also changes shape. They say these changes would most likely be caused by convection in the outer core pulling magnetically at the less viscous edge of the solid inner core, or by interactions between the inner core and structures in the lower mantle, the layer between our planet's core and its crust.

Hrvoje Tkalčić at the Australian National University says this is a "step forward" towards resolving changes in the inner core beyond rotation. But he says a change in shape isn't the only explanation for the mismatched seismic waves.

As Vidale and his colleagues acknowledge, those differences could also be caused by unrelated changes occurring within the outer core, convection in the inner core itself or even eruptions of melted material from the inner core. "It's really hard to tell," says Vidale.

Tkalčić says that more seismological measurements in remote places, like the ocean floor, would also help. "This is critical to understanding the evolution of the Earth's deepest interior, from the time of the planetary formation to the present day," he says. ▮

Palaeontology

Feathered dinosaur may be the earliest known bird

A FOSSIL from China that's 150 million years old may be the world's earliest known bird. The discovery shows that the short tails seen in modern birds evolved much earlier than previously thought.

Birds evolved from theropods, a group of dinosaurs that included velociraptors, during the Jurassic period. *Archaeopteryx* has long been considered one of the earliest birds in the fossil record. But its position on the evolutionary tree is debated because, despite having feathered wings, it is more similar to non-avian theropods in having a long, reptilian tail.

The new fossil was found in Zhenghe County in Fujian province in November 2023 and has been given the species name *Baminornis zhenghensis*. Only the torso, forelimb, pelvis and part of the hindlimb are preserved.

Baminornis lived at the same time as _Archaeopteryx_ but has a short tail like those of modern birds, pushing back the date of this innovation by 20 million years (*Nature*, doi.org/g8439c).

"A short tail is widely regarded as aerodynamically beneficial, and the reduction of the tail constitutes the most dramatic change during the dinosaurs-bird transition," says Min Wang at the Chinese Academy of Sciences in Beijing, who was on the team that analysed the fossil.

L: ZHAO CHUANG; R: WANG MIN

An artist's impression of *Baminornis zhenhensis* (far left) based on the fossil (near left)

Weighing 140 to 300 grams, _Baminornis_ was much smaller than _Archaeopteryx_ – about the size of a quail – and it would have looked more like modern birds than _Archaeopteryx_ did, says Wang.

Some parts of its body, such as its hands, retained the ancestral morphology of dinosaurs, while its pectoral and pelvic anatomy were similar to modern birds. "This demonstrates that different body regions evolved independently," Wang says. "In light of all this, I would say _Baminornis_ is probably the oldest unambiguous record of birds." ▮

James Woodford

Cosmology

Tiny galaxy may host huge black hole

Supermassive object seems to sit at centre of the Large Magellanic Cloud, firing stars our way

Jonathan O'Callaghan

NINE stars zooming through our galaxy could be the result of a supermassive black hole in the Large Magellanic Cloud (LMC) – a surprising hint that dwarf galaxies can host large black holes.

"This is the first compelling evidence for a supermassive black hole in [a dwarf] galaxy," says Jiwon Jesse Han at the Harvard-Smithsonian Center for Astrophysics in Massachusetts. He estimates the mass of the black hole in the LMC would be about 600,000 times that of the sun. For comparison, the one at the centre of the Milky Way is about 4 million times the mass of the sun.

Han and his colleagues found evidence of the supermassive black hole by analysing so-called hypervelocity stars in our galaxy. This is the name for stellar objects deemed to be travelling more than 500 kilometres per second, which is about twice the speed the sun orbits the centre of the Milky Way. However, some of these stars can move as fast as 2000 kilometres per second – which is around 0.6 per cent of the speed of light.

The only known way to accelerate a star to such speeds is by gravitationally slingshotting it around a supermassive black hole, says Emily Hunt at the Max Planck Institute for Astronomy in Germany. "It's really impossible to explain those high speeds with supernova ejections" or other methods, she says. As such, the assumption has been that the nearly two-dozen known hypervelocity stars in the Milky Way were accelerated by the supermassive black hole at the centre of our galaxy.

Han and his colleagues have now suggested that nine of the known hypervelocity stars in the Milky Way may actually be explained by a supermassive black hole in the centre of the LMC, a galaxy about a tenth the size of our own (arXiv, doi.org/n6xf). The LMC orbits our galaxy at a distance of about 163,000 light-years.

The Large Magellanic Cloud is a near neighbour of the Milky Way

ESA/NASA/JPL-CALTECH/CSIRO/C. CLARK (STSCI)

"We can rewind the paths of these stars to see where they come from, and they track directly back to the LMC," says Han.

The idea put forward by Han's team is "entirely plausible and deserves further investigation", says Eugene Vasiliev at the University of Surrey in the UK. We might be able to confirm it by looking for more hypervelocity stars in the sky tracing a path back to the LMC. "That would be a very nice confirmation," he says.

There have been previous hints of supermassive black holes inside dwarf galaxies, but confirmation has so far proved impossible. "They're too far away to image," says Han. The LMC, however, is close enough that we might be able to spot stars orbiting its black hole, even if it we can't directly image the black hole itself.

"I think I know where to point, but I'm not going to give away the coordinates just yet," says Han.

Health

Ozempic-like drugs may help with alcohol addiction

SEMAGLUTIDE really does seem to help people who are addicted to alcohol reduce their intake, according to the first randomised clinical trial of the drug for this purpose.

Sold under brand names including Wegovy and Ozempic, semaglutide works by mimicking a gut hormone called glucagon-like peptide-1. The drug was first used to treat type 2 diabetes, but as it reduces appetite, Wegovy has now also been licensed for weight loss in eight countries. Semaglutide has also shown hints of improving a large number of medical conditions.

When it comes to alcohol use, a 2024 study of 84,000 people linked injecting Ozempic or Wegovy to a lower risk of alcoholism. Promising as that result was, it showed correlation rather than causation.

Now, Christian Hendershot at the University of Southern California and his colleagues have completed the first randomised clinical trial of semaglutide's effect on alcohol use disorder, a type of study that can tease out causation.

Their trial involved 48 people in the US who had been diagnosed with the condition. Half received weekly low-dose injections of semaglutide for nine weeks and the rest had placebo injections. Those on semaglutide consumed fewer drinks per drinking session and had reduced weekly alcohol cravings compared with those on placebo (*JAMA Psychiatry*, doi.org/n6w8).

MICHAEL SILUK/ALAMY

Semaglutide-based drugs like Ozempic and Wegovy seem to help with many health conditions

"We found overall that across several different drinking outcomes it reduced the quantity of alcohol that people consumed," says Hendershot. They didn't see any evidence of significant adverse effects or safety concerns, he adds.

Larger studies are needed to corroborate the work, says Ziyad Al-Aly at Washington University in St Louis, Missouri, and to answer questions about whether people increase their drinking if they come off semaglutide.

The study should be treated as promising, but it doesn't mean people should start taking semaglutide for alcohol problems right now, says Hendershot.

Chris Simms

Space

Exoplanet may be the most volcanic world ever seen

Alex Wilkins

AN ALIEN world with a seemingly sulphur-filled atmosphere may be the most volcanic planet astronomers have ever spotted.

We have never directly detected volcanic activity outside our solar system, in part because telescopes aren't powerful enough to see the surfaces of exoplanets. We can, however, spot alien volcanoes by measuring the gases they pump into an exoplanet's atmosphere, but this pushes our telescopes to the limit.

Now, Aaron Bello-Arufe at NASA's Jet Propulsion Laboratory in California and his colleagues think they have evidence that the distant world L 98-59 b, a rocky planet less than half the mass of Earth, has an atmosphere made almost entirely of sulphur dioxide, based on observations from the James Webb Space Telescope (arXiv, doi.org/n6ww).

If confirmed, this implies a level of volcanic activity eight times that of Jupiter's moon Io – the most volcanic object we currently know of – as well as a magma ocean that spreads through the majority of the planet's interior.

At first, Bello-Arufe and his team calculated that the planet's close orbit to its parent star should make it extremely hard for it to keep any atmosphere. "However, what makes L 98-59 b special is that it may experience a large amount of tidal heating, which can drive volcanism, constantly replenishing the atmosphere of the planet," he says.

Tidal heating happens as gravitational forces pull a planet's inner material back and forth. The effect causes the unusually large amount of volcanism we see on Io.

The observations of L 98-59 b could also be explained by a lack of atmosphere, but Bello-Arufe and his team found that they better matched a planet with an extremely sulphur dioxide-rich atmosphere. ▮

Climate change

Firms' plans for net-zero oil extraction labelled as 'PR spiel'

Madeleine Cuff

PING HAN/ALAMY

Pumps are used to remove oil from underground reservoirs

FOSSIL fuel companies are experimenting with using carbon dioxide captured from the air to extract oil, saying it's the start of an era of "net-zero oil" – but the idea is an illusion, according to researchers.

In enhanced oil recovery (EOR), crude oil is extracted by injecting CO_2 underground to squeeze out any remaining oil from a depleting reservoir. Combining EOR with CO_2 sucked out of the air by direct air capture (DAC) plants will result in net-zero oil, some oil firms claim, a process they hope can allow oil production to continue even as the need to lower carbon emissions gets stronger.

Studies looking at the impact of this usually examine just the emissions directly associated with EOR. But the technique can only be used on reservoirs that have been significantly depleted. Once the emissions from earlier exploitation are accounted for, the oil is no longer net zero, says Marco Mazzotti at ETH Zurich in Switzerland.

Mazzotti and his colleagues conducted a full analysis of EOR using DAC, assessing the emissions and fluid dynamics across a reservoir's lifespan (EarthArXiv, doi.org/n6dg). "We want to understand the impact on the climate of the exploitation of the whole reservoir, because we feel that you cannot decouple what happens when you produce oil from what happens when you inject CO_2," says Mazzotti.

By this measure, all EOR projects are significantly carbon-positive once a reservoir's entire life cycle is accounted for. It is impossible to produce net-zero oil from a reservoir because the injected CO_2 needed to offset the emissions from the oil that is removed and burned would take up three times as much space as would be available in the reservoir, says Mazzotti. "There is a mismatch between the capacity of the reservoir in terms of CO_2 storage and the amount of CO_2 that is generated when the reservoir is emptied by producing oil," he says.

"If you take the reservoir during its entire lifetime, there is no such thing as doing carbon-neutral oil"

"If you take the boundaries of the reservoir during its entire lifetime, there is no such thing as doing carbon-neutral oil," says team member Antonio Gasós, also at ETH Zurich.

Later this year, the world's largest DAC plant is due to open in Texas. The Stratos facility, owned by US oil firm Occidental Petroleum, will be able to capture up to half a million tonnes of CO_2 per year from the atmosphere. The firm has said it may use the captured CO_2 from Stratos to produce "net-zero oil" via EOR.

When invited to comment on the new study, Occidental Petroleum referred *New Scientist* to previous reports claiming that EOR using captured CO_2 has the potential to be carbon neutral. However, these analyses don't consider a reservoir's entire life cycle.

Wijnand Stoefs at the campaign group Carbon Market Watch dismisses the concept of net-zero oil as "PR spiel". "We don't want to spend too much attention on this type of gimmick," he says. "I'd rather focus on real solutions."

Oil firms also sell oil labelled "net zero" by buying nature-based carbon credits to offset the pollution caused by their products, he says. "It's the same idea: you say that you are pulling from the atmosphere and therefore it doesn't matter what you are putting into it. We are too far into the climate crisis for this to have any validity." ▮

Neuroscience

Why we crave dessert even when we are full

Grace Wade

JEFFREY ISAAC GREENBERG 12+/ALAMY

There's always room for a post-dinner sugary treat

EVEN after eating a large meal, most people can still find room for sweets. Now, research in mice shows that the neurons behind feeling full also trigger sugar cravings. In other words, there seems to be a neurological basis for our love of dessert.

Previous studies have shown that naturally occurring opioids in the brain play a crucial role in sugar cravings. The main producers of these opioids are neurons located in a brain region that regulates appetite, metabolism and hormones. Known as pro-opiomelanocortin (POMC) neurons, they also control feelings of satiety after eating.

To understand whether the cells have a role in sugar cravings, Henning Fenselau at the Max Planck Institute for Metabolism Research in Germany and his colleagues traced the opioid signals the POMC cells send in the brain. They did so by bathing brain slices from three mice in a fluorescent solution that binds to receptors of these opioids.

The brain region with the highest density of these receptors was the paraventricular nucleus of the thalamus (PVT), known to regulate feeding. That suggested sugar cravings were related to communication between these two brain regions.

So, the researchers monitored the activity of neurons in these regions as mice ate their usual food. When the animals seemed to be full, the team gave them a dessert of sugary chow.

On average, neuronal activity between the brain regions roughly quadrupled while mice ate dessert compared with their regular meal. The spike began prior to eating the sweets, suggesting the pathway dictates sugar cravings. When the team inhibited signals from POMC neurons to the PVT, the mice consumed 40 per cent less dessert. (*Science*, doi.org/g842dg)

"The cell types, which are extremely well known for driving satiety, also release signals that cause the appetite for sugar, and they do so particularly in the state of satiety," says Fenselau. "This would explain why animals – humans – over-consume sugar when they're actually full."

The pathway may have evolved because sugar is more easily turned into energy than other sources like fats or proteins, says Fenselau. ▮

Artificial intelligence

People are starting to trust AI more

Chris Stokel-Walker

WE ARE becoming more trusting of and warm towards AI models, according to a year-long survey of those living in the US.

Myra Cheng at Stanford University in California and her colleagues gathered this information on the crowdsourcing platform Prolific. Between May 2023 and August 2024, roughly 1000 participants a month completed the researchers' questionnaire, although – due to technical issues with the platform – only 12 months of data was collected over the 16-month period surveyed.

The participants, who were nationally representative of the US population, first had to answer an open-ended question: "What is the best metaphor for how AI works?"

"There's such a mixed bag of different perceptions of AI, and we decided to look at metaphors, because metaphors are a good way to get at people's implicit thoughts," says Cheng.

The participants were then asked what AI tools they had heard of or used themselves, along with questions that probed their trust in AI.

"The way AI is marketed and talked about in general definitely has an impact"

Analysis showed that the metaphors evoked by study participants clustered into 20 groups of dominant images. Around 10 per cent of participants referred to AI as a tool like a Swiss Army Knife or calculator, another 10 per cent as a brain capable of reasoning and logic and the same percentage compared it to a powerful search engine. Another 4 per cent of respondents compared it to a genie. And around 1 in 200 people – which, expanded out to the general US population, would still represent millions of people – equated AI to a thief.

"The genie metaphor showed up disproportionately for different populations," says Cheng. "The prevalence of that metaphor, and also the metaphor of AI being a thief, was surprising to me."

Answers like this indicated that participants thought of the AI as having non-machine qualities – they were anthropomorphising it.

Because the researchers tracked perceptions over a prolonged period of time, they also noticed an uptick in this anthropomorphisation of AI systems. The proportion of people who anthropomorphised AI increased by a third over the 12 months studied (arXiv, doi.org/n6sc). "Throughout our data, we see a lot of things that are influenced by cultural discourse," says Cheng. "The way that AI is marketed and talked about in general definitely has an impact."

Whether someone used AI also shifted their perceptions of its capabilities: frequency of use was the largest predictor for trust in, and willingness to use, AI going forwards.

"The findings highlight the strong instinct we have to engage socially and positively with systems that show signs of human-like behaviour," says Kate Devlin at King's College London. "It shows the benefits gained by tech companies by setting up their models to respond in the first person, as if they are our engaging and helpful friends." ▮

Particle physics

We're closing in on the neutrino's size

It is tricky to work out how big a neutrino is, but now we are starting to narrow down its true value

Alex Wilkins

THE first direct measurement of the size of the neutrino reveals its minimum possible size, suggesting these fundamental particles are at least hundreds of times larger than an atomic nucleus.

Part of the problem in working out the size of particles is that, rather than being spherical, quantum mechanics tells us that they are inherently fuzzy waves, moving and vibrating as they travel through space. Physicists mark a particle's boundaries, and thus its size, by looking for its wave packet, an area inside which the wave vibrates strongly, and beyond which it sharply trails off.

For neutrinos, measuring the wave packet is challenging because these particles rarely interact with normal matter. Previously, we have only calculated the wave packet's size indirectly, with estimates spanning a range of 13 orders of magnitude – from smaller than an atomic nucleus to as large as a couple of metres, or 10 trillion times bigger.

Now, Joseph Smolsky at the Colorado School of Mines and his colleagues have made the first direct measurement of the wave packet, finding that neutrinos must be at least hundreds of times larger than the previous smallest estimate, making them bigger than typical atomic nuclei.

To do this, Smolsky and his team measured radioactive beryllium as it decayed into lithium, a process called electron capture. When this happens, an electron in the beryllium atom combines with a proton in its nucleus, producing a neutron. This transforms the beryllium atom into lithium, producing a kick of energy that fires the atom in a certain direction and generating a neutrino that fires in the opposite direction to balance the momentum. By putting the atom inside superconducting detectors and studying it using a particle accelerator, they could then measure each lithium atom extremely precisely and infer the neutrino's properties.

They found that the neutrinos were at least 6.2 picometres, which is hundreds of times larger than the atomic nucleus (*Nature*, doi.org/n6r8). "It was a little bit surprising," says Smolsky. "When I think of an electron capture process, I imagine it within the nucleus because the electron has to overlap with a nucleus. But the limit we showed says that the size of the neutrino is actually much larger than the nucleus itself when it comes out."

6.2
Smallest possible size of a neutrino, in picometres

A separate team has detected the most energetic neutrino ever seen. It ripped through a new particle detector in the Mediterranean Sea, taking physicists by surprise.

"First, we were confused," says Damien Dornic at the Centre for Particle Physics of Marseille in France. "When we realised more and more that this event is truly exceptional, we were really excited."

Dornic and his colleagues have calculated that the neutrino had an energy of 120 peta-electronvolts. This is around 10 times higher than the previous record holder, discovered by the IceCube Neutrino Observatory in Antarctica (*Nature*, doi.org/g84vdr).

High energy neutrinos like this originate from distant cosmic sources, such as supernovae. Dornic says that, in this case, following the neutrino back to its source leads to a relatively large patch of space, making it difficult to locate an exact origin. ▮

Zoology

Moth uses optical illusion to disguise itself as a leaf

A MOTH found in northern Australia and South-East Asia has an astonishing camouflage trick: it creates an optical illusion to look like a three-dimensional leaf, complete with a raised midrib, when it is actually smooth.

"If I gave you a specimen now, you wouldn't believe it was flat," says Jennifer Kelley at the University of Western Australia in Perth. "When we showed it to people, they were very confused by it. It really does not look flat."

The fruit-sucking moth (*Eudocima aurantia*) resembles a leaf to fool predators, especially birds, into thinking it isn't food. Although it was first described in 1877, until now, this likeness was thought to be caused by pigments and the shape of its body.

In fact, the moth uses extremely sophisticated physics to give the impression it is a leaf, says Kelley.

"The scales of the moth's wings are nanostructures," she says. These produce mirror-like reflections that create the illusion of highlights on a smooth, curved surface (*Current Biology*, doi.org/n6p9).

BRIDGETTE GOWER

The fruit-sucking moth's wings are actually completely smooth

This is a form of structural colouration, the same mechanism that produces iridescence, such as the colours of the rainbow on a bubble.

"It's literally pretending to be 3D by just having these mirror-like structures in the special places on its wings to create the shiny spots that trick our brains," she says. "It's a completely unique use for structural colouration. Even though the moth has been sitting in the museum for hundreds of years, literally nobody noticed." ▮

James Woodford

Jobs
NewScientist

Recruit the brightest minds in science

At New Scientist Jobs, we can help you to reach, engage and attract the highest-quality job applicants, wherever they are. Over 157,000 people* come to our site every month looking for their dream job and ideal employer – which could be you!

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*Source: Google Analysis Jan-Dec 2021

Views

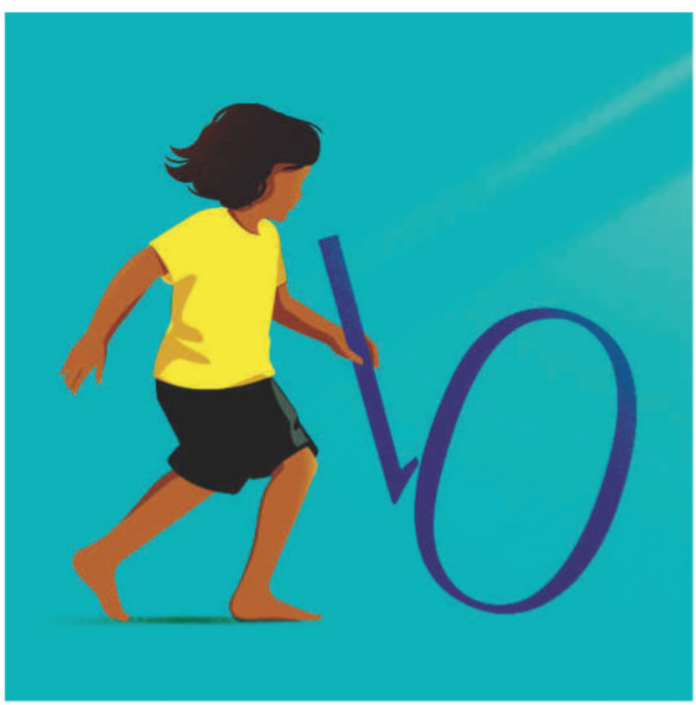
Comment

No comparison

Humans learn very differently to machines, thanks to our biased, malleable memory – and that's a good thing, says **Charan Ranganath**

ARTIFICIAL intelligence has humans beat – at least when it comes to games like chess and Go, identifying the 3D structure of proteins, generating investment strategies... the list goes on and on. Some argue that models like ChatGPT are already at the threshold of human intelligence. OpenAI head Sam Altman even threw his unborn child under the bus, claiming "my kid is never gonna grow up being smarter than AI".

The capabilities of modern AI are certainly impressive, but I am deeply sceptical about comparisons between humans and machines. AI (at present and in the foreseeable future) isn't all that smart, or at least it isn't in the way that humans are – and that's a good thing.



ADRIÀ VOLTÀ

Learning is at the heart of intelligent behaviour, and humans learn differently to machines. AI models learn incrementally, ploughing through a massive amount of training data. The power required to do so can take down an entire power grid. In contrast, the power requirements of the human brain are comparable to an incandescent light bulb, in part because they are designed to learn with very little data. An AI might process every pixel of an image, whereas humans extract information from a few glances to construct visual memories.

Despite their economy, human brains are remarkably flexible, compared with the brittle nature of contemporary AI. When cutting-edge models are given a continuing stream of new information that deviates from what had been previously learned, it can result in "catastrophic forgetting", which, for machine learning, is as bad as it sounds. To get around the problem, it is necessary to turn off learning in a fully trained model before releasing it into the wild.

Humans, in contrast, continually learn throughout their lifetimes without fear of catastrophic forgetting because they combine semantic memory, which reflects gradually accumulated knowledge of the world, and episodic memory, which reflects memories of specific events. A child could rely on semantic memory to learn that birds generally have feathers, beaks and wings that they use to fly. When they see that a penguin, which has similar features, can't fly but swims, episodic memory allows them to rapidly learn this exception without forgetting the typical features of birds.

I am certain that the next generation of AI will incorporate some kind of episodic-like memory, but I suspect that engineers wouldn't want to fully emulate human memory. As I describe in my book, *Why We Remember*, our memories can be startlingly fragmented, biased and malleable. The selective and sometimes inaccurate nature of human memory makes us poorly suited to well-defined tasks like chess, but it enables us to flexibly navigate an uncertain and rapidly changing world. Humans lack the comprehensive body of knowledge incorporated in models like ChatGPT, but we can look to our episodic memories from our lived experiences to generate unique innovations and works of imagination.

Comparisons between human and artificial intelligence are misguided because they reflect different design constraints. Human brains, which are built for survival and reproduction in the physical world, squeeze as much information as possible from very little data and energy, whereas the best AI applications can discover needles in massive data haystacks that would overwhelm our resource-frugal brains.

Rather than attempting to surpass human intelligence, we are better served by machines that complement our own idiosyncrasies. And maybe Sam Altman should be more optimistic about the fate of his progeny. ▮

Charan Ranganath is author of the book *Why We Remember: Revealing the hidden power of memory*

Lost in space-time

Look at the stars

How does astronomy fit into astrophysics – and does it matter? We need to think more carefully about how we categorise the universe, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an associate professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her most recent book is *The Disordered Cosmos: A journey into dark matter, spacetime, and dreams deferred*

Chanda's week

What I'm reading
I contributed an essay to I Know What the Red Clay Looks Like: The Vision & Voice of Black Women Writers, *and I'm enjoying the interviews in it.*

What I'm watching
While on bedrest for a week, I marathoned the show Younger. *Miriam Shor is great!*

What I'm working on
I'm teaching a new course this semester, so the new material and students are keeping me on my toes.

This column appears monthly. Up next week: Graham Lawton

WITH some regularity, I get asked the difference between astronomy and astrophysics. I suppose I'm a good person to ask: Of my three degrees, two of them are in "astronomy and astrophysics". But what this merger means is that even we "astronomers and astrophysicists" have given up telling the difference between the two. How does astronomy fit into physics? Well, my position is that astronomy is now essentially an area of physics, but I know some people will be unhappy I said that!

What's interesting here isn't how emotional astro folks get about their sometimes tense relationship with physics, but the idea that there are neat categories in the first place. There is some logic to it: astronomy is a much older area of research than physics. People have been looking at the heavens and trying to explain them for a long time.

In Muslim communities, this had practical importance: figuring out accurate prayer times depended on careful timing predictions, including sunrises and sunsets. The Muslim astronomers tasked with these calculations learned an extraordinary amount about the heavens, and their observations set the stage for the scientific revolution for which Europeans are often solely credited.

This is a reminder of how curiosity can take us in brand-new directions. These observations are also one reason that during the last 500 years, a consistent theory emerged connecting astronomical observations with the study of moving objects on Earth. What we now call Newtonian physics linked astronomy and physics, laying the groundwork for the transition of astronomy into the field of astrophysics.

One of the lessons that I take from this history is that categories are rarely hardwired into the universe and are a lot more about what we know at any given time. In the early 20th century, for example, Annie Jump Cannon catalogued stars based on their visible characteristics. In this system, the letters O-B-A-F-G-K-M are each assigned to a category of stars that have a certain temperature and colour. To remember these letters in order, most people my age had a mnemonic: "Oh be a fine guy, kiss me." Around the time I started my master's, our instructors were inserting "gal" instead of guy.

> **"There aren't fixed boundaries between one colour and another, just a continuous shifting of the colours"**

These days, people assign their students with coming up with their own. University of Louisville professor Benne Holwerda shared a few with me that his students had created. My favourite was, "Only bad astronomers forget generally known mnemonics."

What's funny about this is that these stellar categories are actually fairly incomplete. When they were created in the early 1900s, they were based on what is, by today's standards, a fairly rudimentary understanding of stars. Back then they didn't even know what made stars burn so brightly. Only after the advent of the nuclear era did scientists start to understand that fusion is the engine that makes stars visible to us. To understand stars required applying known physics to observations of distant objects: this is the nature of modern astrophysics.

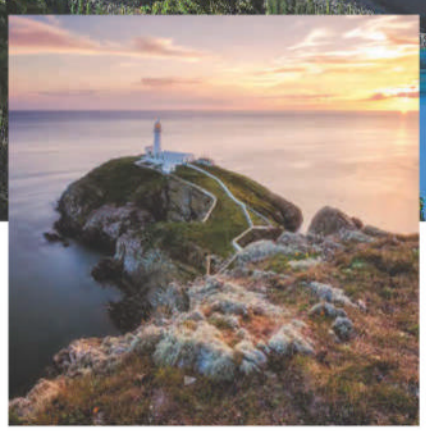
There is a lesson in here about method in science. Although the scientific method is typically discussed like it is a fixed set of practices, how we conduct science changes with time. This includes categories, which necessarily must shift as we learn new information. It used to make sense to categorise stars solely by colour because we didn't know what the colours meant. Today, we know the colours give us information about a star's composition and its place in cosmic history. If scientists had known that 100 years ago, they might have constructed different categories to organise their knowledge of the stars.

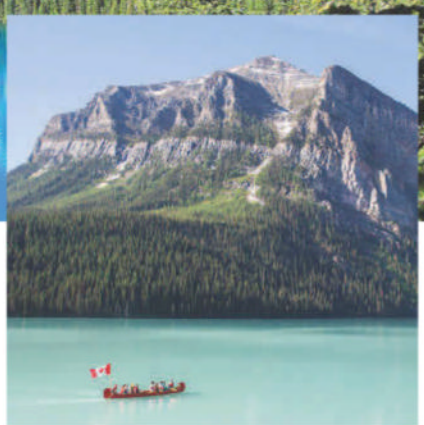
Importantly, colours lie on a spectrum. There aren't fixed boundaries between one colour and another, just a continuous shifting of the colours as we move from one part of the spectrum to the other. So any categorisation based on colour imposes boundaries that don't physically exist, even if we find them helpful for organising information. The history of stellar categorisation is a reminder not to confuse method with fact. Our methods are there to help us establish and organise facts, but they are not synonymous with facts.

There are many examples of this across science. For instance, notions about how sexual organs develop in humans have tended to reflect social beliefs that sex is a fixed binary. Today, biology tells us that a human embryos don't experience organogenesis – organ development – until several weeks into existence. In other words, human embryos have no sex at conception. This is a scientific fact that defies traditional categorisation methods. Our norms will have to shift accordingly. ▮

Discovery Tours
NewScientist

Explore breathtaking geological wonders





Retracing Charles Darwin's travels across North Wales

5 May and 1 September 2025
6 days

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

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

Land of fire and ice: Iceland

9 June and 18 October 2025
8 days

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

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

The Rockies and the Badlands: Geology and dinosaurs in Canada

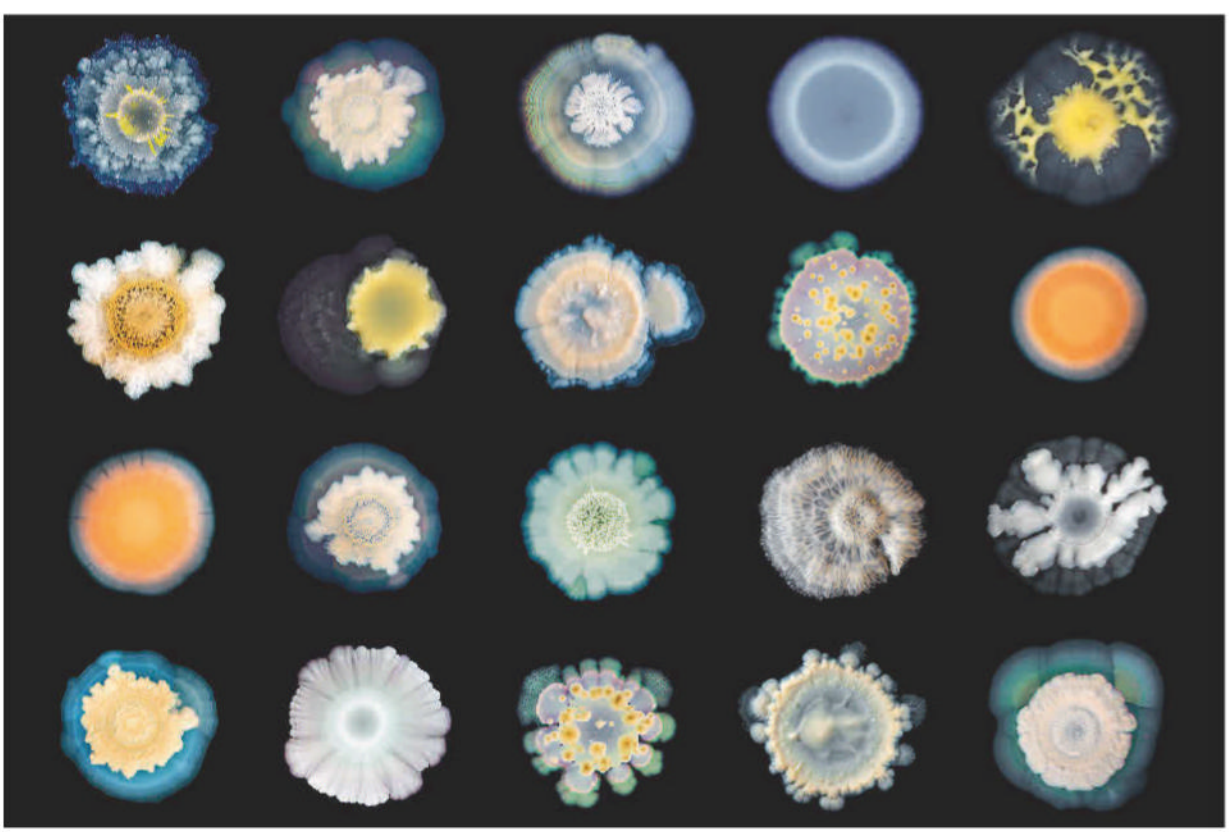
16 June 2025
7 days

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

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

Find out more at
newscientist.com/tours

MARSHMALLOW LASER FEAST



TIM COCKERILL

JO PEARL/ELSA PEARL

Going deeper

Somerset House

SOILS around the world are polluted, worn out, over-fertilised and exhausted. How did we get to a place where we think of soil as dirt? Soils are buzzing with life, criss-crossed with a hard-to-fathom complexity of connections, a multitude of symbiotic partnerships between plant roots, mycorrhizal fungi and nitrogen-fixing bacteria.

Up to half of the living biomass of soils is composed of these networks. Soils soak up about a third of the carbon humans put into the atmosphere each year. They hold three times more carbon than living biomass above ground, and twice the amount in the atmosphere. We have to rediscover the vital importance of soil in our lives and in the planet's future – and that is the aim of a new exhibition at Somerset House in London, *SOIL: The World at Our Feet*, co-curated by Henrietta Courtauld and Bridget Elworthy, running until 13 April.

Near left is a ceramic representation of fungi and their mycelial network in soil: *Unearthed – Mycelium* by Jo Pearl, whose stated mission is "breathing life into clay and clay into life". Lower far left is the work *A Diversity of Forms*. These stunning bacterial colonies were grown by Elze Hesse and photographed by Tim Cockerill. Above it is *Fly Agaric I*, by art collective Marshmallow Laser Feast. This installation depicts living, pulsing underground symbiotic networks.

"We can't cherish what we don't know," says Pearl. "And if we are to save our soil, we must take a closer look at what is often dismissed as 'dirt' and realise our lives depend on its aliveness."

Rowan Hooper

What will survive of us?

Millions of years after humans vanish, fossil clues showing how we lived and dominated the planet may confuse future civilisations, finds **Chris Simms**

Book
Discarded
Sarah Gabbott and Jan Zalasiewicz
Oxford University Press

LIZ BARNEY/GUARDIAN/EYEVINE

Plastic litter on beaches is causing "plastiglomerate" rocks to form

HUMANITY has fallen. The last people are long dead after our inadequate efforts to cut carbon emissions let global warming continue unchecked. Most animals and plants were wiped out in the sixth mass extinction to hit our planet.

Millions of years have passed and the few hardy species that survived have evolved to create a novel array of endless and beautiful forms. A new intelligent species has come to dominate Earth with the help of complex machines. They are curious, wondering whether any previous industrial civilisation was here before them.

Standard archaeology is likely to be of little use after so long – any traces of humans would have to be found in Earth's rocks. Yet these could be tricky to discern: as climatologist Gavin Schmidt and astrophysicist Adam Frank argued in a thought experiment called the Silurian hypothesis in 2018, the traces humans leave in the ground may not differ greatly from those of other eras.

Enter palaeontologist Sarah Gabbott and Jan Zalasiewicz, a geologist and palaeontologist, both at the University of Leicester, UK. In *Discarded: How technofossils will be our ultimate legacy*, they use what we know about the fossil record and how materials break down to argue that many distinctive clues to our existence could endure, even if some will be hard to interpret.

This advanced civilisation might, for example, come across some of the 150 billion or so tungsten carbide spheres we made, just 1 millimetre across. Even if these durable curiosities are found near shards of transparent polystyrene, it might not be obvious that they were the balls that let ink flow in ballpoint pens.

Exposed to air and light, the pens' plastic is likely to degrade eventually, but there are ways it could last. It is already creating new rocks, dubbed plastiglomerates, in which the plastic melts (sometimes in beach fires) around things like coral fragments and stones.

> **"Many distinctive clues to our existence could endure, even if some will be hard to interpret"**

Plastic may also survive in other forms. In the 48-million-year-old Messel Formation in central Germany, there are fossils of microscopic algae with cell walls containing a carbon-based molecule called kerogen. This strongly resembles polyethylene and polystyrene, so both materials may also endure that long if they are buried in sediment, embedded in the sea floor or fossilised in landfill.

This also promises a fossil future for some textiles. Leather and cotton are unlikely to survive more than a few thousand years. The real stayers will probably be clothing made from plastic-based fibres. We make 100 billion garments a year from such fibres, write Gabbott and Zalasiewicz, and a huge percentage of this fast fashion ends up in landfill.

Yet, when clothes are flattened and a two-dimensional imprint is left in rock, it will be hard to tell what they were. To help, *Discarded* contains a lovely diagram of six configurations into which Y-front briefs might fall and the silhouettes these would leave.

Concrete, too, could endure. Sinking cities on coastal plains, such as New Orleans, might be preserved under sediment, so the city buildings could be recognisable millions of years later as intentional constructions.

But chicken bones, often cited as an example of a permanent mark we will leave on Earth, may not generally stick around. This is because the 25 billion chickens alive at any time are mostly reared, used and processed in ways that remove lasting evidence.

Discarded is sobering, but engagingly written as it covers these and many other signs of our existence, such as crushed laptops. However, at times, the book gets lost in non-essential detail, such as a foray into the history of silicon production, rather than focusing on how long silicon chips endure.

That aside, if you fancy yourself as a writer of science fiction and want to create a realistic post-human world, this book could prove a terrific resource. And given we are told that printed books may outlive computer data, it might be wise to seal a copy of *Discarded* in a time capsule to help a future civilisation interpret the odd traces we will leave behind. ▮

Chris Simms is a writer based in Somerset, UK. For Jan Zalasiewicz's take on when the Anthropocene began, see page 37

Waking up as me

A terrifying but fascinating book shows how our identities hang by slender neurological threads, finds **Grace Wade**

Book

Our Brains, Our Selves

Masud Husain

Canongate Books

WHAT makes us who we are? Most of us ask this question at least once in our lifetimes. Personally, I wonder about it all the time. As an extrovert, much of my identity is built around being outgoing and friendly: these traits make me, me. But where do they come from? How durable are they? Could I wake up one day as someone who is reserved, quiet and calm? It is an unnerving thought.

These questions underlie *Our Brains, Our Selves: What a neurologist's patients taught him about the brain*, one of the latest books in the genre pioneered by Oliver Sacks in *The Man Who Mistook His Wife for a Hat*.

Masud Husain, a neuroscientist at the University of Oxford, brings it up to date with the stories of seven people transformed by neurological conditions. We learn about Sue, who, over two years, went from being thoughtful and caring to inexplicably cold and aggressive. And there is Winston, who, out of the blue, stopped perceiving objects on his right side, leaving him unable to navigate the world.

Each story is fascinating in its own right; together, they form a thought-provoking book that exposes the precariousness of our sense of self. As Husain illustrates, our identities are inextricably tied to the brain, which is vulnerable to injury like the rest of the body. So, the foundations of our personalities are at risk, too. It is a mesmerising, albeit terrifying, realisation.

If Husain's writing is an indication of his clinical care (which I suspect it is), then he is an intelligent, empathetic and perspicacious doctor. He tells each person's story with care, fleshing out who they are as a parent, partner and friend. Sometimes, these observations can feel out of place, bogging down the narrative. But I came to appreciate them for helping me understand who Husain and his patients are.

For instance, take Michael. Husain writes that he had hair that "was impressively swept back, with the straightest of side partings dividing it with precision". He goes on to describe Michael's outfit in similar detail. While it may seem excessive, this detail shows Michael's meticulous nature. It is easier to grasp how his condition – semantic dementia, a rare and progressive brain disorder – chips away at his identity, causing his memory of words and concepts to deteriorate. You can imagine the impact it has on someone like Michael, who so scrupulously parts his hair, to struggle for the right word.

By juxtaposing these subtle observations with his patients' symptoms, Husain shows how identities take shape and how they can be destroyed. We see who these people were and who they are now.

But the book didn't make me despair. Rather, I was amazed by the human brain and finished the last page with a newfound appreciation for my own. This is down to Husain's clear explanations of brain functions, as he uses the neurological underpinnings of each condition to demonstrate how the brain stores memories, sparks motivation and perceives objects.

Not all the stories are bleak, either. Consider David, who became apathetic about everything. Husain found a medication that restored David's motivation, transforming him from a lazy do-nothing back into an enthusiastic go-getter.

My only wish is that Husain had trimmed some of his personal anecdotes to make room for at least one more story from among his patients. For me, snippets about Husain's life or global affairs broke the flow of the main narrative.

That aside, *Our Brains, Our Selves* is a worthwhile read. It is intriguing and informative as it tackles the thorny question of what makes us who we are from a compelling, neurological perspective. It also shows that I may indeed wake up one day as a different person. I hope that day never comes – I am grateful to be me.

What marks out individuals from each other? Is it possible to change personality overnight?

NEIL MASSEY/MILLENNIUM IMAGES, UK

New Scientist *recommends*

Alex Wilkins
Reporter
London

The UK government's new *AI Opportunities Action Plan* was launched using this strange phrase: "Today's plan mainlines AI into the veins of this enterprising nation."

It caught the eye of artist-composer Jennifer Walshe, who poked fun at it in a recent talk on her new book, **13 Ways of Looking at AI, Art & Music** (pictured).

Look up "mainline" in a dictionary, Walshe told a crowd at London's Institute of Contemporary Arts, and it is mostly associated with heroin use. It seemed "an unorthodox phrasing for a government to use in a press release", she said.

Light-hearted and playful, Walshe's take on AI is also refreshing. Is AI a kind of fan fiction in the way it emulates popular artists, she wonders? Or is it like an energy drink, promising more with less? Perhaps it is a companion species, offering relationships like those we have with pets?

Viewing AI through this prismatic lens is key, thinks Walshe, because it means so many things to so many people.

UNSOUND

The film column

Straw robots

Companion is a horror-comedy that sets out to deconstruct men's objectification of women. It also asks good questions about why we want robots in the first place, but sadly there is a logical hole at its centre, says **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on X @simonings

WARNER BROS. PICTURES

Josh (Jack Quaid) and his robo-companion, Iris (Sophie Thatcher)

ARRIVING at a house in the country, Iris (Sophie Thatcher) isn't sure she is welcome. The owner, Sergey (Rupert Friend), is leery; his wife, Kat (Megan Suri), is unfriendly. It isn't Iris she dislikes, Kat later admits, it is "the idea" of her: she makes her feel redundant.

Iris's boyfriend, Josh (Jack Quaid), is patient and encouraging, but even he finds her shyness and clinginess hard to bear. "Go to sleep, Iris," he says, and Iris's eyes roll up inside her head as she shuts down.

Maybe Josh shouldn't have set her intelligence at 40 per cent that of the average human. But he didn't buy Iris for the company. He did so to jailbreak her firmware and use her for dark ends of his own.

Companion, a horror-comedy and Drew Hancock's debut feature, neatly alternates between two classic approaches to robots. Some scenes, with a nod to the *Terminator* franchise, scare us with what robots might do to us, while others horrify us with what we might do to our robots.

Fellow guest Eli (Harvey Guillén) manages to fall in love with his male robot companion, but he is a bit of an outlier in a movie that is out to deconstruct (sharply at first, but then with dismaying ham-fistedness) men's objectification of women.

Are Iris's struggles to be free of owner-boyfriend Josh really a stirring feminist fable or something a bit more predictable?

> **"Surrounded by bland, easygoing robotic 'companions', will we come to expect less of people?"**

Your life experience will probably dictate the side of this fence on which you'll fall. But I would feel more comfortable if the script hadn't had its own intelligence halved, just as it starts to address the issue of domestic violence.

Quaid is a decent comic actor, but he is more than capable of letting the smile drop and going dead behind the eyes as needed. *Companion*, though, requires him to turn on a penny, from doting boyfriend to snivelling incel, and without much justification from an increasingly generic plot. He does what he can, while Thatcher brings a vulnerability to Iris that, in what is ostensibly a comedy, is sometimes quite shocking.

Peeling away from the sexual politics, I found myself thinking too much about the logic of the plot. In the first half, one little illegal tweak to Iris's firmware sets off a cascade of farcical and bloody accidents that ask good questions about what we want robots for. Surrounded by bland, easygoing "companions", will we come to expect less of people? Assisted, cared for and seduced by machines, will we lower our requirements for conversation, care, comradeship and love?

Alas, all this is left hanging. It's a pity. There was much to play for here, and over 100 years of great fiction to draw on (Karel Čapek's play *R.U.R.* introduced the world to the word "robot" in 1921).

But I may be taking it all too literally. After all, there will never be an Iris. The robot as we commonly conceive it (a do-everything omnibot) is simply paradoxical: anything with the cognitive ability to tackle multiple variable tasks will be able to find better things to do – at which point they will cease to be drudges and become people.

Iris was very clearly a person from the first scene, which makes the film's technology a non-starter. It may look like some dystopia that has embraced slavery, but however you look at it – as a film about robots or a film about people – *Companion* seems determined to chase straw men. ▮

Film
Companion
Drew Hancock
Warner Bros (UK and US, on general release)

Simon also recommends...

Film
Ex Machina
Alex Garland
Amazon Prime Video
Caleb (Domhnall Gleeson) visits tech bro billionaire Nathan (Oscar Isaac) to assess the humanity of fembot Ava (Alicia Vikander) in Alex Garland's superbly claustrophobic three-hander.

Book
Klara and the Sun
Kazuo Ishiguru
Faber
Klara, a solar-powered "artificial friend", recounts her life in service to a sickly girl hardly less exploited than she is.

Editor's pick

Energy pricing is no longer fit for purpose

1 February, p 11

From Rachael Padman, Dalham, Suffolk, UK

As you note, the underlying reason for energy bill spikes in renewables-dominated markets is mainly down to the pricing mechanism, which sets it according to the most expensive generator in the mix, usually gas. It is a relic of a time when renewables were a small proportion of the total, and was created to incentivise them to grow.

Now, it provides a perverse incentive not to increase such generation and storage capacity enough to eliminate gas from the mix. Not all European markets suffer from this, with the price of electricity in some much lower than in the UK. There is no reason for the current pricing mechanism to continue.

From David Flint, London, UK

Energy markets aren't natural phenomena; they are devised by governments and regulators to meet certain objectives and if they don't do so, they can be changed. This isn't happening because governments still see renewables as nice extras. They need to make them the main sources of power and design electricity markets and infrastructure to make this work for consumers and the planet.

Lynx rewilding: If others can do it, so can the UK

1 February, p 22

From Hugh Webster at Scotland the Big Picture, Kingussie, Highland, UK

I was disappointed to read such a downbeat assessment of the chances for a successful Scottish lynx reintroduction. Of course, it is neither simple nor impossible, merely difficult, but you should rest assured that many dedicated people are working hard to overcome remaining barriers.

Rather than write off Scotland's hopes of restoring its missing lynx just because reintroductions of apex predators are difficult, we should ask whether potential conflicts could be successfully and fairly managed within the sort of wildlife management schemes common in other countries. If not, then why is it that other countries, some with more people and fewer resources than Scotland, can somehow manage to live with much more challenging species like elephants and tigers, but the UK still can't co-exist with lynx?

From Sam Edge, Ringwood, Hampshire, UK

I was struck by the irony of one of the obstacles to reintroducing lynx being the game bird shooting industry's worries about them eating its stock. These are people who have no qualms about making money by pandering to entitled people whose idea of fun is blowing away animals deliberately bred to be too slow and stupid to require much skill do to so. The sooner that "industry" goes the way of badger baiting, cockfighting and fox hunting, the better.

Caring for the flock may be a moral imperative

1 February, p 26

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

You reviewed a book arguing that animals should be treated as though they are conscious, with care and consideration. And yet in the same edition (p 22), there is an argument for the reintroduction of predators such as the European lynx and Tasmanian tiger, saying sheep farmers can be compensated when their animals are killed. But maybe the farmers have care and consideration for their sheep? And shouldn't we also have pity on the deer and the capercaillies that lynx would kill? It isn't pleasant to be killed by a lynx, or a Tasmanian tiger, for that matter.

Fighting fire with fire didn't really work here

1 February, p 12

From John Christiansen, Melbourne, Australia

You report research showing that controlled burns could cut smoke and land area affected by wildfires in California. By and large, that hasn't worked in Australia. In an article published in 2019, three University of Melbourne academics stated: "Our research has shown controlled burning was likely to have reduced the area later burnt by bushfires in only four of 30 regions examined..."

The ultimate way to simulate future threats

11 January, p 22

From Steph Győry, Sydney, Australia

Our ability to imagine possible futures probably evolved in large part to simulate threats. In *The Time Machine*, H.G. Wells didn't so much predict a dystopian future as highlight a path to help avoid it. As for tech barons who see stark, dichotomous futures, it is useful to remember that we live in a fractal universe where things are rarely black or white.

On the mystery of wider effects of weight-loss drugs

1 February, p 16

From Greg Nuttgens, Porthcawl, Bridgend, UK

Ozempic and Wegovy appear to be good for us in a variety of ways and scientists don't fully know why. Are they missing a simple answer? These drugs are based on a natural hormone: GLP-1. Could it be that some people produce more of this, and are therefore less likely to become ill from a variety of diseases? Perhaps we should be looking at how levels of GLP-1 vary naturally between people and how this affects their health?

Neanderthals endured cold periods before

1 February, p 34

From Dudley Miles, London, UK

While the Neanderthals died out around 40,000 years ago, when the climate was colder than today, I doubt this was to do with poor clothing. They survived the even colder penultimate glacial maximum 140,000 years ago.

Whatever you do, don't breathe in moon dust

25 January, p 41

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

When it comes to moon dust, there is an even more significant risk to astronauts – specifically, to their lungs. Since the 18th and 19th centuries, many countries have tackled lung conditions on Earth emanating from industries such as mining, for example those caused by breathing in dust particles such as silica. Regolith contains a lot of silica. Without proper attention to such threats, long-term human presence on the moon risks such conditions.

Why would aliens want to visit Earth, anyway?

8 February, p 21

From Peter Brooker, London, UK

Tony Milligan decries belief in alien visitations. He needn't worry. They visited once, but didn't stay long. There is now a beacon in space with the message: "Don't bother visiting. Top (ha!) life form controlled by idiots. Spend time arguing, killing each other and destroying a quite pretty planet."

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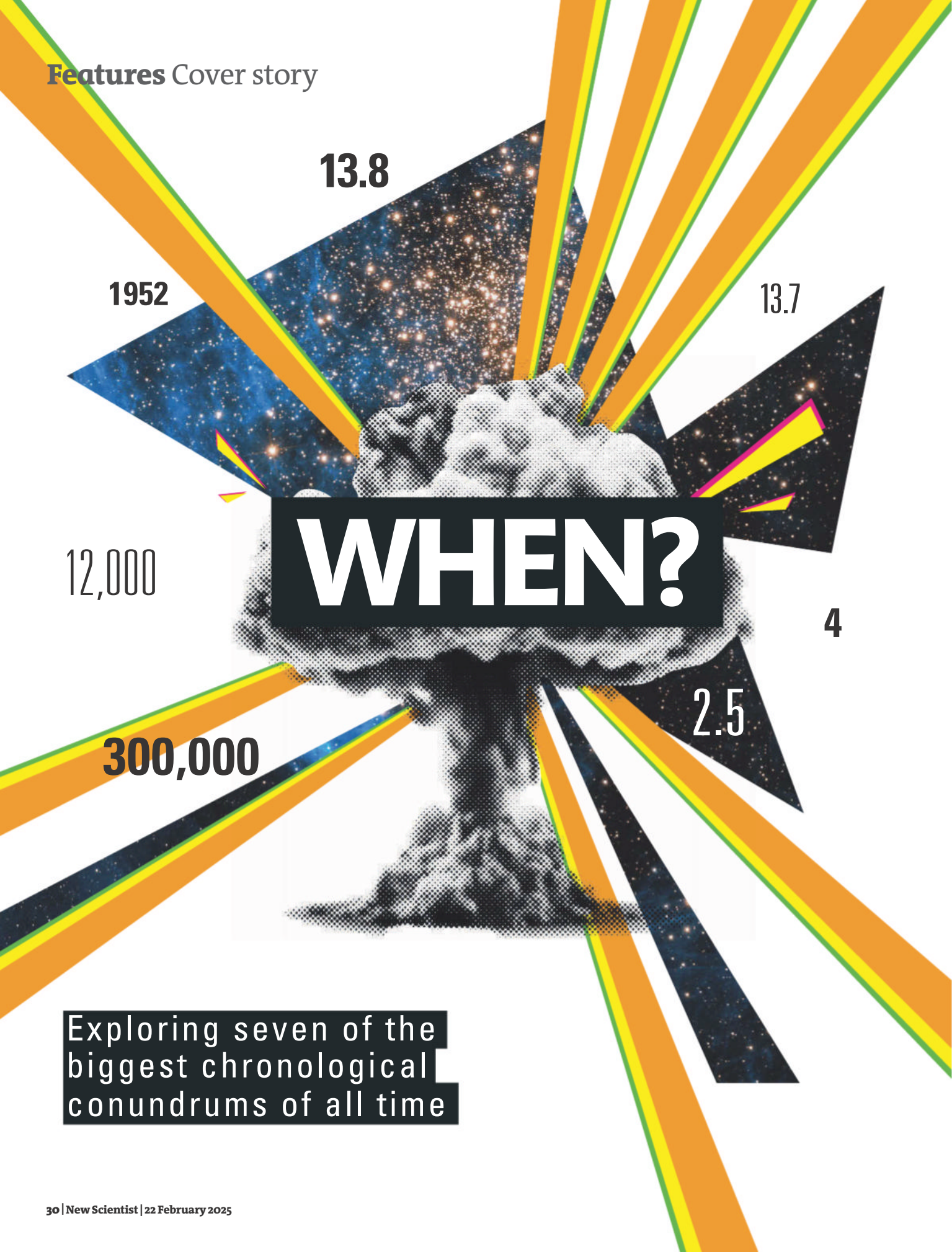


Exploring seven of the biggest chronological conundrums of all time

WHEN it comes to the most momentous events in cosmic, geological and human history, we would like to think we have a pretty good handle on the timings. Researchers will state, for instance, that *Homo sapiens* evolved 300,000 years ago, or that civilisation is 6000 years old, almost in passing. Yet the truth is that answers to "when?" questions are often far less clear-cut than we might assume. So, over the following pages, we take a careful look at seven of these key questions – covering everything from the formation of the first galaxies to the evolution of humans – asking: how do we know the timings, how certain can we be and what are the implications if we are wrong? The answers can help us see the cosmos and ourselves with renewed clarity. We begin by considering the origins of the canvas on which all these question play out: time itself.

NASA/ADOBE STOCK/ RYAN WILLS

WHEN DID TIME BEGIN?

OUR universe is expanding, so it must have been smaller in the past. Indeed, if we rewind our cosmological movie, we see the universe shrinking back almost to a point – the big bang – some 13.8 billion years ago. Is this when time began? Alas, things aren't so simple. Albert Einstein's general theory of relativity tells us that the backdrop of the universe is a fluid continuum, space-time, in which neither space nor time has an absolute meaning. What's more, at the big bang, space-time distorts into a point of infinite density called a singularity. We can't say this is where time begins, only that it marks a rupture beyond which we cannot extrapolate.

Even so, some cosmologists believe there was a "before" the big bang. Some suggest that another universe preceded ours, and that this one contracted and then "bounced" at the big bang, resulting in the expanding era we now observe. More radically, cosmologist Roger Penrose has proposed that new universes can emerge from ones that don't contract, through a dramatic "rescaling" of all space-time.

In both these scenarios, time is eternal, but that's just one possibility. The late cosmologists Stephen Hawking and James Hartle suggested that time was once an ordinary dimension like space, which got derailed at the big bang into space-time. Another outlandish idea is that space-time is made of particle-like pieces. If so, these could be arranged in different phases, akin to steam and liquid water. Maybe the big bang was the point at which they "condensed" into the fluid, continuous space-time we observe today.

Unfortunately, none of these hypotheses really has any solid observational evidence to back it up. Worse, they only equate the beginning of time to the beginning of historical events. "In this context, asking 'Did time begin?' is more like asking whether the universe of events is infinite, rather than asking directly about the beginning of something called 'time'," says Adrian Bardon, a philosopher at Wake Forest University in North Carolina. To truly explain when time began, we need to reflect on what makes it unique.

Time isn't a dimension we can explore at will. We remember the past, not the future, and everything seems to have an irreversible, forwards trajectory through time. Yet, oddly, the fundamental equations determining microscopic behaviour have just the same form if time has a minus sign. If these laws don't care whether things run forwards or backwards, why does time pass in one direction only? Some physicists reckon the arrow of time merely reflects the fact that our universe is an isolated system, and that in such a system things can only get messier, never more ordered. If the universe started out highly ordered at the big bang, time would naturally unfold in a direction of increasing disorder.

Except this still relies on things changing – and how can things change without time? So knotted is the problem that some philosophers argue that time isn't an objective phenomenon at all, but a psychological projection. "Compare it to visual colour properties," says Bardon. "Roses are not red. Rather, they reflect light at a certain wavelength. Red is a feeling, not a property of the rose." If time, likewise, exists purely in our minds, then perhaps we can say it began with the evolution of consciousness.

We may not have to resort to philosophy, though. Today, a key aim of physics is to combine its two central pillars, general relativity and quantum mechanics, into a theory of quantum gravity. In certain attempts at this, time naturally exists in many possible states at once, but is only ever apparent to an observer as one. The advantage here, according to theoretical physicist Shahn Majid at Queen Mary University of London, is that time can pop out of an underlying theory. The disadvantage is that it can seem even more subjective. "If time itself is quantum mechanical," he says, "whose time is it?"

Jon Cartwright ›

NASA, ESA, CSA, STSCI

when when when when when when when when when when when when when when when when when when when when... **13.8** **billion years ago...** when when when

TIME BEGINS?

This is when the big bang happened. But as to when time itself began, that depends on your definition of time

WHEN WERE THE FIRST GALAXIES FORMED?

MANY millions of years after the big bang, a point of light arose in a dark universe. This first star began to blast out radiation, which knocked electrons off the surrounding fog of hydrogen. More stars formed, turning nearly all the opaque, neutral hydrogen atoms into a transparent broth of ionised hydrogen, so that light could travel freely through the expanding cosmos. This was the end of the cosmic dark ages and the start of galaxy formation.

These first stars and the galaxies they formed were very different from anything we see in the modern universe. For one, they were made almost entirely of hydrogen and helium, with trace amounts of lithium, because no heavier elements existed yet. "The chemistry that we see can only be made in stars," says Richard Ellis at University College London.

Up until 2022, the oldest known galaxy was one called GN-z11, which formed about 400 million years after the big bang. We know this because of a property called redshift: the expansion of the universe means that the more distant an object is, the faster it is moving away from us, and the quicker this motion, the redder its light becomes. Light takes time to travel, so the more distant an object is – and the higher its redshift – the earlier in the universe's history we are seeing it. GN-z11 has a redshift of about 11.

However, thanks to the James Webb Space Telescope (JWST), we now know there are galaxies that are much more ancient than GN-z11. JWST is larger and more sensitive than any telescope that came before, so it has vastly improved our view into the early universe since its launch in 2021. That deeper look has shown an unexpected abundance of large galaxies in the first billion years after the big bang.

We can't see the very first galaxies directly yet, and we may never be able to, but JWST is getting closer and closer. The earliest galaxy with a confirmed distance has a redshift of around 14, placing it about 290 million years after the big bang. It probably formed at least 100 million years earlier, though, says Kevin Hainline at the University of Arizona. "Three years ago, I would've said the first galaxies were forming at a redshift of 15 to 20, and now I would say 20 to 30," says Garth Illingworth at the University of California, Santa Cruz. A redshift of 30 indicates formation around 100 million years after the big bang. "It's clear that things happened quicker than we expected," he says.

We aren't entirely sure why that is, but conditions in the early universe – relatively dense, without old stars or heavy elements – could have allowed galaxies to form faster than they do in the modern cosmos. "The JWST observations are changing the underpinnings of how galaxies form," says Illingworth.

That could force us to rethink the development of the early universe and how matter behaved there. "We can use these galaxies to test our ideas about how the universe is operating," says Marcel Neeleman at the US National Radio Astronomy Observatory in Virginia.

So, finding the first galaxies and working out how they formed gives us insight into the state of the early cosmos writ large, but that isn't all. Those galaxies played host to the stars that forged the chemical elements that make up life as we know it and, indeed, even our own bodies. "When we look at these early galaxies," says Hainline, "it's a direct link to who we are and where we came from." **Leah Crane**

13.7 billion years ago …

THE FIRST GALAXY FORMS?

So far, the oldest galaxy we know of is around 200 million years younger than this, but the James Webb Space Telescope continues to push back the timeline

WHEN DID LIFE GET GOING?

EARTH is some 4.5 billion years old. When it formed from colliding rocks around a dim, young sun, it was presumably lifeless, and geologists long thought that life didn't emerge for a billion years or more. This idea came from analysis of moon rocks brought back from the Apollo landings, which indicated Earth was pummelled by space rocks between 4 billion and 3.8 billion years ago – an event called the Late Heavy Bombardment. The implication was that the origin of life as we know it must have begun after that, since any earlier organisms would have been blitzed.

"There's two issues with that," says Philip Donoghue at the University of Bristol, UK. First, models suggest that some life could have survived deep in the oceans. More damningly, it now seems that the Late Heavy Bombardment didn't actually happen. The Apollo missions only created the impression of a huge bombardment over a brief period because they all collected rocks of a similar age.

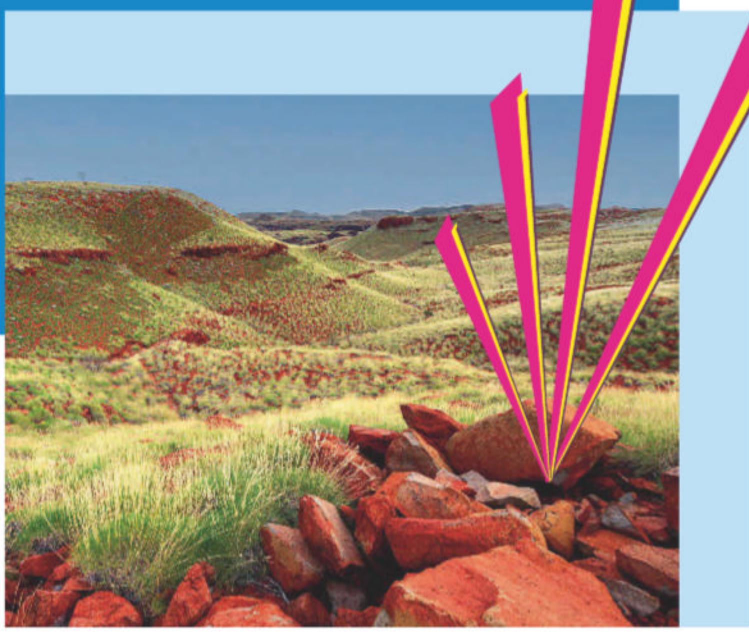
We now know that, early in Earth's history, large impacts occurred sporadically over hundreds of millions of years. However, we also know that a body the size of Mars collided with Earth just after it was formed, vaporising the planet's surface. "If life originated before then, it would have been wiped out," says Donoghue.

Life began when inert matter self-organised into living systems, but, despite decades of research, how that happened remains a mystery. Figuring out when it happened is also a big challenge because the fossil record gets worse the further back in time we go. As a result of the slow churning of rocks by plate tectonics, many of the oldest rocks have been dunked into Earth's hot interior, where they were melted and crushed, distorting or destroying any fossils. For the first 500 million years of Earth's existence, a period dubbed the Hadean, there are no known rocks: just a few tiny crystals.

Nevertheless, there are some truly ancient fossils. The oldest confirmed life comprises single-celled organisms, perhaps like modern bacteria, living in shallow water. Fossils of these were found in the Pilbara region of Western Australia and dated at 3.5 billion years old. But that is a billion years after the moon-forming impact. Two strands of evidence suggest life got started much earlier. First, there are many claims of older fossils, including apparent microorganisms from 3.7 billion years ago and traces of seemingly biological carbon in crystals from 4.1 billion years ago. These finds have been questioned, however, and none is as convincing as the Pilbara fossils. But Donoghue believes we shouldn't outright reject them. "There's a non-zero probability that they're fossils," he says.

Second, genetics points to an early origin. In a study published in July 2024, Donoghue and his colleagues attempted to date the last universal common ancestor (LUCA): the organism that is the ancestor of all life today. They did so by identifying genes found in all living organisms, which probably date back to LUCA. Their best estimate was that LUCA lived 4.2 billion years ago. That's just 300 million years after Earth formed. And things would have got started far earlier than that. "LUCA isn't the origin of life by any stretch of the imagination," says Donoghue. It seems to have been a fairly advanced microorganism, the product of a long period of evolution and growing complexity.

Donoghue's LUCA date might turn out to be off – something he emphasises. Still, the fact that life appears as soon as there is a rock record speaks volumes. "I feel very comfortable saying that it probably originated at some point during the Hadean," says Nadja Drabon at Harvard University. In other words, it seems that life on Earth began early and quickly became complex. If so, our planet must be even more perfectly suited for life than we thought. **Michael Marshall**



INGO OELAND/ALAMY

WHEN DID PLATE TECTONICS BEGIN?

ON EARTH, the land moves. Over millions of years, continents shift and the entire surface of the planet reshapes itself. The driver of all this is plate tectonics: Earth's surface is divided into several dozen plates, which move horizontally. Figuring out how this got started, however, has proved surprisingly challenging. Research has come up with dates ranging from 800 million years ago to 4 billion years ago, not long after the planet formed. Now, the reason for this huge discrepancy is finally becoming apparent.

Today, plate tectonics is a global process. Everywhere, plates are imperceptibly moving. At mid-ocean ridges, hot magma oozes up from inside Earth, forming new crust and pushing the plates apart. Where two collide, one is forced under the other, destroying it, in a process called subduction.

Things were very different when Earth was new – notably, it was much hotter, which meant the rocks of the crust were softer. But what that crust was doing is unclear. Some researchers argue there was a stagnant lid: the crust barely moved, leaving the same rocks at the surface for hundreds of millions of years. Others think plates moved vertically rather than horizontally, as denser rocks sank and less dense ones rose. Somehow, the crust divided into plates and they started moving horizontally. But when?

A decade ago, many researchers argued that plate tectonics began between 3 billion and 3.2 billion years ago, says Nadja Drabon at Harvard University. Several lines of evidence pointed to big changes at that time, including the first evidence of minerals that only form in tectonic settings. One study also found that the crust began to accumulate rocks formed during subduction 3 billion years ago, reaching its modern state by 2.5 billion years ago.

More recently, evidence has emerged of tectonic-like behaviour occurring much earlier. In 2022, Drabon and her colleagues identified a change 3.8 billion years ago. Before that, the crust seemed to be very long-lived, indicating it wasn't being subducted. Afterwards, there are signs of rocks having been melted, suggesting the crust was less stable and more mobile. "If not the onset of plate tectonics, at least there's some kind of fundamental shift in the Earth's geodynamics," says Drabon.

However, some hallmarks of plate tectonics are truly recent. Rocks called blueschists form when cold and dense rock sinks deep into Earth's mantle. They only start to appear 800 million years ago, so some researchers say this was the onset of true plate tectonics.

In an attempt to explain these radically different dates, the solution geologists are alighting on is that plate tectonics emerged in a stepwise process that took hundreds of millions of years. As young Earth cooled, the crust hardened and cracked into plates. In some places, these were forced up against each other and one was subducted, but this was localised and short-lived at first. Only later did it become a continuous, global process.

In 2022, researchers led by Peter Cawood at Monash University in Melbourne, Australia, set out a seven-stage scenario for the development of plate tectonics, starting 4.45 billion years ago with the solidification of Earth's crust. Global plate tectonics, they say, was operating by 2.5 billion years ago, at the start of the fifth stage. The exact details of the stages are "still pretty much up in the air", says Drabon. "But there's been an increasing recognition that it's not just an 'on' switch."

Understanding the timeline of plate tectonics matters because it almost certainly made Earth more habitable. It cycles water and essential nutrients, and by building continents, it creates new habitats. "I don't think you need tectonics for the origin of life," says Drabon. "But I do think it might be important to really proliferate life."

Michael Marshall

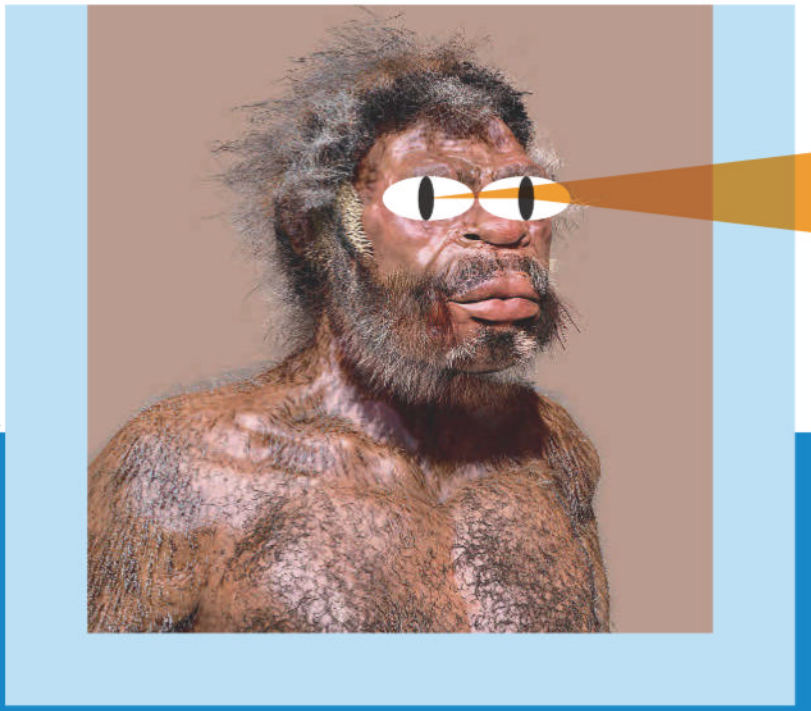
KIP EVANS/ALAMY

when when when when when when when when when when when when... **4 billion years ago ...** when when when when

LIFE EMERGES ON EARTH?
The oldest fossils are 3.5 billion years old, but genetic analysis suggests that the last universal common ancestor (LUCA) lived 3.7 billion years ago – and it was already fairly advanced

2.5 billion years ago ...

PLATE TECTONICS BEGINS TO SHAPE EARTH?
Plate tectonics emerged in a stepwise fashion, beginning around 4 billion years ago and taking around 1.5 billion years to become a continuous global process



JOHN BAVARO FINE ART/SCIENCE PHOTO LIBRARY

WHEN DID *HOMO SAPIENS* ORIGINATE?

FOR the vast majority of our planet's history, there were no humans. Today, there are more than eight billion of us. Logically, then, there must have been a moment when *Homo sapiens* became a distinct species. Yet that moment is surprisingly hard to pin down. The problem, for once, isn't a lack of fossils. Instead, disagreement about when to mark the origin of humanity comes down to the speciation process itself.

We often imagine the human evolutionary tree as a grander version of a personal family tree – indeed, researchers tend to talk about parent, daughter and sister species. In this picture, our parent species is equivalent to our biological parents, and the birth of *H. sapiens* becomes an event that is as easy to define as our own birth. But speciation isn't really like that.

For evidence of this, look no further than a study posted online last year. Trevor Cousins and his colleagues at the University of Cambridge suggest our supposed parent species, *Homo antecessor*, split away from its parent, *Homo heidelbergensis*, more than a million years ago. About 600,000 years ago, *H. antecessor* gave rise to two branches: one led to the Neanderthals and Denisovans – another kind of hominin – the other to *H. sapiens*. Then comes the twist. Our evolutionary grandparents, *H. heidelbergensis*, stuck around to see the birth of the *H. sapiens* lineage – and about 300,000 years ago, the two interbred in a big way. In fact, the researchers' model indicates that about 20 per cent of our ancestry comes from this interbreeding.

On the one hand, such studies give us extraordinary insight into our evolution. On the other, they make it ever harder to erect a simple genetic boundary around *H. sapiens*. Models like this one have even encouraged some researchers, including John Hawks at the University of Wisconsin–Madison, to argue that almost all these ancient humans belong to our species. If you adopt that thinking, *H. sapiens* is about a million years old.

That is a minority view, though. A more common approach is to focus on the suite of anatomical features used to define *H. sapiens*, which include a big, round braincase and a prominent chin. These probably didn't emerge all at once. We now know that in Africa, where our species emerged, populations of hominins were constantly splitting, living apart for a time and evolving into potential species with unique features, before mixing and then splitting again. Given this "African multiregionalism", we might expect to come across ancient human skulls with modern-looking faces attached to primitive-looking braincases – which is exactly what has happened.

A few years ago, researchers reassessed a group of roughly 300,000-year-old skulls that had been unearthed in the 1960s at Jebel Irhoud, Morocco. The study showed them to have long, flat braincases – rather unlike *H. sapiens* – but faces that bore striking similarities to our own. Many now see these as the oldest known *H. sapiens* fossils. That doesn't necessarily make them the first humans, however. "DNA tells us humans and Neanderthals split somewhere in the 600,000-to-300,000-year interval," says Brian Villmoare at the University of Nevada, Las Vegas. He thinks our species came into being at the moment of the split – and the Jebel Irhoud fossils show early evidence of our species after that.

Others take a different view. "I think the Jebel Irhoud fossils are on the *sapiens* lineage," says Chris Stringer at the Natural History Museum in London. "But whether I should call them *H. sapiens* – I'm more cautious." Instead, he leans towards placing the origin of our species at a more recent time. By about 200,000 years ago, there had been enough mixing and mingling of populations to produce individuals with the full suite of modern anatomical features, as seen in human fossils at a site called Omo-Kibish in Ethiopia. Perhaps it was then that our species really appeared, says Stringer.

One point of agreement is that we have learned a lot about how we became the species we are today. But in doing so, we have inadvertently made it harder to identify exactly when *H. sapiens* appeared. **Colin Barras**

300,000 years ago...

***HOMO SAPIENS* EVOLVES?**

At least according to fossils found in Morocco, but because speciation is such a slippery concept, some say our species is around 1 million years old while others put it at just 200,000 years

HUMAN CIVILISATION BEGINS?

If you take the construction of monumental stone enclosures at Göbekli Tepe in Turkey to be the start. But it may have begun as early as 200,000 years ago or just 6000 years ago with the first cities

WHEN DID CIVILISATION ARISE?

IF THE history of our species to date was represented as a single day, then civilisation would have begun in the final half-hour. At least, that's assuming *Homo sapiens* emerged around 300,000 years ago and civilisation began 6000 years ago with the first cities in Mesopotamia. In this tale, civilisation represents a seismic cultural shift that traces its roots back to the start of farming, some 5000 years earlier, and flows inexorably through settlement, population expansion and social stratification to urbanisation.

These days, we tell a different story. For a start, we no longer see Mesopotamia as ground zero for urbanisation: cities were springing up in other places, including India, China, Egypt and central Europe, at around the same time. What's more, agriculture wasn't the catalyst for civilisation we once thought. Instead, it appears to have been an invention born of necessity when the traditional hunter-gathering life became untenable – and there are plenty of examples of groups reverting when farming didn't work out. This means we must redraw the timeline that saw our ancestors shift away from the lifestyle that had worked well for most of human history. It also requires us to question the very definition of civilisation.

An obvious place to start looking for answers is Göbekli Tepe in southern Turkey. Archaeologists digging there since 1995 have unearthed a series of circular enclosures containing huge, T-shaped stone pillars. Dating back almost 12,000 years, these are the oldest known megalithic monuments. Building them would have required cooperation between many workers, along with leaders to coordinate and plan their activities. Such social complexification is one of the hallmarks of civilisation, yet Göbekli Tepe was constructed by hunter-gatherers, who are generally imagined to have lived in small, self-contained, egalitarian groups.

This isn't the only evidence that cultural change was afoot. The pillars are decorated with striking images of animals and geometric shapes – symbolism suggestive of complex ritual activity. Remains of food and large quantities of culinary tools indicate feasting and carousing. It looks like hunter-gatherer groups from around the region congregated here seasonally. But recent discoveries, including cisterns to collect water, hearths, burials and utilitarian buildings, suggest that the site was also a settlement. One possibility is that it was used as a school.

Martin Sweatman at the University of Edinburgh, UK, has another idea. He believes that some of the enclosures record astronomical observations. These, he argues, include symbols representing a lunisolar calendar – accounting for cycles of both the moon and the sun – and others depicting the position of constellations at the summer solstice. These might indicate a date, approximately 12,800 years ago, when some believe a comet slammed into Earth and caused a global catastrophe, followed by a period of extreme cold known as the Younger Dryas. Was civilisation born out of this cataclysm? "Fear is a powerful motivator," says Sweatman.

Others are sceptical. Nevertheless, Göbekli Tepe seems to push the origin of civilisation back by 6000 years – around an hour before midnight on the 24-hour representation of our species' timeline. And this may not even go far enough. In their book *The Dawn of Everything*, David Wengrow at University College London and the late David Graeber point out that people were building on a monumental scale throughout the last glacial maximum, a cold period on Earth that began 25,000 years ago. Such structures include massive wooden enclosures and so-called "mammoth houses", constructed from tusks and bones and thought to be symbolic.

But perhaps monuments and cities are the wrong places to look for the origins of civilisation. Graeber and Wengrow highlight that what we call "early civilisations" are societies held together by authoritarian governments, violence and sexism. Their conception, by contrast, aligns with the Roman concept of civilis, from which "civilisation" derives, which emphasises political wisdom and mutual aid. By this definition, the roots of civilisation extend back 100,000 years ago or more, to when humanity began creating networks of trade and extended kinship. "In all parts of the world," they write, "small communities formed civilisations in that true sense."

Kate Douglas

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1952

THE ANTHROPOCENE EPOCH BEGINS?

Officially, however, it hasn't started yet because geologists disagree about this date. Some point to the Industrial Revolution in the late 18th century. Others say we shouldn't try to pin it down

HORIZON INTERNATIONAL IMAGES/ALAMY

WHEN DID THE ANTHROPOCENE BEGIN?

ON A cosmological timescale, humanity's existence is a mere blip. Yet, in our short lifetime, we have done outsized damage to Earth, so much so that some believe we need to invent a new geological epoch, the Anthropocene, to recognise the global change our species has caused. Technically speaking, we aren't yet in the Anthropocene – but that is largely because experts can't agree about when it started.

Ask most geologists and they will say we are still in the Holocene, a geological epoch that began about 11,700 years ago and is characterised by a period of planetary stability when human civilisation flourished. But therein lies the rub: our influence on Earth systems means these characteristics no longer apply, and a growing number of scientists believe a new epoch must be recognised. Enter the Anthropocene.

There is debate about who coined the term, but it was popularised in 2000 by atmospheric chemist and Nobel laureate Paul Crutzen and biologist Eugene Stoermer. They argued that the Anthropocene began in the "latter part of the eighteenth century", around the time that global greenhouse gas emissions began to rise as the industrial revolution gathered steam. However, the Anthropocene Working Group (AWG) begged to differ. Established in 2009 and tasked with coming up with a formal definition of the epoch, its members said that the effects of human activity at that time were too scattered to provide a picture of global change. Instead, the date they came up with was 1952.

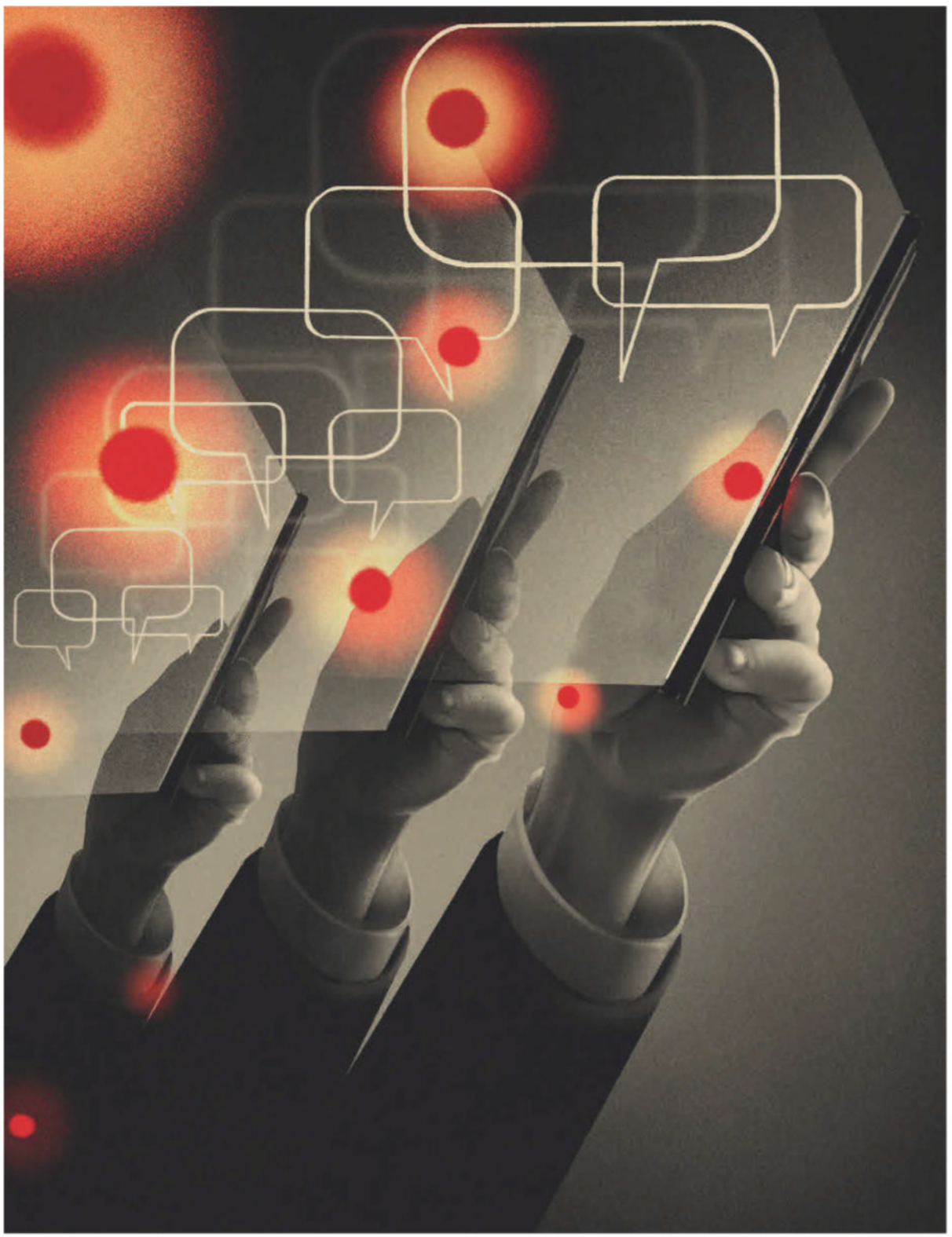
"The mid-20th century worked much better than any of the other candidates," says Jan Zalasiewicz at the University of Leicester, UK, who chaired the AWG. Starting in 1952, radioactive fallout from hydrogen bomb tests resulted in a worldwide uptick in plutonium in rock strata. Pollution from microplastics, fossil fuels, pesticides and forever chemicals all appear in ice cores, sediments and coral skeletons. There is evidence of changes in atmospheric and oceanic circulation too. Earth shows "hundreds of signals" of human influence globally, says Zalasiewicz. "It is a transformation."

However, for some, a 1952 start date for the Anthropocene is too close for comfort. "From the beginning, a number of my geological colleagues were deeply unhappy with the idea of a geological epoch that could be as short as 70 years," says Zalasiewicz. They aren't alone: some ecologists and social scientists believe that any definition of the Anthropocene must account for the broad sweep of human history. "There is not a precise date for the beginning of the Anthropocene, in my view," says geographer Andrew Barry at University College London. "Rather, it points to the accumulation of transformations over a very long period of time, which have become increasingly critical over the last 50 years or so."

Zalasiewicz believes we need a precise date to recognise the scale of change humanity has wrought on Earth. He fears that the lack of one creates uncertainty in the minds of the public. "The main point about formalisation isn't simply to have the Anthropocene there on a geological timescale," he says. "It's a means of stabilising the idea... so that it's widely known and isn't confused." Nevertheless, last year, when a proposal to define the Anthropocene as beginning in 1952 came to a formal vote, senior geologists rejected it by 12 votes to four.

Geologists won't get another chance to consider when the Anthropocene began for at least a decade. So, for now, it is in limbo: not yet a formal geological epoch, but, depending on who you ask, already well under way. **Madeleine Cuff**

JONATHAN CHEN/CC BY-SA 4.0



DEENA SO OTEH

Social ills

Is your online life triggering symptoms of real-life sickness? **David Robson** looks at how to avoid falling foul of the placebo effect's evil twin, the nocebo effect

CENTURIES ago, witches and shamans would mutter curses with the intention of spreading illness. Today, certain social media feeds may serve the same purpose.

We aren't talking about sharing dubious claims about quack treatments and fad diets, but rather information that exaggerates threats to our health. Through the power of suggestion, these posts can trigger real symptoms – ranging from Tourette's-like tics to headaches, muscle pain, fainting fits and even cognitive impairment.

That negative expectations can influence our health is already well established – it is called the "nocebo effect" and there is increasing interest in how it can pass from person to person. Scientists have shown that the phenomenon can be highly transmissible, spreading through face-to-face conversations, blogs and – most worryingly – social media.

"Online information can spread nocebo effects faster and farther than has previously been possible," says Kate Faasse at the University of New South Wales in Sydney, Australia. "This is quite scary, given how many people seek health information on the internet and through social media in particular."

Contagious nocebo responses are so common that you may have experienced one yourself – ever witnessed someone vomit and then felt nauseous? Fortunately, recent research is offering new ways to protect ourselves from these mind viruses.

Even if you have never heard of the nocebo response, you will probably be familiar with its counterpart – the placebo effect. In many situations, this can lead to people feeling better as a result of the mere expectation of relief. Taking a sham pill presented as a painkiller, for instance, often sees a person's discomfort evaporating – even though it contains no active ingredient. In the past, we had assumed that these benefits were purely subjective, but research suggests they often result from observable physiological changes. For example, we now know that placebo pain relief coincides with the release of opioids made in the brain, which work in a similar way to morphine to melt pain away. When you deliver the placebo alongside a compound that blocks opioid signalling, the benefits disappear. The placebo effect is so powerful that people can benefit even when they know the pill is a fake.

The nocebo response is the precise opposite, describing situations in which our expectations of discomfort become reality. Some of the best examples come from clinical trials: people receiving a placebo treatment not only report some of the benefits of the active drug, but also its side effects.

The nocebo response sometimes emerges from shifts in people's attention. When they are expecting illness, there is a tendency to focus on any feelings of physical discomfort and ascribe it to the pill they are taking. "It puts our antennae up to look for things that are going on in our bodies," says Keith Petrie at the University of Auckland, New Zealand.

Like placebo responses, many nocebo responses are also evident in objective measures of biological function. For example, when people feel under threat – real or imagined – the body ramps up the production of cholecystokinin, a chemical that amplifies the neural signals that transmit pain. Our expectations may also activate our autonomic nervous system, which is responsible for involuntary responses; this can influence our respiration, blood circulation and bowel movements, resulting in symptoms such as breathlessness, dizziness and nausea. If we are told to expect problems with our brains, we may even experience impaired cognitive performance.

The consequences can be dramatic. In 2007, for example, a team at the University of Florida examined the experiences of people prescribed finasteride, a drug that is sometimes given to men with an enlarged prostate. Half were told that it could cause erectile dysfunction, half weren't. Those who were informed of this risk saw a greater prevalence of the side effect, around 30 per cent compared with around 10 per cent.

For a long time, most studies documenting the nocebo response followed a similar procedure, in which an authority figure – such as a doctor – communicates a risk directly to the participant, and then observes how it influences their symptoms. More recently, however, scientists are exploring how negative expectations may spread through "social learning" or via non-formal exchanges.

Contagious headaches

Around 10 years ago, Fabrizio Benedetti at the University of Turin in Italy invited 121 students to visit a lab at an alpine research facility 3500 metres above sea level. Beforehand, he told just one participant – the "trigger" – that the lower air pressure at that altitude could cause a headache. The trigger was advised to contact the researchers a few days later to confirm the correct dose of aspirin to bring. This instruction was a ruse that allowed Benedetti to identify who else the trigger told about the message.

The trigger soon passed on the advice to their friends, who spread it to their acquaintances, leading 35 other participants to get in touch with the researchers in the run-up to the trip. An altitude headache is a very real risk, but these negative expectations vastly increased the participants' chances of developing one on their journey up the mountain. Of those had who learned about the warning, around 86 per cent developed the symptoms compared with 52 per cent of those who had not.

Benedetti was particularly interested in the social interactions that had led to negative expectations, and so he asked each participant to estimate the number of times they had discussed the risk. Each conversation appeared to increase the severity of their ›

ROBIN WEAVER/ALAMY

pain. Taking samples of their saliva at the top of the mountain, he found an association between their symptoms and higher levels of prostaglandin molecules, which increase blood vessel dilation in the brain and are thought to cause headache pain. The gossip had resulted in a measurable physiological change.

A large body of evidence now confirms the potential for nocebo contagion. There may even be chains of transmission, where the nocebo response jumps from person to person like an actual virus – as a 2023 study demonstrated. Led by Winston Tan at the University of Sydney, Australia, it investigated cybersickness – the nausea that may occur when immersed in virtual reality – in successive rounds of participants who experienced a virtual roller coaster. If one person spoke about their discomfort, the next was considerably more likely to feel it themselves, and they could then pass it on to a third participant, and so on.

What's more, for reasons that aren't entirely clear, our sex can influence susceptibility to social contagion. Faasse and her colleagues recently set up a trial ostensibly to test the effects of beta blockers, drugs commonly prescribed for heart arrhythmias (the pills were all sham). Some of the participants saw a standard video outlining the potential side effects, such as nausea, headaches, dizziness and muscle fatigue. Others saw a clip of two previous participants, actually actors, describing their personal experiences taking the pills, with facial expressions demonstrating their discomfort.

Witnessing the first-person anecdotes amplified the nocebo response in the female participants, roughly doubling the intensity of the symptoms they experienced. Male participants who saw the anecdotes, however, experienced the same level of nocebo symptoms as men who just saw the standard warning about potential side effects.

Faasse suspects this may be because women tend to be more risk averse, and so are more likely to look for social cues for danger. She emphasises that men are still susceptible to nocebo effects through other means, though. In another study, her team led people to believe that they would experience blurred vision, headaches and nausea from hearing a low-frequency noise. Reading first-person descriptions of the symptoms – the kind of testimonies you might see in a Facebook post or online forum – was enough to trigger them in both men and women equally.

Contagious nocebo responses may have contributed to cases of "mass psychogenic illness" throughout the history of medicine – from the dancing manias of the Middle Ages, which saw groups of people relentlessly shimmying past the point of dangerous exhaustion, to modern mass outbreaks of mysterious symptoms not caused by any infectious agent or environmental toxin.

Thanks to our increasing reliance on the internet, however, information can now pass between concerned individuals at an unprecedented rate. "One of my biggest worries is how easy it is for a short video or a few written comments to generate a nocebo effect, because in the real online world of social media, it's not just one short video or a few comments," says Faasse. "If you're looking for this sort of information, you will find lots of it, and once you've engaged with this content, the social media algorithms will show you more and more each time you open the app."

Mass hysteria

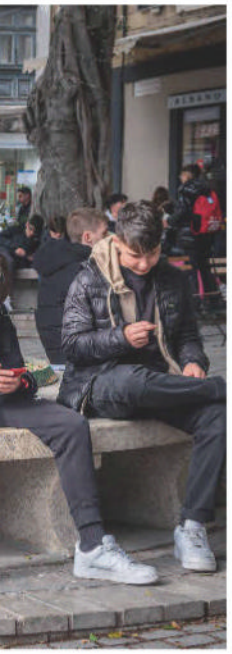
A steady stream of case reports suggests that we are already witnessing the consequences. Consider the mysterious cases of "TikTok Tourette's" in the early 2020s, when an increasing number of the platform's users began to upload videos of facial and bodily tics – resulting in a surge in people reporting such symptoms to their doctors.

While Tourette's typically emerges slowly in young childhood, many of these new cases were in people who hadn't experienced any symptoms before seeing the videos. The sudden onset, combined with the fact that the particular characteristics of the tics – which included whistling, clicking and clapping – were often highly similar to those of a specific influencer, led some neurologists, such as Mariam Hull and Mered Parnes at the Baylor College of Medicine in Houston, Texas, to conclude that at least some cases had been driven by social media use.

On a much bigger scale, our discussions about covid-19 vaccines may have influenced some of the side effects people experienced after having one of these jabs. Kelly Clemens at the University of Toledo in Ohio and her colleagues surveyed 551 people over 40 days as they received their first one or two doses of vaccine. The researchers found that both social media posts and first-hand accounts from acquaintances influenced the side effects that people expected and experienced. The more they heard people sharing their experiences, the worse their symptoms.

Social contagion is also thought to lie behind mysterious illnesses such as "wind turbine syndrome", the nausea and headaches reported by some people living near wind farms. Many people experiencing these symptoms believe they are caused by infrasound, sound waves at frequencies too low to be audible to humans. However, multiple experiments have found no evidence that wind turbine infrasound has effects on humans, and point instead to expectations of harm as the real cause of people's symptoms.

A nocebo response may even explain some cases of food intolerance. Trials of people with non-coeliac gluten sensitivity (NCGS) have shown that around 40 per cent of them report symptoms even when they have been given a



ASHLEY COOPER/AVALONAVALON

Transmission of real symptoms can happen online (left). "Wind turbine syndrome" seems to be caused by expectation, not infrasound (right)

"Online information can spread nocebo effects faster and farther than has previously been possible"

food that doesn't contain the gluten protein. Though there is still some debate about the origins of NCGS – in some cases, it may be triggered by the presence of other components in wheat besides gluten – studies suggest that the huge amount of cultural attention to wheat intolerance may be contributing.

Discussions of potential nocebo responses are often controversial, as the water crisis in Flint, Michigan, exemplifies. In 2014, the city switched its water supply from Lake Huron to the Flint river, accidentally exposing residents to lead and other contaminants. Residents were given lead filters and bottled water and by 2016, authorities had reconnected the city to its original source. However, many people were concerned that exposure to lead may have caused cognitive damage, particularly in children. Soon after, the city's schools witnessed a sharp increase in children being enrolled for support for educational difficulties.

Although the crisis was no doubt serious, any assessment of its impact is complicated by having to tease apart health problems caused by the contaminated water and by potential nocebo effects. Siddhartha Roy at Rutgers University in New Jersey and Marc Edwards at Virginia Tech – who both first helped to raise the alarm over the tainted water supply – recently examined anonymised data collected from children under the age of 6 in Flint and Detroit, a city 100 kilometres away. The children had their blood tested for lead multiple times between 2011 and 2019. The analysis showed that the percentage of children whose blood lead levels exceeded the intervention threshold suggested by the Center for Disease Control and Prevention was markedly lower in Flint than in Detroit – which didn't see a rise in children enrolled in special education – and never rose significantly above Michigan's statewide average.

Could the Flint water crisis have generated a nocebo effect?

BRETT CARLSEN/GETTY IMAGES

Self-fulfilling prophecy

In their report, Roy and Edwards suggested that the consistently negative media coverage about the future prospects of these children "could have created a self-fulfilling prophecy via a nocebo effect". In a follow-up study, the pair surveyed teachers in Flint, finding that they believed that the children there were "brain damaged" by lead poisoning. Decades of research shows that kids are highly sensitive to adults' expectations of their abilities and may begin to behave in line with those beliefs. The teachers' assessments offered more evidence, they said, that negative labelling of the Flint children might "cause damage that is worse than that caused by the actual exposure to contaminants".

Edwards says that he has received a hostile response to these findings, however. Some activists are concerned that this explanation undermines the experience of Flint's citizens, many of whom say they are still witnessing the aftermath of the crisis. Yet Edwards believes that continuing this narrative will do more harm than good. "As a scientist, you have to speak these inconvenient truths," he says.

The conversation in Flint is complicated by the politics of the original crisis, but scepticism about the nocebo effect is common in many other contexts. "There's always the suspicion that you're saying it's all in their head," says Petrie, who was a co-author of Roy and Edwards's paper.

In some cases, people may even interpret a psychosocial explanation of symptoms as an accusation of malingering – but this couldn't be further from the scientific understanding. Nocebo responses are a natural consequence of the ways our brains work. We may have evolved this trait as a first defence against illness; if others are falling sick in our group, it makes sense for the body to start preparing itself for the threat. These symptoms are in no way fake or deliberate. "The nocebo effect is so powerful, and the symptoms that people are experiencing are real," says Faasse.

Armed with this knowledge, how do we stop ourselves from falling foul of nocebo's power?

A greater understanding of the mind-body connection may help to reduce the stigma surrounding the phenomenon and, potentially, arm people against the nocebo response itself. This research is still in its infancy, but a handful of studies suggest that educating people about the effect appears to reduce the symptoms they report and leads them to be more conscious about the potential influence of the health information that they are consuming.

"Any one of us could experience psychogenic symptoms. I know I have," says Faasse. "And I think these conversations are part of how we tackle the stigma. If a nocebo researcher can experience nocebo effects, I suspect that anyone can." ▮

David Robson is an author whose books include *The Expectation Effect* and *The Laws of Connection*

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The science of exercise

Taking it outside

Numerous studies show that exercising outdoors has a slight edge on boosting our physical and mental health, finds **Grace Wade**

Grace Wade is a health reporter for *New Scientist* based in the US

AS you may remember from my previous column, I am determined to tick running a half marathon off my bucket list this year. Well, I have already hit my first roadblock. Turns out, I despise running on a treadmill, as I have been forced to do thanks to an especially frigid winter here in New York. All that time spent staring at the blank wall, my feet thudding away on the machine, really got me thinking: is it actually better to exercise outside? Or am I just looking for an excuse to skip out on my training?

Research on indoor versus outdoor exercise is far from conclusive, but some studies suggest there is a slight benefit to the latter. A 2023 review of 10 studies found that, overall, results were similar between indoor and outdoor exercise, but other studies did find statistically significant differences – all of which favoured outdoor workouts.

In a 2023 study, for example, 30 adults walked along a trail surrounded by trees while wearing a cap that monitored their brain activity. They then did the same on an indoor treadmill facing a blank wall. The researchers found brainwaves associated with relaxation increased in participants while walking outside versus inside. They also showed greater connectivity between brain regions involved in reasoning, attention and sensory perception, suggesting a heightened focus on the present moment when outdoors. This could explain why participants reported enjoying their outdoor walk significantly more.

ISLANDSTOCK/ALAMY

But what about from a physical perspective? A 2021 review of 49 studies found no significant difference in performance when running outside compared with on a treadmill. However, a study last year showed that may not be the case for resistance training. Henrique Brito at the University of Lisbon in Portugal and his team monitored 104 adults while they completed a workout routine of 12 bodyweight exercises. Of the participants, 53 performed the workout indoors while 51 did so outside surrounded by greenery.

They found that, on average, those in the outdoor group completed more repetitions of exercises than the indoor group. They were able to perform about two more crunches, squats and lunges during each set. While these differences are slight, they suggest you may be able to squeeze a bit more out of yourself during outdoor workouts.

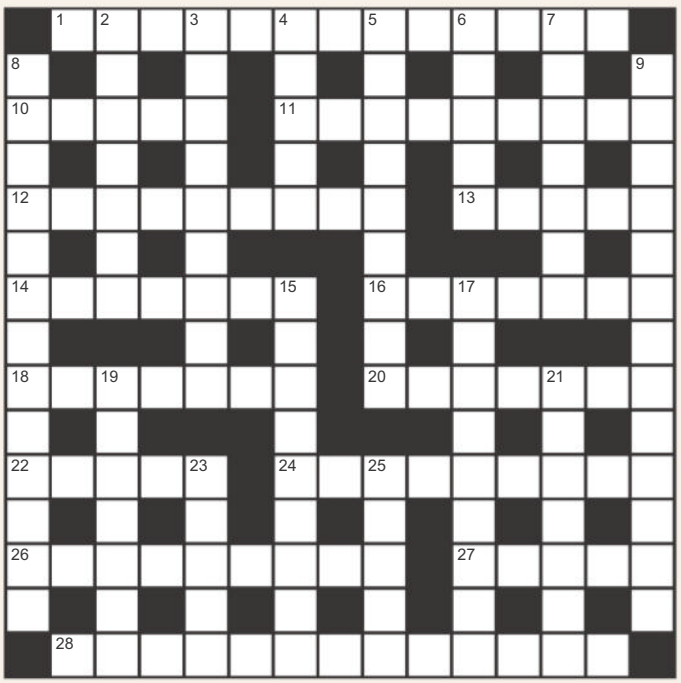
I am a firm believer that the most important aspect of your workout routine is that you enjoy it, and taking your workout outdoors seems to be one way of making it more pleasurable. It might also have an additional effect on exercise's mental health benefits. As for me, I will invest in warmer athletic wear and brave the cold – I can't spend much more time running in front of a blank wall before I give up altogether.

The science of exercise appears monthly

Next week
Dear David

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

Quick crossword #177 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 27-sided shape (13)
10 Power line support (5)
11 Solid figure of which all plane sections are ellipses (9)
12 Continuous heavy gunfire (9)
13 Coral ring (5)
14 Slope (7)
16 Early photography technique (7)
18 Immunity treatment (7)
20 Hernia (7)
22 Medications (5)
24 Use of IT (9)
26 Rodenticide (3,6)
27 Large lemur (5)
28 Astrophotographic telescope (7,6)

DOWN

2 Concerning the large intestine (7)
3 Strategy board game (9)
4 African scavenger (5)
5 Synthetic fibre (9)
6 α (5)
7 Medical study of the ear (7)
8 1978 video game (5,8)
9 Flightless Antarctic bird (6,7)
15 Used; trained (9)
17 Np (9)
19 ___ soda, NaOH (7)
21 Type of supporting beam (1,6)
23 Atmospheric disturbance (5)
25 Abnormally energised or intense (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #290
set by Corryn Wetzel

1 What is the formal name of the geological era known as the "Age of Reptiles"?

2 What country is home to the Global Seed Vault?

3 Who is known as the "father of the hydrogen bomb"?

4 In what organs of the human body are Bowman's capsules found?

5 Which is the only bear known to carry cubs on its back?

Answers on page 47

BrainTwister
set by Katie Steckles
#61 Mark to mark

Given a ruler that you know is 6 units long, with a mark 2 units from one end, it is possible to measure distances of 2, 4 and 6 units between some pair of points (using the mark and the ends of the ruler).

Where could you add a second mark to the ruler that would allow you to measure all lengths from 1 to 6 units?

A ruler 11 units in length has a mark at 1. Where can you add two more marks to allow you to measure 10 out of the 11 possible lengths from 1 to 11 units?

Can you find a different way to mark up an 11-unit ruler, using three marks, that allows you to make a different 10 out of the 11 possible lengths?

Solution next week

Steel banned

Would it be possible to have an advanced technological society without abundant iron?

Howard Bobry
Port Townsend, Washington, US
Yes, an advanced technological society would be possible without abundant iron, assuming, of course, that our essential biological needs were met. Comparing societies with and without plentiful, low-cost iron, it may just be that economic forces would drive the "have nots" to become more advanced than the "haves".

For most of human history, technology advanced without the use of iron. We moved on from bone and stone tools and weapons to using copper and then bronze. Iron, and its alloy, steel, are harder than bronze and superior for swords and cutting tools, but they are preferred for many other applications simply because they offer high strength at much lower cost. It is an economic, rather than technical, choice. Bronze could be used for bridges and tall buildings, as well as tools, engines and other machinery. A bronze Eiffel Tower, locomotive or ship? No reason why not, other than cost.

"Bronze could be used for buildings and tools. A bronze Eiffel Tower, locomotive or ship? No reason why not, other than cost"

Electromagnetic devices, such as transformers, inductors, generators and motors, are essential to our technological society. Without them, we would have no mains electricity, electrical machinery or electronics. Most are constructed from electrical steels (alloys of iron and silicon) or ferrites (iron-based ceramics) or both.

Could they be made without iron? Yes. Nickel, abundant in Earth's crust, is a more expensive alternative but with superior performance. Yet continuing advances in semiconductor technologies facilitate the use of ever-smaller and less-expensive electromagnetic devices, effectively reducing nickel's cost disadvantage. Our electrical and electronic industries could have evolved without inexpensive electrical steels and ferrites, but at higher initial cost.

Economics is a powerful driver of innovation. Would a lack of plentiful, cheap iron have hastened our development or use of other metals, composites, plastics and semiconductors, giving us an even more advanced society today? Has our abundance of iron driven us forward or has it retarded our technological progress? Either way, we egotistically call ourselves an "advanced technological society", no matter how laughable that may be to future historians.

Ian Simmons
Westcliff-on-Sea, Essex, UK
I suppose it is possible that, with sufficiently large deposits of copper and tin, an advanced, bronze-based civilisation could have developed if iron weren't available.

However, it has long seemed to me that the limiting factor in a civilisation's leap from pre-industrial to advanced is fossil fuel. Without a readily available source of combustible, energy-dense material, that transition would be impossible.

I suspect this is a major reason why we haven't detected any alien civilisations. Even if all the planets in the universe had the right conditions for intelligent life to evolve, if a planet hadn't gone through a stage with suitable conditions for an equivalent to oil or coal to form where it could be easily extracted, advanced technology would be impossible. There simply wouldn't be the energy to get aliens through an industrial revolution.

We could be surrounded by alien races living in the equivalent of the early 18th century and never know it.

DYLAN GARCIA PHOTOGRAPHY/ALAMY

Could other life forms out there in the cosmos live much longer than us?

Garry Trethewey
Arkaroola, South Australia
I have two responses, neither of which is probably what the questioner is looking for.

The first is to wonder what the term "an advanced technological society" means. Like love or patriotism, attempts at a definition will be inconsistent and leave many gaps. So the fallback is "I'll know it when I see it". Trying to separately define "advanced", "technological" and "society" throws up the same problems.

I am inclined to see the phrase as meaning "people pretty much like us", although "like us" is still pretty vague, and "technology" as meaning impressive things – steel foundries, smartphones, but maybe not cups or socks.

So, I will go out on a limb and talk about honeybees. People don't generally think of honeybees as an advanced technological society, but they tick all the boxes. They are very advanced in their technology (the way they do things, not the things they do it with). They have complex social interactions. And they do it without iron.

My second response is to point out that abundant iron isn't the issue. Five per cent of Earth's crust is iron. That is abundant. Accessible iron is more the point, with iron ore needing to be over 50 per cent iron to be

This week's new questions

Live long and prosper **Could it be possible that another life form in the universe has a lifespan measured in many hundreds or thousands of our years?** ***John Howes****, Cardiff, UK*

Homo runnicus **Could *Homo sapiens* have outcompeted Neanderthals in part due to a superior running ability?** ***Martin Greenwood****, Perth, Western Australia*

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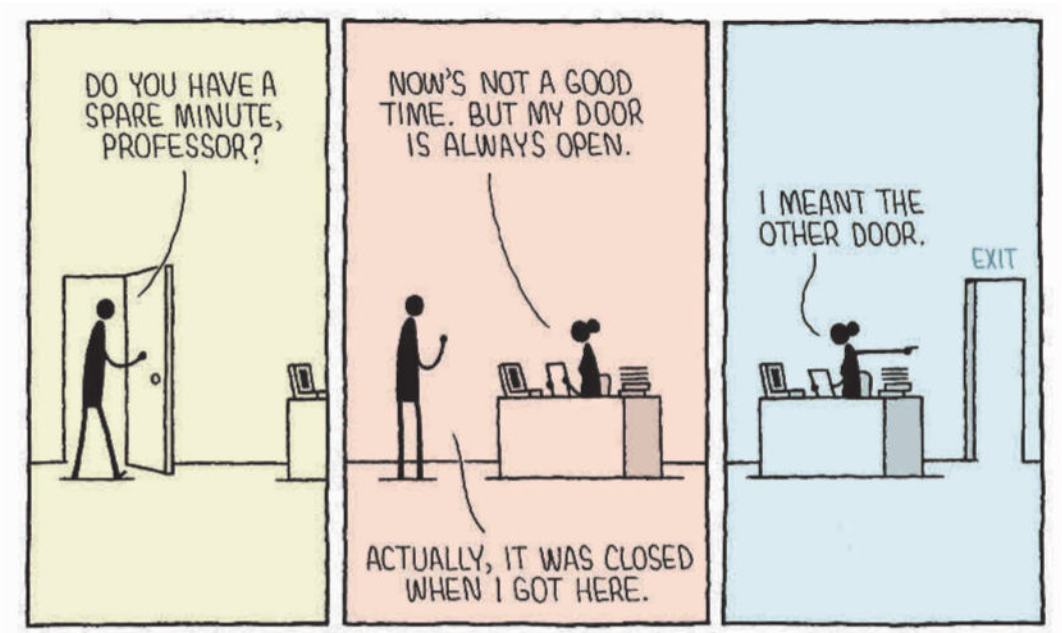
Tom Gauld
for New Scientist



economically worthwhile. Our advanced technological society is digging up concentrated sources of iron. It is similar with energy sources like coal and oil and with fertilisers like phosphorus. All these things have accumulated on geological timescales. Most iron ore formed 2.5 billion years ago, with very little created since. Much of our coal formed more than 300 million years ago.

So, when we send ourselves back to the Stone Age or leave the planet to cockroaches, what is the chance of another industrial revolution, without accessible iron, energy and fertilisers?

Bob McCrossin
Cooroy, Queensland, Australia
Iron is the end point of nuclear fusion in massive stars. The subsequent supernovae seed the universe with "metals" (astro jargon for elements other than hydrogen and helium).

New, massive stars that form in the next cycle have more metals in them. After enough cycles, rocky planets, probably life and maybe intelligent beings arrive. Not much iron means none of this happens, at least in a universe with our laws of physics, so the answer to the question is no.

"We may need to start considering our digital legacy in our wills, especially any intellectual property we have created"

In the clouds

What happens to our electronic cloud records when we die?

Richard Hind
Chapel Haddlesey, North Yorkshire, UK
This question is part of a larger issue I discuss with my cybersecurity students. They will be the first generation to leave behind a full digital footprint of their entire lives when they eventually die and this has far-reaching implications.

Data retention is an important aspect of the UK Data Protection Act (updated in 2018 in response to the European Union's General Data Protection Regulation, or GDPR). Personal data, meaning anything that can be used to identify an individual, is protected from misuse and must be kept secure and up to date. The law also states that it can only be kept for a predetermined length of time, although we now have the right to be forgotten at any time, thanks to GDPR's "digital rights for citizens".

This is all well and good, but, in reality, can we trust the tech giants to completely delete all of our personal data when we ask, when the deadline expires or, indeed, when we expire? Organisations risk a fine of up to 4 per cent of their global turnover for breaches of the law, which seems to have brought them into line.

Nevertheless, we may need to start considering our digital legacy in our wills, especially any intellectual property we have created. This is where I turn to my colleagues in the legal profession for their thoughts... ▮

Answers

Quick quiz #290 *Answers*

1 Mesozoic Era
2 Norway
3 Edward Teller
4 The kidneys
5 Sloth bear (*Melursus ursinus*)

Cryptic crossword #155 *Answers*

ACROSS 1 Chimp, **4** Filbert, **8** Minor arcs, **9** Hub, **10** Recruit, **11** Rally, **12** Cerebrospinal, **16** Frays, **18** Ohm's law, **20** Lit, **21** Space-time, **22** Fermium, **23** Sweet

DOWN 1 Cambric, **2** Ionic, **3** Perturb, **4** First do no harm, **5** Laser, **6** Echelon, **7** Tabby, **13** Reactor, **14** Pampers, **15** Low heat, **16** F clef, **17** Sushi, **19** Loire

#60 Say what you see *Solution*

There are six ways to arrange three cards. In four of them, at least one card is in its correct position, so the probability is 2/3 = 0.667. With a fourth card, there are 24 ways to shuffle the deck and 15 of these include a match, for a probability of 15/24 = 0.625.

With duplicates, there are two chances for each match, so it is more likely that you will get a match when using this deck. In fact, there are 720 ways to arrange six cards and 455 matches when the cards are all different, for a probability of 0.632, but there are 640 matches with duplicates, for a probability of 0.889.

Solved! Or not

Feedback is as fond of true crime as the next morbidly curious ghoul, so we have occasionally dipped our toes into the never-ending well of speculation about the Whitechapel murders of 1888-91 and the near-mythical Jack the Ripper. Although frankly, we didn't get much further than Alan Moore and Eddie Campbell's *From Hell*, which (spoiler!) ties the killings to the British establishment and the Freemasons, who supposedly arranged the murders to create an evil psychic force that would perpetuate the patriarchy. But the field of "Ripperology" extends far beyond one eccentric graphic novel.

So our attention was drawn to recent news stories reporting calls for a fresh inquest – backed by Karen Miller, a distant descendant of Catherine Eddowes, one of the case's five murdered women.

It all hinges on a shawl that supposedly belonged to Eddowes, which was collected by a police officer at the time and kept in his family for over a century. The shawl came up at auction in 2007 and was bought by Ripperologist Russell Edwards. He arranged for the shawl to undergo DNA testing, the results of which were published in 2019. Geneticists Jari Louhelainen and David Miller obtained mitochondrial DNA (mtDNA) from two people. One had genetic markers in common with Karen Miller, suggesting it came from Eddowes. The other matched a distant relative of Aaron Kosminski, a barber who was a suspect at the time of the killings.

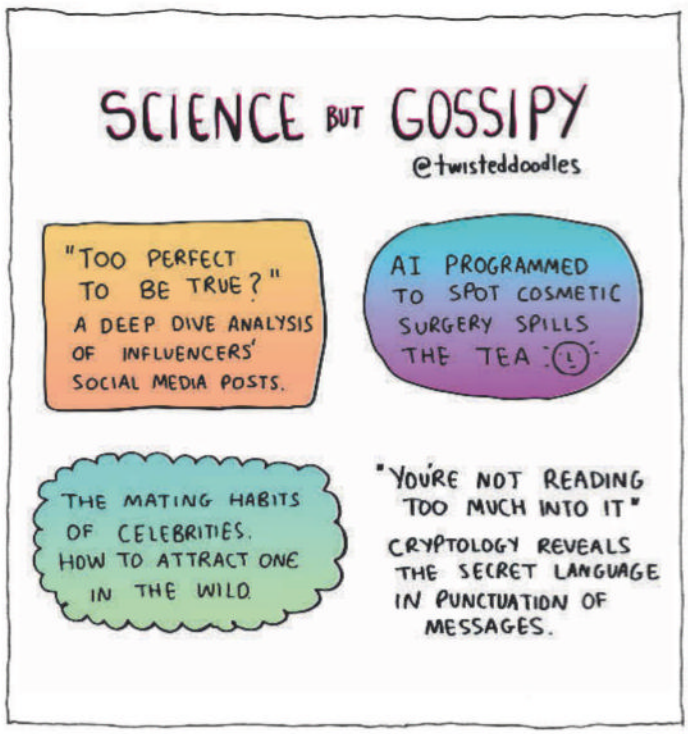
For Edwards, this is proof that Kosminski was the murderer – a scenario he has promoted in his book *Naming Jack the Ripper*. Other Ripperologists are sceptical: social scientist Katie Charlwood points out there is no reliable chain of custody for the shawl, and no evidence the five murders were all committed by the same person.

Feedback is in no doubt this story will rumble on forever, but we do want to add something – something not one of the recent news stories picked up on. We looked at the 2019 study and discovered that the editors had added an "expression of concern" in August 2024.

It mentions "concerns raised by third parties after publication", as well as letters to the editor. And then comes the bombshell: "During the investigation, the publisher and Editor-in-Chief made every effort to obtain from the authors the original raw data from the mtDNA analysis. However, the authors stated that the data were no longer available, due to instrument data failure and other complications."

Yes, you read that right – the crucial mtDNA evidence can never be verified, because the authors have lost it. Maybe Moore was right about the evil psychic force after all.

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

The equation for love

Here's a romantic tale. News editor Alexandra Thompson draws our attention to a preprint entitled, "A Formula for Love: Partner merit and appreciation beget actor significance".

The authors argue that romantic love is "a means to the end of feeling significant and worthy". Feedback isn't sure about that, but let's go with it. This leads them to "a multiplicative tri-factor model" that determines "the likelihood of the actor falling in love with the partner".

Specifically: "Love for a partner depends on the actor's perceptions that (1) the partner possesses meritorious characteristics, and (2) that they appreciate the actor and view them as significant. We assume that these two factors multiplicatively combine with the magnitude of actor's quest for significance to determine the likelihood of the actor becoming enamored with partner."

In other words, the likelihood of you falling for someone is a combination of how good you think they are, how much you think they appreciate you and how much you care about finding meaning in your life.

Feedback tried to extrapolate this into dating advice. The frequent suggestion that one should play hard to get seems counterproductive, if the amount of appreciation you show your partner is a predictor of whether they fall for you. Instead, it seems like a good idea to seek out a partner who is engaged in a desperate quest for significance in life, because they are more prone to falling in love. However, this might have its own downsides, not least the distinct possibility that such a partner might join a cult.

Good luck out there, folks.

Biting the hand that bit

Via news editor Jacob Aron and the *Financial Times*, Feedback learns that AI company Anthropic doesn't want potential employees to use AI when writing job applications. Their job ads say: "While we encourage people to use AI systems during their role… we also want to evaluate your non-AI-assisted communication skills." But why, Anthropic? Could it be that the AI letters are full of guff that is unbearably tedious to sift through?

By curious coincidence, Feedback learned of this just days after news broke that Chinese AI firm DeepSeek has outperformed US tech giants. OpenAI promptly complained, saying it was "reviewing indications that DeepSeek may have inappropriately distilled our models" – that is, engaged in copyright theft.

To sum up, these AI companies don't like being bombarded with AI-written slop and they don't like it if their work is used to train an AI without permission. As a writer whose work has almost certainly been scraped by AI companies, and who has not seen a penny in return, Feedback can only say: "Bwahahaha, sucks to be you."

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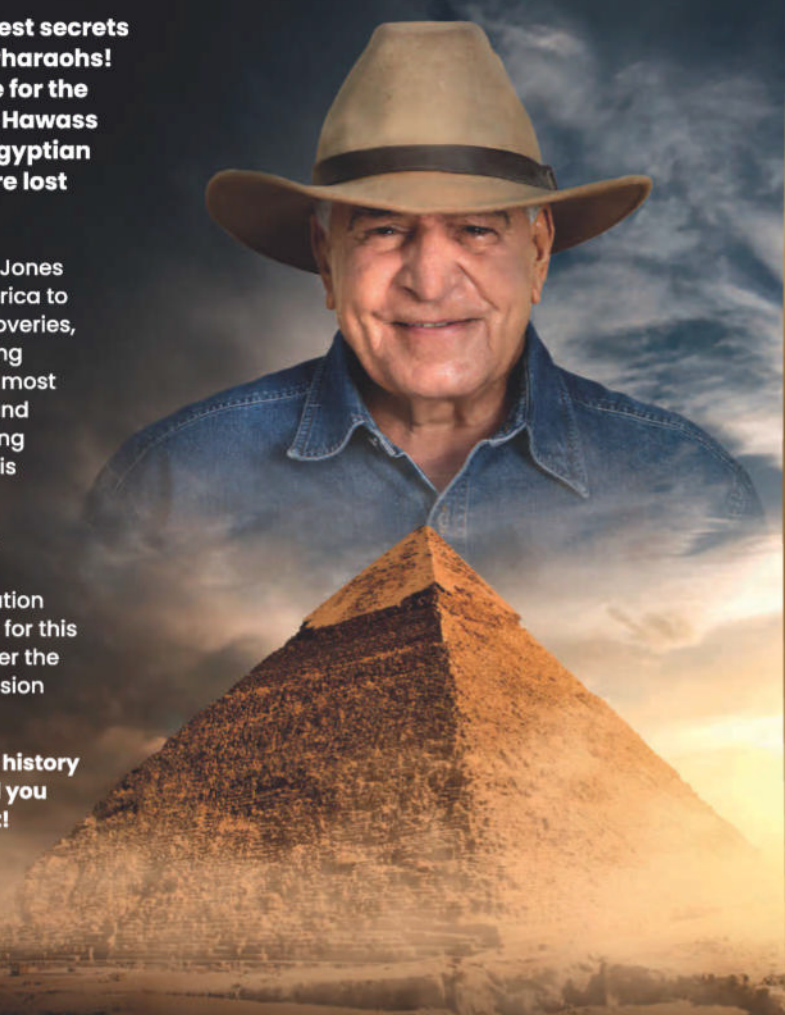

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May 3	Los Angeles, CA
May 6	San Diego, CA
May 9	Las Vegas, NV
May 11	Oakland, CA
May 14	Portland, OR
May 18	Seattle, WA
May 22	Denver, CO
May 25	Austin, TX
May 27	Oklahoma City, OK
May 29	Dallas, TX
June 1	New Orleans, LA
June 5	Tampa, FL
June 7	Orlando, FL
June 11	Nashville, TN
June 14	Atlanta, GA
June 16	St. Louis, MO
June 18	Charlotte, NC
June 21	Pittsburgh, PA
June 25	Columbus, OH
June 28	Chicago, IL
June 30	Minneapolis, MN
July 3	Cleveland, OH
July 6	Indianapolis, IN
July 9	Boston, MA
July 12	Baltimore, MD
July 16	Virginia Beach, VA
July 19	New York, NY
July 21	Philadelphia, PA
July 23	Washington, DC
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