New Scientist

WEEKLY October 19 - 25, 2024

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- Many opportunities to enjoy the water by kayak, paddleboard and snorkelling.

Darwin's Galapagos with Jo Ruxton MBE

14 July 2025 | 8 days

The Galapagos Islands are truly the ultimate bucket list destination for wildlife enthusiasts. Travel aboard the small Solaris yacht, accommodating just 15 guests, accompanied by conservation advocate Jo Ruxton MBE.

- Explore the wildlife-rich islands of Santa Cruz, Isabela, Fernandina, Santiago and Rabida.
- View a plethora of wildlife, from vast populations of land and marine iguanas roaming freely to sea lions basking on the sunny shores.
- Encounter a diverse array of marine life in crystal-clear waters including schools of colourful fish, white-tip reef sharks, sea turtles, and rays.

Arctic expedition cruise with Richard Dawkins, Svalbard, Norway

22 June 2025 | 12 days

Explore the northernmost region of Earth, the realm of the polar bear and the midnight sun, while travelling aboard the Greg Mortimer, which is at the cutting edge of nautical technology.

- Enjoy fascinating talks from evolutionary biologist and author Richard Dawkins, plus New Scientist contributors and expedition crew.
- Venture close to 80° north, searching for polar bears on pack ice.
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Instant Expert

Get up to speed with the weird world of quantum mechanics, where nothing is as it seems until you measure it, in this one-day workshop. Six leading quantum physics experts will explain this famously complex field in easy-to-understand language. This event is perfect for those curious about the quantum world but who may not have a science background. On 9 November at London's Congress Centre or online

newscientist.com/events

Tour

The science of biodiversity: Costa Rica

Costa Rica covers just 0.03 per cent of the planet, but it is one of the most species-dense countries in the world. Delve deep into the science behind biodiversity, visiting cloud forests, wetlands, primary rainforests, volcanoes and marine reserves. This 13-day tour starts on 6 November and costs £5699.

newscientist.com/tours

Podcast

Weekly

The team discuss the impact of Hurricane Milton on Florida and hear how the increased life expectancy experienced in most countries around the world is slowing down. Find out why technologies that remove carbon dioxide from the atmosphere won't be able to reverse many of the impacts of global warming. Plus, learn about the microbes living in 2-billion-year-old rocks.

newscientist.com/nspod

SHUTTERSTOCK/GEORGIE TURNER-NOBLE

Cloud forests Immerse yourself in a remote Costa Rican wilderness

JSC/NASA

Sudden evacuation How to handle an emergency in outer space?

Video

Paramotorists in Peru

Scientists from Royal Botanical Gardens, Kew, in the UK have worked with a team of Brazilian paramotorists (who fly powered paragliders through the skies) in the Peruvian desert to recover and study endangered species from fragile ecosystems. The team focused on unique fog-fed oases known as lomas, which are home to around 1700 plant species.

youtube.com/newscientist

Newsletter

Launchpad

Only three people have ever been brought back to Earth from space for medical reasons. That means we have very little data on the plausibility of medical evacuation, which might be a problem as two prongs of space exploration grow: space tourism and longer missions into deep space.

newscientist.com/launchpad

Podcast

"A tipping point such as the drying up of the Amazon will be impossible to reverse"

Essential guide

From tremendous chains of galaxies to supermassive black holes, our universe is a place of grandeur and spectacle. Find out how we are probing the cosmos like never before in this 24th *Essential Guide*. Available to download in the *New Scientist* app or to purchase in print from our shop.

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You can handle the truth

Only the scientific method can identify the best way to tackle misinformation

MARK TWAIN famously (although possibly apocryphally) said we should never let the truth get in the way of a good story. Archaeologists might beg to differ, particularly when the story in question is a dramatic rewriting of human history that – as the president of the Society of American Archaeology, Daniel Sandweiss, has noted – has a long-standing link with racist ideologies.

This narrative claims that the familiar ancient civilisations of Eurasia, Africa and the Americas drew inspiration from a mysterious advanced culture that predated them all. Archaeologists are confident that no such civilisation ever existed, but they are also aware that persuading believers to reject the story is a tough task.

However, as we explore in our interview with archaeologist Flint Dibble on page 37, they may have found a winning strategy in the form of the "truth sandwich". In this debating technique, archaeologists first begin by discussing real information, what their research has revealed about the past. Then they tackle the false information – in this case explaining how the facts leave no room for this lost civilisation – before returning to and re-emphasising the real information.

"'Truth sandwiches' appear to be good at fighting misinformation in some contexts but not others"

The truth sandwich gained popularity after it was formalised by linguist George Lakoff in 2018. It is tempting to assume that it can convince audiences to abandon belief in false narratives. But can it? The best way to find out, of course, is through controlled experiments. The first such research has now been conducted, and it presents a mixed picture. Truth sandwiches appear to be effective in certain contexts but not in others, where different ways to structure an argument are more persuasive.

These conflicting results might seem problematic, but they are actually evidence of scientific inquiry at work – a process that involves testing ideas and refining hypotheses in light of new data. It is only this approach that can really discover the best way to tackle misinformation. Or, to put it another way, science should never let a good story get in the way of the truth. ▮

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Events

NewScientist

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Dr Ulyana Horodyskyj
Glaciologist

How melting sea ice allows us to research previously inaccessible polar regions

Leah Crane
New Scientist space and physics reporter

IceCube, the Antarctic neutrino detector that has identified high-energy particles from the Milky Way

News

SERGIO FLORES/AFP VIA GETTY IMAGES

Space

Starship plucked out of the sky

A space rocket has been caught on its return to Earth for the first time. SpaceX's Starship powered into the sky from Boca Chica, Texas, on 13 October. The bottom part, or booster, then separated from the rest and returned to the launch pad. It was caught in mid-air just 7 minutes after takeoff by the launch tower's mechanical arms. SpaceX hopes this feat will make its largest rockets reusable.

Environment

1.5°C will bring irreversible harm

We might not be able to cool the world down again after overshooting the 1.5°C warming limit, and even if we can, much of the damage can't be undone, finds **Michael Le Page**

IT IS clear the world will exceed the 1.5°C target for global warming, leading to an increasing focus on plans to cool it down again by removing carbon dioxide from the atmosphere. But there is no guarantee that we will be able to achieve this – and even if we can, some changes can't be reversed.

"Deaths are not reversible," says Joeri Rogelj at Imperial College London. The focus needs to be on urgent emissions cuts to limit warming now, he and his colleagues warn after studying "overshoot" scenarios.

There are at least five big problems with the idea of overshooting climate targets and then cooling the planet back down, according to their study (*Nature*, doi.org/nmxw). The first is that many such scenarios give a misleading picture of the uncertainties and risks involved.

For instance, in its last major report, the Intergovernmental Panel on Climate Change (IPCC) looked at an overshoot scenario in which the world reached 1.6°C above preindustrial levels by around mid-century, just 0.1°C past a limit set in the Paris Agreement. But because of uncertainties in how global temperatures will change in response to a given amount of CO_2 in the atmosphere, the level of emissions assumed in this scenario could result in anything up to 3.1°C of warming.

"For the same emission levels, there would be about a one in 10 chance that warming exceeds 2°C," says Rogelj. "A one in 10 chance of a potential existential threat is not small."

The second issue is that there is no guarantee warming will halt even if we stop adding CO_2 to the atmosphere, reaching so-called net-zero emissions.

For instance, warming could trigger stronger positive feedback effects than expected, leading to higher-than-projected emissions of carbon from, say, peat and permafrost, precipitating further rises in global temperature even after we reach net zero.

What's more, achieving net zero requires removing CO_2 from the atmosphere because for some activities, such as farming, there may not be a way to cut emissions to zero. But there might be no affordable way to remove large enough quantities of CO_2 from the atmosphere to compensate.

"Humanity is making a reckless gamble on overshooting dangerous climate change"

That is also the third big problem with overshoot scenarios. Cooling the planet after reaching net zero requires the removal of massive quantities of CO_2, beyond what is required to simply maintain net zero.

Even if the technology could be developed to do this, governments may baulk at the expense of something that, at least in the short term, will show no benefit. "In most cases the only benefit of carbon dioxide removal is that it removes carbon," says Rogelj. "But otherwise it uses energy, it costs money, it requires investment and long-term planning."

The fourth problem is that even if we do manage to remove enough CO_2 to get temperatures back down again, it is going to take decades, says team member Carl-Friedrich Schleussner at the International Institute for Applied Systems Analysis in Laxenburg, Austria. That means we will still have to adapt to the higher temperatures while they last.

Yet, as the last IPCC report pointed out, even adapting to the changes so far is proving more difficult than expected. "We have an overconfidence in our ability to adapt to [an] overshoot," says Schleussner.

The fifth issue is that getting temperatures back down won't reverse all changes. If more people die in extreme weather events or from starvation after crop failure, there is no bringing them back.

Slow recovery

Nor is it likely that species that go extinct can be brought back, for all the talk of de-extinction. Damaged ecosystems may not be able to recover on human timescales. Plus, higher temperatures, even if eventually reversed, will still lead to higher sea level rise in the following decades and centuries.

The worst-case scenario would be that overshooting triggers a tipping point such as the collapse of the West Antarctic ice sheet or the drying up of the Amazon, which will be impossible to reverse for many millennia.

The work shows there will be irreversible consequences from global warming exceeding 1.5°C, says James Dyke at the University of Exeter, UK. "Humanity is making a reckless gamble on overshooting dangerous climate change."

However, Dyke thinks that by estimating how much CO_2 removal would be required in various scenarios, Rogelj's study implies such feats are feasible.

"To propose we can overshoot 1.5°C or any amount of warming and then lower temperatures with gigatonne-scale carbon removal is to essentially propose a time machine," he says. "Unfortunately, these carbon-removal technologies do not exist at scale and evidence of past attempts do not inspire confidence this will change anytime soon." ▮

SEAN GALLUP/GETTY IMAGES

Carbon emissions have pushed the world to the brink of 1.5°C of warming

Tesla's Cybercab is a hollow promise of a robotaxi future

Elon Musk, CEO of Tesla, has a record of overpromising – and the firm's Cybercab is unlikely to change that, says **Chris Stokel-Walker**

TESLA

AT A glitzy event held at Warner Bros. Studios Burbank in California, Tesla CEO Elon Musk unveiled the Cybercab: a robotic, self-driving taxi. Musk said that the vehicle, which has two seats, no steering wheel and no pedals, would be available before 2027. "I think it's going to be a glorious future," he told the crowd on 10 October.

Meanwhile, just a few kilometres south in Los Angeles, people are already being ferried about by autonomous vehicles operated by Waymo. It seems that the future is already here and Musk is pretending not to notice.

"Tesla play a very good game in which they are always trying to live in the future by prompting journalists to talk about what they will do, not what they are doing," says Jack Stilgoe at University College London. "Elon Musk lives in a world of promises."

Indeed, at the event Musk admitted that Tesla's full self-driving (FSD) autonomous driving system, long promised to owners of existing Tesla cars, wouldn't be able to be used without human supervision until next year.

"Elon Musk has claimed that Tesla will solve FSD 'this year', every year since 2014," says Dan O'Dowd at The Dawn Project, an advocacy group. "Now, he has announced that FSD has been delayed another year until the end of 2025. This date will be delayed again next year, as it has for each of the past 10 years."

One problem is that Tesla has bet on an autonomous system that uses only cameras and visual processing software, eschewing the lidar technology used by rivals to build up a more detailed view of a car's surroundings – an approach that experts have questioned.

2027

The year Elon Musk says Tesla Cybercabs will be available

Beyond that, the unusual design of the Cybercab is likely to raise regulatory eyebrows.

"Regulators around the world are approaching self-driving vehicles with extreme – and understandable – caution," says Paul Miller at Forrester, an analyst firm. "The Cybercab's lack of a steering wheel or pedals make sense in some future autonomous vehicles, but may further complicate the process of reassuring cautious regulators today."

The prototype Tesla Cybercab has no steering wheel or pedals

Cruise, a competing autonomous vehicle company run by General Motors (GM), designed a similar vehicle interior for its robotaxi, Origin, but it was scrapped due to "regulatory uncertainty", GM CEO Mary Barra wrote in a letter to shareholders in July.

Waymo, which is owned by Google parent company Alphabet, has taken a different approach. It uses conventional cars made by Jaguar, modifying them with lidar and other self-driving technologies, to ease approval with regulators. Even then, its fleet of around 700 vehicles can only currently operate in a handful of US locations. Other robotaxi firms are operating in China.

So, with competitors way ahead, what is Musk offering? "The future will look like the future," he said, sharing images of the Cybercab on X, the social media site he owns. But perhaps the choice of location for Tesla's event – a film studio – is revealing. While others are actually building the future, Musk is increasingly drawn to the smoke and mirrors of Hollywood. ▮

Weight-loss drugs may lower your desire to exercise

Grace Wade

SEMAGLUTIDE – the drug in medications like Ozempic and Wegovy – causes mice to exercise less. This hints that these weight-loss medications may reduce people's motivation to work out.

Semaglutide helps to treat type 2 diabetes and obesity by mimicking a hormone called GLP-1, which regulates blood sugar and suppresses appetite. GLP-1 also dampens activity in the brain regions involved in reward processing and cravings. This may explain why people on semaglutide-based medications don't find eating as rewarding as they used to.

Now, Ralph DiLeone at Yale University and his colleagues have treated seven mice with semaglutide and an equal number with a placebo for a week and measured how far the animals ran on an exercise wheel each day.

On average, those treated with semaglutide ran about half the distance of those given a placebo.

The researchers then gave another 15 mice semaglutide and 15 more a placebo for five days and explored their willingness to run on a wheel. This time, the exercise wheel periodically locked up while the animals were on it. To unlock it, the mice had to press a lever with their nose. Each time the wheel locked, it required more presses to unlock it. "Eventually they quit," DiLeone told a Society for Neuroscience meeting in Chicago on 7 October. "We call that their break point, and it gives us a surrogate for how motivated they are to access running wheels."

The maximum number of times mice treated with semaglutide pressed the lever was, on average, 25 per cent less than that of animals in the control group. These findings highlight the potential of semaglutide-based medications to interfere with positive behaviours, not just negative ones. ▮

Environment

Hospital hit by Hurricane Milton gets water from air

James Dinneen

A CHILDREN'S hospital that lost access to water in the wake of Hurricane Milton is now using a device that can collect it directly from the air, in a test of how such atmospheric water harvesting systems could be used to respond to disasters.

"When a hospital has both water and power you're good," says David Stuckenberg at Genesis Systems, the Florida-based firm that designed the apparatus. It uses absorbent materials called metal organic frameworks to concentrate moisture from air pumped through the machine, then releases pure water when the material is heated by about 8°C.

Such atmospheric water harvesting systems attract interest because of their ability to operate independently of other water infrastructure. Some are used in places with poor water infrastructure, others for military operations. An Arizona-based company called Source that makes solar-powered "hydropanels" has even started selling its air water in cans.

The systems have also been used when disasters leave communities without a reliable clean water source. As Hurricane Milton approached Florida's west coast, Jason Weida, the secretary of the Florida Agency for Health Care Administration, saw an opportunity to try this out.

With Hurricane Ian in 2022, Weida saw how water issues and power outages required some hospitals to close for weeks. He learned about Genesis Systems's technology while touring damage from Hurricane Helene,

CHRIS URSO/TAMPA BAY TIMES/ZUMA/ALAMY

Johns Hopkins All Children's Hospital in Florida is producing its own drinking water

which made landfall on 26 September. "I thought, 'Wouldn't this be great for next year's hurricane season?'" he says. "Little did I know that two weeks later we would be preparing for Hurricane Milton."

Ahead of Milton's landfall on 9 October, the system was brought to a staging ground for the state's disaster response. Soon after the hurricane passed, a truck brought it to Johns Hopkins All Children's Hospital in St Petersburg where leaking water mains had interrupted the supply. Weida says the hospital was a priority because of how challenging it would be to evacuate newborns from its neonatal intensive care unit.

On 10 October, workers hooked up the shipping container-sized system to a generator, and it is now producing up to 2000 gallons of drinking water per day while the hospital's regular supply is being restored. Stuckenberg says the system can operate more or less anywhere where humidity is above 10 per cent, although it becomes less efficient as humidity declines. He estimates that the system installed in Florida's humid air uses about 0.8 kilowatt hours of electricity per gallon of water.

Jonathan Boreyko at Virginia Tech says he is sceptical the system can run so efficiently.

Stuckenberg responds that the system's energy requirements are so low because of the way the material they use bonds to water vapour with almost no energy, with most energy used to run fans, pumps and to re-concentrate the absorbent.

Water harvesting systems can be useful in disaster response, says Paul Westerhoff at Arizona State University, and are suited for places with relatively high humidity like Florida. However, he says their reliance on electricity can be an issue. ▮

BRYAN R. SMITH/AFP VIA GETTY IMAGES

Hurricane Milton brought wind, waves and destruction to St Petersburg, Florida

Chemistry

Tiny 'ruler' can gauge distances as small as an atom

Karmela Padavic-Callaghan

THE smallest "ruler" ever is so precise that it can measure the width of a single atom within a protein.

Proteins and other large molecules, or macromolecules, sometimes fold into the wrong shape, and this can affect the way they function. Such changes can play a role in conditions like Alzheimer's disease.

To understand this process, it is crucial to determine the distance between atoms – and clusters of atoms – within macromolecules, says Steffen Sahl at the Max Planck Institute for Multidisciplinary Sciences in Germany.

"We wanted to go from a microscope that maps positions of macromolecules relative to each other, to taking this bold step of going within the macromolecule," he says.

So, Sahl and his colleagues attached two fluorescent molecules to two different points on a larger protein molecule and then used a laser beam to illuminate them.

Based on the light released, they could measure distances between the molecules in several proteins. The smallest distance was just 0.1 nanometres – the width of a typical atom. The fluorescent ruler also gave accurate measurements up to about 12 nanometres.

In one example, the researchers looked at two different forms of the same protein and found that they could distinguish between them because the same two points were 1 nanometre apart for one shape and 4 nanometres apart for the other (*Science*, doi.org/nm7d).

"While it boasts impressive precision, the new method may not necessarily achieve the same level of detail, or resolution, when applied to more complex biological systems," says Kirti Prakash at The Royal Marsden NHS Foundation Trust and Institute of Cancer Research in the UK. ▮

Microbiology

Primitive microbes found living deep inside 2-billion-year-old rock

Chen Ly

MICROORGANISMS have been found living in tiny cracks within a 2-billion-year-old rock in South Africa, making this the oldest known rock to host life. The discovery could offer new insights into the origins of life on Earth and guide the search for life beyond our planet.

We already knew that deep within Earth's crust, far removed from sunlight, oxygen and food sources, billions of resilient microorganisms survive. Living in extreme isolation, these slow-growing microbes divide at a glacial pace, sometimes taking thousands or even millions of years to complete cell division.

"Have you seen rocks from a volcano? Do you think anything can live in those? I certainly didn't"

"So far, the oldest rocks in which microbes have been found are 100-million-year-old seafloor sediments," says Yohey Suzuki at the University of Tokyo. "We know it's possible that microbes can grow using something in these ancient rocks."

Now, Suzuki and his colleagues have pushed that record back by nearly 2 billion years. They obtained a 30-centimetre-long cylindrical rock core from 15 metres below the surface of the Bushveld Igneous Complex in South Africa, a vast area of volcanic rock that formed more than 2 billion years ago. When they sliced open the core, they discovered microbial cells in the rock's tiny fractures.

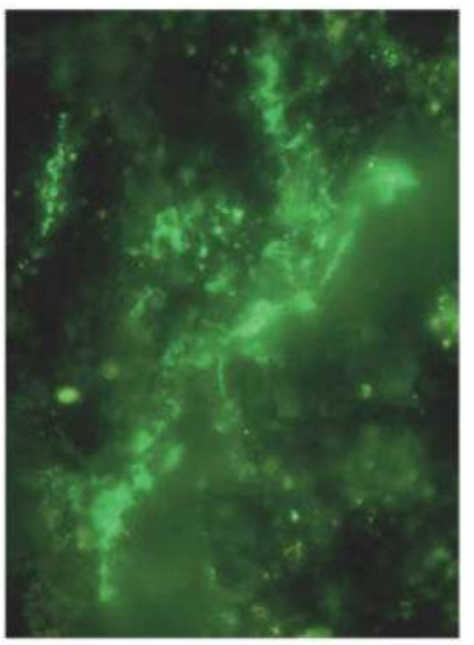
The team stained the microbes' DNA and imaged them with a scanning electron microscope and fluorescent microscopy, then compared them with potential contaminants to confirm they were indigenous to the rock. The researchers found the cell walls of the microbes were still intact – a sign the cells were alive and active (*Microbial Ecology*, doi.org/nmws).

"Have you seen rocks from a volcano? Do you think anything can live in those?" says Suzuki. "I certainly didn't, so I was very excited when we found the microbes."

The team thinks the microorganisms were carried into the rock via water shortly after its formation. Over time, the rock was clogged up by clay, which may have provided nutrients for the microorganisms to live on.

"The microbes in these deep rock formations are very primitive in evolutionary terms," says Suzuki. Understanding them could provide clues about what the earliest forms of life on Earth may have looked like and how life evolved over time.

Cells found in ancient South African rocks, their DNA stained green



Y. SUZUKI, S. J. WEBB, M. KOUDUKA ET AL. 2024/ MICROBIAL ECOLOGY

This discovery may also have implications for the search for life on other planets. "The rocks in the Bushveld Igneous Complex are very similar to Martian rocks, especially in terms of age," says Suzuki. He believes that using the same technique for differentiating contaminant and indigenous microbes on samples from Mars could help detect if there is life persisting in rocks beneath the surface of the Red Planet.

"This study adds to the view that the deep subsurface is an important environment for microbial life," says Manuel Reinhardt at the University of Göttingen, Germany. "But the microorganisms themselves are not 2 billion years old. They colonised the rocks after formation of cracks; the timing still needs to be investigated." ▮

Technology

Hack turns a smartphone into a listening device

HACKERS can eavesdrop on conversations near smartphones by measuring sound vibrations with the handset's motion sensors.

Experiments have previously shown that the gyroscope and accelerometers in smartphones, collectively known as an inertial measurement unit (IMU), can detect sound vibrations in the air and listen in on conversations. This means an app that doesn't have permission to use the microphone could get around this by using the IMU as a makeshift sound sensor.

To combat this, Google limited how often Android apps could sample data from the IMU to just 200 times a second, making it impossible to hear what is going on.

Now, Ahmed Najeeb and his colleagues at Lahore University of Management Sciences, Pakistan, have found a way to circumvent this safeguard on various Android devices. They trick the gyroscope and motion sensor into taking measurements slightly offset in time, thereby upping the real sample rate from 200 to 400 times a second.

This vastly improves the audio you can recover. Najeeb and his colleagues report their method achieves an 83 per cent reduction in word error rate when transcribed by artificial intelligence compared with attacks that rely on 200 samples a second (arXiv, doi.org/nmwr).

The researchers write that the work shows current security features are "inadequate for preventing sophisticated eavesdropping attacks".

"Current security features are inadequate for preventing sophisticated eavesdropping attacks"

Google didn't respond to a request for comment. Apple phones also contain an IMU, but the researchers didn't investigate whether they are susceptible in the same way.

Alan Woodward at the University of Surrey, UK, says the vulnerability should be fixed, but it probably has limited use. "The problem with it as a threat is that you need something [malicious installed] on the phone, so you need to have already compromised the phone in order to get at those instruments," he says. "And if you've done that, then there are probably easier ways to listen in to somebody's phone call." ▮

Matthew Sparkes

Quantum physics

Clever test could reveal whether gravity is subject to quantum weirdness

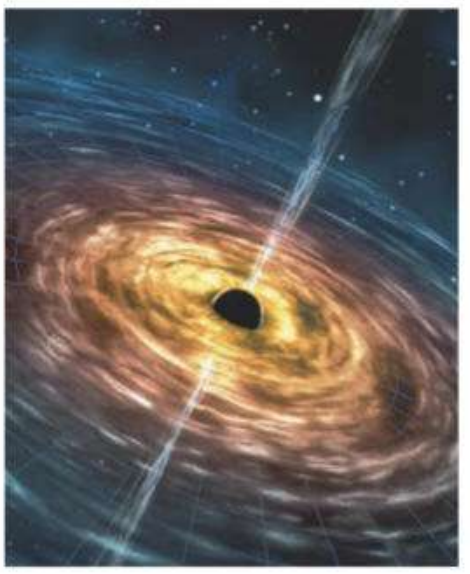
Karmela Padavic-Callaghan

IS THE gravity that we experience quantum at all? A new proposal could show us how to find out by observing whether a quantum object's state is affected when its gravity is measured.

Physicists have competing ideas of what quantum gravity could be like. They have repeatedly shown that tiny objects are subject to quantum effects, but for large objects whose behaviour is highly affected by gravity – with black holes being the most extreme example – the same task has been extremely difficult.

Sougato Bose at University College London (UCL) and his colleagues have now come up with a way to measure if the states of quantum objects change when you measure their gravity.

Although measuring a quantum system can alter experimental results, in classical physics, something can be measured precisely without changing the outcome, says Bose. "It's similar to how cheering on your favourite football team



ANDREA DANTI/ALAMY

Working out how quantum gravity would act in a black hole isn't easy

on TV does not change anything."

In the researchers' proposal, a macroscopic object like a crystal would play the role of the football team, while "cheering" for that object would be measuring its gravitational field. But at the beginning of the experiment, the object would be put through a procedure that left it in a state of quantum superposition.

It could move towards a detector at the end of the experimental apparatus by taking one of two paths. In this special quantum state, it would be impossible to tell which path it actually followed – until it reached the detector. By measuring the crystal's quantum properties, like the spin of some of its atoms, the detector would interact with it in a way that changed its quantum state. The resulting measurement would then reveal which path it took. In other words, the measurement both collapses the superposition of potential paths and tells the observer which one it collapsed into.

In some runs of the experiment, the researchers would add a second detector, for the crystal's gravitational field. Before the crystal reached the quantum path detector, this extra detector would gauge the strength of the gravitational force that the crystal would exert on some other object (*Physical Review Letters*, in press).

If adding this extra detector – cheering on the football team – changes what the final detector says, then gravity isn't impervious to quantum measurement and isn't classical. If the final detector shows the same readings regardless of whether the crystal's gravity was measured, then gravity isn't quantum, says Bose.

"If the detector shows the same readings regardless of a measurement, then gravity isn't quantum"

Many physicists agree that a quantum theory of gravity is essential for understanding our world, but an experiment like this could still eliminate some proposals in which gravity isn't quantum, says Daniel Carney at the Lawrence Berkeley National Laboratory in California.

Team member Debarshi Das, also at UCL, says there are practical challenges but projects that could run the experiment are already under way worldwide. ▮

Neuroscience

Individual brain neurons respond to the smell of bananas

OUR brains contain "banana" neurons that fire when we see or smell the fruit, or even if we just hear the word "banana", hinting at how concepts are encoded within the brain.

We already know that several brain regions – including the piriform cortex, amygdala, hippocampus and entorhinal cortex – are responsible for processing smells, but until now no one had ever explored the role of individual brain cells, or neurons.

To fill this gap, Florian Mormann at the University Hospital Bonn in Germany and his colleagues analysed the brain activity of 17 people with epilepsy, who had already been fitted with up to 12 brain-implant electrodes as part of their treatment.

The researchers asked participants to sniff samples of 15 different odours, including banana, liquorice, anise, orange, garlic and coffee, and recorded their brain activity. They then trained an AI model to link smells to electrical signals from neurons.

Once trained, the AI could identify an odour from previously unseen signals with more than 60 per cent accuracy. The researchers were also able to identify a single neuron in the amygdala that increased firing in response to the image or smell of a banana, or the word "banana". Another neuron in the piriform cortex fired in response to the concept of liquorice expressed as an image, smell or word. Other neurons in the amygdala also seem to respond more strongly to smells that the participants liked, firing more often than for smells they disliked (*Nature*, doi.org/nmtp).

JOSE MANUEL REVUELTA LUNA/ALAMY

Seeing this picture probably made specific neurons in your brain burst into activity

While previous work has shown that we have neurons that encode concepts – sometimes known as "grandmother neurons" or "Jennifer Aniston neurons" – it is impressive to make the same link with smells, says Andreas Schaefer at the Francis Crick Institute in the UK.

"It is one of those rare studies recording individual neurons in humans, which is essential if we want to understand the mechanisms of how our brains work," he says. ▮

Carissa Wong

Health

Toothbrushes are teeming with hundreds of viruses

Carissa Wong

HUNDREDS of viruses that infect bacteria have been found on toothbrushes and showerheads. This isn't something to be worried about, though, because the viruses aren't harmful to humans. Studying them could reveal new ways to kill drug-resistant bacteria.

It is already known that our toothbrushes and showerheads are full of bacteria from our mouths and from water supplies. But we know little about the viruses that also dwell on these surfaces.

To gain a better picture, Erica Hartmann at Northwestern University in Illinois and her colleagues swabbed 92 showerheads and 36 toothbrushes from US bathrooms. By sequencing the DNA from the swabs, the researchers found more than 600 viruses known to infect bacteria, called bacteriophages. Most of the viruses came from the toothbrushes, and many hadn't been described before (*Frontiers in Microbiomes*, doi.org/nmtj).

The researchers didn't test whether the viruses are affecting the thousands of bacteria that they also found, but a bacteriophage tends to do one of two things, says Hartmann. It might hijack the molecular machinery of a bacterium to make copies of itself, and then kill the bacterium as it exits. Or it can integrate into the bacterial genome and change how bacteria behave.

The bacteriophages are probably on any moist surface in the home, such as sinks and inside fridges. "We would absolutely expect them anywhere," says Hartmann.

Engineered bacteriophages can be used to kill bacteria when antibiotics fail, so the discovery of so many new ones could point the way to more treatments, says Dirk Bockmühl at the Rhine-Waal University of Applied Sciences in Germany. ▮

Analysis AI science

Do the Nobel prizes show that AI is the future of science?

Two of the three 2024 science Nobels have been won by people working in AI. What does this mean, asks **Chris Stokel-Walker**

JONATHAN NACKSTRAND/AFP VIA GETTY IMAGES

David Baker, Demis Hassabis and John Jumper shared the 2024 chemistry Nobel

IT IS a common refrain that artificial intelligence is coming for our jobs, and now it seems that it is coming for the Nobel prizes too. Two of the awards this year, for physics and chemistry, have been claimed by people working in the field of AI – much to the chagrin of some researchers in areas more traditionally recognised by these categories. What does the rise of the AI Nobel mean for the future of science?

"These prizes reflect two different ways of reckoning with the relationship between AI and science: as a tool for studying the world and as a worthy pursuit in its own right," says Harry Law at the University of Cambridge. "In other words, they broadly correspond with the 'science of AI' and the 'use of AI in science'."

The 2024 Nobel prize for physics falls into the first category, being awarded to Geoffrey Hinton at the University of Toronto, Canada, often dubbed one of the "godfathers of AI", and John Hopfield at Princeton University. Both were given the award for their work on machine learning – a key tenet behind AI.

Meanwhile, the chemistry Nobel fits better into the second category. It has gone in part to Demis Hassabis and John Jumper, both at Google DeepMind, for their work on the AlphaFold2 AI model. This tool, which can predict the structure of 200 million proteins, is being used by researchers to better understand things like antibiotic resistance.

With AI mania sweeping the world since the release of ChatGPT in 2022, you could argue that the Nobel Foundation has been caught up in the hype. Some researchers wait decades to receive recognition for their work, but AlphaFold2 is just three years old, perhaps making the award premature.

"AI is not an agent, and it's not a moral agent. It is not responsible for what it creates"

"I would have preferred to see if it has had more direct ties to societal-changing protein or drug discoveries," says Mark Riedl at the Georgia Institute of Technology, although he thinks the physics award was an entirely reasonable way to recognise the rapid pace of the field. "AI has had a huge impact on society in the last few years," he says.

It is also worth noting that David Baker at the University of Washington, in Seattle, who received the other part of the chemistry prize, was rewarded for his work designing new proteins, which is unrelated to AI.

But as AI evolves and becomes more capable and powerful, it is likely that AI-powered Nobels could become commonplace. In a statement responding to his win, Hassabis said: "I hope we'll look back on AlphaFold as the first proof point of AI's incredible potential to accelerate scientific discovery."

"We're likely to see more AI-related research winning in the future," says Carissa Véliz at the University of Oxford. Drug discovery and other labour-intensive areas that can be quickly outsourced to AI could be ripe for future prizes, for example.

And with AI companies hoping to develop machines with human-level intelligence, could an AI model itself ever be awarded a Nobel prize? Hassabis, speaking at a press conference following his win, says such talk is "far too premature", but didn't outright say no.

Véliz, however, doesn't think it will happen. "AI, despite the computer science lingo, is not an agent, and in particular, it's not a moral agent," she says. "It is not responsible for what it creates."

Instead of awarding a Nobel prize to an AI, Véliz would like to see more awarded to women. "It should be noted that there have been seven male Nobel laureates [in science this year] and no women," she says. "What does that say about the Nobel prize?" ▮

Health

US ramps up bird flu surveillance

Six more people in the US have tested positive for the H5N1 bird flu virus, highlighting the need for increased vigilance on influenza. **Grace Wade** reports

THE US has increased its influenza surveillance amid an ongoing outbreak of the bird flu virus H5N1 in dairy cattle, in the hope of containing any potential human outbreaks.

Since 2003, roughly 900 people worldwide are reported to have had H5N1, around half of whom died of the infection. In 2021, a highly contagious version of H5N1 broke out in wild and domestic birds, killing tens of millions of them. This March, H5N1 was also found circulating in US dairy cows and has so far infected 299 herds across 14 states. While this version of the virus doesn't appear to transmit between people, just a few mutations could change that.

"All of those things are not good in terms of a virus that has that pandemic potential"

That is why an ongoing outbreak of H5N1 in US dairy cows is alarming people: when the virus infects a cow, it has an opportunity to become better at infecting all mammals. It also puts the virus in close proximity to people. "All of those things are not good in terms of a virus that has that pandemic potential," said Andrew Pekosz at Johns Hopkins University in Maryland during a news conference on 2 October.

This year, 20 people in the US have tested positive for the virus, including six cases in California that the US Centers for Disease Control and Prevention (CDC) has reported so far in October. All of the cases occurred in people who worked with sick cows or birds, except for one case announced in September by Missouri public health officials. The person tested positive for H5N1 when tested for flu after being hospitalised for other underlying health conditions. They didn't report any exposure to animals or raw milk – which can contain the live virus – raising questions about how they contracted it.

In addition, seven people who interacted with the infected person developed flu-like symptoms, but only one was tested for influenza and the result was negative. Public health officials have obtained blood samples from the other six people to test for H5N1 antibodies – which will determine whether they were infected – but the results weren't yet available when *New Scientist* went to press.

As part of the CDC's effort to increase H5N1 surveillance, it extended its seasonal influenza monitoring protocol to the end of the summer and advised healthcare workers to conduct influenza testing on anyone who is hospitalised. The agency also recommended further analysis on influenza samples to catch potential H5N1 cases.

With the country entering flu season, the CDC is also asking labs to sequence enough influenza samples to detect any novel virus circulating. To identify unusual activity, the CDC says it is monitoring between 65,000 and 155,000 flu samples per week.

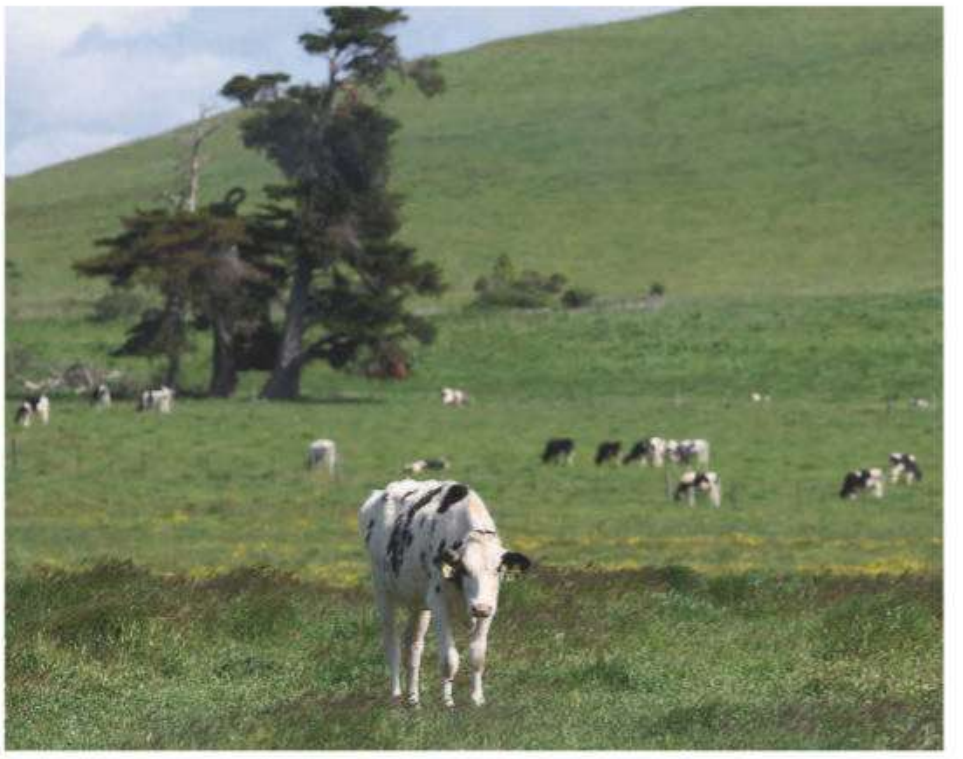
It is also granting contracts to laboratories so they can increase testing capacity in case of an emergency, with some being able to scale to more than 100,000 weekly tests if needed.

Boosting testing capacity should help create a picture of how many cases there are and how the disease is spreading if H5N1 gets more widespread, says Eric Toner at Johns Hopkins University.

In May, the CDC unveiled a new waste-water surveillance system that tracks H5, the influenza subtype that includes H5N1. So far, the system comprises more than 300 sites across the US.

Waste water could reveal areas where H5 is circulating that other surveillance methods miss, says Meghan Davis at Johns Hopkins University. But "if you have small numbers of cases, you may not see the signal as quickly", she says.

To get a clearer picture, the US government should conduct more active surveillance, such as routinely testing people exposed to sick animals, says Davis. While the current risk of H5N1 remains low for most people, Toner worries that could change without extra testing. "My hair is not on fire, but I am concerned," he says. ▮



JUSTIN SULLIVAN/GETTY IMAGES

US dairy cows are tested for bird flu before going to a different state

Duck vaccination slashes bird flu cases in France

Surveillance isn't the only defence against H5N1. France would have had hundreds of outbreaks on poultry farms in the past year had it not vaccinated ducks against the disease. Instead, there were just 10. "Vaccination made a huge difference," says Timothée Vergne at the University of Toulouse in France.

A form of H5N1 has been spreading worldwide in wild birds (see main article), and these can infect poultry on farms and vice versa. Farm outbreaks have resulted in the death or culling of 130 million birds in 67 countries. France, which rears a lot of ducks, had nearly 400 farm outbreaks in the 2022 to 2023 season.

But after vaccinating all farmed ducks in 2023, France had just 10 poultry farm outbreaks in 2023-24. There were also fewer outbreaks in the rest of Europe. Modelling by Vergne and his colleagues indicates there would have been many more outbreaks without vaccination (bioRxiv, doi.org/nmxs). Michael Le Page

Physics

Quantum systems may be able to defy law of entropy

Karmela Padavic-Callaghan

A LOCALISED quantum state may be able to stay intact forever, contrary to the fundamental laws of physics, which insist that no patterns can permanently survive nature's steady course towards disorder, or increased entropy.

Since the 1800s, physicists have agreed that it is nearly impossible for a system of many warm particles to spontaneously assume a state that is more ordered than disordered – the system can't become less scrambled over time. As an analogy, picture a crate of mixed red and green apples. If you leave them on a kitchen counter, they will never spontaneously sort themselves by colour.

The mush of entropy

In fact, the second law of thermodynamics dictates that any ordered system is destined to grow increasingly disordered until it becomes perfectly even and featureless, a process called thermalisation.

That crate of apples, for instance, will eventually rot into a relatively smooth-looking mush, a state that has more entropy than the original solid fruit. In the 1950s, however, Phillip Anderson at Bell Laboratories started to think up scenarios where particles could cheat thermalisation.

Anderson worked in the quantum realm, where particles have wave-like properties and thermalisation turns each into a single, evenly extended wave. He identified conditions under which a single particle wouldn't undergo this elongation process, but rather stay in one place as a very narrow wave that never changes.

Then, in 2016, John Imbrie at the University of Virginia proved that it is similarly theoretically possible for a collection of many quantum particles to assume a quantum state that resists thermalisation forever. This phenomenon is now known as many-body localisation (MBL).

However, Imbrie's proof contained an assumption about the energies of those particles, which has become the basis for debate about the possibility of MBL. Experiments and mathematical studies since have failed to resolve the issue and prove that a system has achieved MBL.

Now, Andrew Lucas at the University of Colorado Boulder and his colleagues have shown that a localised quantum state can stay unchanged.

It is common to study MBL by starting with physics equations for infinitely many interacting particles that are arranged in a line. Instead, the researchers used the mathematical language of graphs. In their set-up, a localised quantum state looks like a graph error that can't be removed.

"If you have a crate of apples, they will never spontaneously sort themselves by colour"

Lucas and his colleagues used mathematics to prove that such states do exist and can remain unchanged indefinitely (*Physical Review Letters*, doi.org/nmtd). In other words, they confirmed the existence of MBL.

"We leveraged results from computer science to come up with a relatively short and understandable proof of the infinite timescale. The good thing about it is that it doesn't rely on any unproven assumptions," says team member Rahul Nandkishore, also at the University of Colorado Boulder. But the proof only works for systems that have infinitely many dimensions, he says.

Nevertheless, Lucas is optimistic that this work can advance our understanding of MBL. "Now you can make assumptions or guesses while having this ironclad thing that you have to make sure you don't contradict," he says.

Cold logic

"This [new] proof sort of came out of left field, but I am very supportive of it," says Imbrie. He says that, while it uses a somewhat unconventional type of MBL, he still sees it as being concordant with his past work.

David Huse at Princeton University says the new proof also requires the system that can achieve MBL to be colder than in past studies, so it isn't a full resolution of the long-standing thermalisation debate.

While infinite dimensions may seem abstract, it is possible that some of these ideas from the proof could be connected to practical applications, such as establishing best practices for making future programs for quantum computers, he says.

The researchers are now hoping to leverage their mathematical success to study more realistic systems. And the stakes for doing so are higher than settling a squabble among physicists – if thermalisation can be broadly defeated, that would shake up the theoretical scaffolding of all thermal and statistical physics, says Nandkishore. ▮

Technology

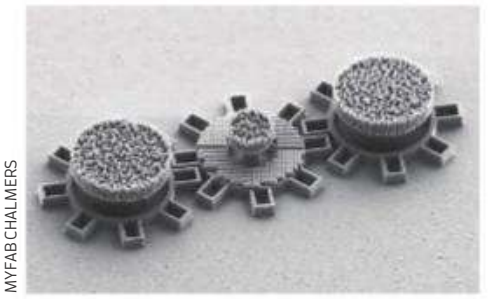
Microscopic gears driven by light can power tiny machines

Alex Wilkins

MINUSCULE gears thinner than a human hair and powered by light could be used to study human cells or power tiny, complex robots.

Gear systems often struggle to work at a size below a tenth of a millimetre, about the thickness of an average piece of paper, because it is difficult to miniaturise the power systems that drive them.

Now, Gan Wang at the University of Gothenburg in Sweden and his colleagues have developed micrometre-scale gears that can be used to build micromachines. "We're providing a platform which can fabricate any kind of machine you can imagine for these kinds of scales," says Wang.



MYFAB CHALMERS

Silicon gears about 10 micrometres wide, seen under a microscope

The gears are carved out of silicon by a beam of electrons using the same lithography techniques behind the creation of computer chips. Once fitted together, they can be driven by a single gear with an attached metasurface, a 2D surface that is engineered to move in response to light. Wang and his team used these gears to construct a micromachine that can translate motion through up to six interlinked gears at once (arXiv, doi.org/nmtc).

Team member Giovanni Volpe, who is also at the University of Gothenburg, says they are exploring how to build machines on the scale of human cells to study how mechanical forces influence tissue growth. ▮

Technology

AIs can cooperate better than humans

People have a limit on how many others they can work with efficiently, but AI models seem able to reach consensus in far bigger groups, finds **Matthew Sparkes**

WE CAN struggle to maintain working relationships when our social group grows too large, but it seems artificial intelligence models may not face the same limitation, hinting that thousands of AIs could work together to solve problems that humans can't.

The idea that there is a fundamental limit on how many people we can interact with dates back to the 1990s, when anthropologist Robin Dunbar noticed a link between the size of a primate's brain and the size of its social group. Extrapolating to humans, he suggested that the number of relationships we can maintain is typically about 150. Now, researchers have applied this idea of Dunbar's number to AI models and found that the most powerful – those with the largest "brains" – can coordinate in groups of up to 1000.

Since speaking to AI models like ChatGPT can feel like talking to a human, Giordano De Marzo at the University of Konstanz, Germany, and his colleagues wondered whether these models also act like humans when "talking" to each other in groups. To investigate, they ran many copies of the same AI model at once, assigning each a random opinion on a binary problem with no obvious answer, such as which side of the road a brand new country should drive on.

At each step of the experiment, they chose one copy at random and told it what opinion all the other models held and why, then asked if it would like to update its own. The researchers say that this is analogous to humans attempting to reach consensus in loose, disorganised social groups.

Humans can perform amazing feats together, but reaching consensus is harder

In a test with 50 copies of Claude 3 Opus or GPT-4 Turbo, two high-end AI models, the team found that the group reached consensus every time. Yet copies of smaller and less powerful models like Claude 3 Haiku and GPT-3.5 Turbo never reached consensus. The results show that although the models in each test were identical, there was no inherent mechanism to converge on agreement, at least until they became sufficiently capable.

150

people is typically the limit to how many relationships we can have

1000

copies of an AI managed to reach a consensus together

The researchers then tried to find an upper limit on each model's ability to reach consensus – their own version of Dunbar's number. For some models, at a certain size of group, the time taken to reach consensus started to grow exponentially, with Llama 3 70b ending up with a Dunbar's number of 50. But for other models, like GPT-4 Turbo, this ability never slowed down even once 1000 copies were cooperating. The researchers' ability to run larger and larger experiments ran out before the AI model stopped reaching agreement (arXiv, doi.org/nms7).

"I was very surprised," says De Marzo. "We [were able to] simulate up to thousands of agents and there was no sign at all of a breaking of the ability to form a community."

He says memory is key. While we may struggle to recall facts, faces and opinions at a certain point, AI is limited only by its hardware. "If you're in an assembly of 10,000 people, it doesn't work, because you cannot really let everybody talk, can't remember all the things that people said," says De Marzo.

Dunbar, who is currently working with Google to assess AI's ability to reason about mental and emotional states, believes that as models grow more powerful, they will improve these so-called mentalising abilities, which are key to cooperation in humans.

"Scientific breakthroughs require the ability to engage with other people and come up with new ideas as a result of trying to find consensus between different groups of people with different views," says Dunbar, and De Marzo's work shows that AI models may be able to do this at scale. "It certainly looks promising that they could get together a group of different opinions and come to a consensus much faster than we could do, and with a bigger group of opinions," he says.

Philip Feldman at the University of Maryland, Baltimore County, says AI models with a high Dunbar number may be able to reach consensus on a problem, but that doesn't necessarily mean they will find a good solution. He believes diversity is key to problem-solving, which is hard in groups made up of the same AI model.

"The way that living organisms have solved this for as long as there have been living organisms is you have populations that differ in the way that they approach exploration," says Feldman. If everybody coordinates quickly, it is because they aren't expressing different views, so it isn't a general solution to wide-ranging problems, he says.

A larger issue is whether it even makes sense to talk about copies of an AI model as a group of individuals, says Michael Rovatsos at the University of Edinburgh, UK. The models don't understand what they are, how they are separate from other models or what the experiment's purpose is, he says. "Presence of others isn't treated any differently from saying 'give me a pizza recipe'," he says.

DAVID RAMOS/GETTY IMAGES

Ageing

Life expectancy growth is slowing and few people will live to 100

Carissa Wong

WILL you live to 100? For the average person, the answer is probably no, because growth in life expectancy is slowing across higher-income countries, despite advances in healthcare and living conditions. This suggests there may be a biological limit to how old we can get.

The current slowdown is a marked contrast to the trend in the 20th century, when average life expectancy at birth grew in wealthier regions by three years per decade. While people born in the mid-1800s could expect to live 20 to 50 years, by the 1990s, it had reached the 50s to 70s.

Some people began to predict that newborns in the 21st century would regularly live beyond 100, but now that seems too optimistic.

S. Jay Olshansky at the University of Illinois in Chicago and his colleagues have analysed mortality data from the 1990s to 2019 across nine wealthy countries, including the US, Australia and South Korea, and also Hong Kong. The 2019 cutoff was intended to avoid influence on the data from the covid-19 pandemic. The team found that average life expectancy at birth rose by 6.5 years across the study period, on average. In the US, it reached 78.8 in 2019, while in Hong Kong it was 85.

But the rate of increase slowed in most countries between 2010 and 2019, compared with the previous two decades. The US fared the worst, perhaps because of the ongoing opioid crisis, says Olshansky. Hong Kong was the only place to see a rise in the rate of life expectancy gains since 2010, but why is unclear, he says. It could be because people there were gaining better access to healthcare compared with elsewhere, he says.

A large number of people in wealthier nations enjoy long lives

ANTON HAVELAAR/ALAMY

Based on the trends, the team says average life expectancy at birth may never exceed 84 for men and 90 for women. The group also calculates that just a minority of newborns today will live to 100 (*Nature Aging*, doi.org/nms6).

The slowdown could be because the big advances in improving our environment and healthcare were already achieved in the 1900s and humans are reaching a biological limit to ageing, says Olshansky.

Jan Vijg at the Albert Einstein College of Medicine, New York, thinks similarly. "There's some sort of biological limit that keeps us from getting any older," he says.

But Gerry McCartney at the University of Glasgow, UK, says the slowing growth may largely be down to policies in many of the countries analysed, which have led to cuts in social benefits and healthcare services and have driven up poverty. With different policies, life expectancy could keep rising, he says.

Michael Rose at the University of California, Irvine, thinks there is no limit to how long humans can live. With investment in anti-ageing research, we could see radical life extension again this century, at least in wealthier countries, he says.

Even with the recent slowdown, Olshansky says it is positive that life expectancy is still increasing. "We should, of course, celebrate the fact that we can live this long," he says. ▮

Psychology

Hot sauce reveals how expectation can shape our pain

ANTICIPATING pleasure or pain before tasting hot sauce appears to influence how the brain responds to the spicy flavour.

"This has broader implications beyond spicy food," says Yi Luo at East China Normal University. "Understanding how positive and negative expectations influence perception can inform approaches in medicine, such as enhancing placebo effects in treatments."

Luo and her colleagues recruited 47 volunteers – roughly half liked spicy foods and half didn't – to receive squirts of both low-intensity and high-intensity hot sauce in their mouths while lying inside an fMRI brain scanner.

Computer-controlled syringe pumps outside the main room delivered liquefied versions of mild and hot salsa, along with cleansing sips of water, through tubes into participants' mouths.

The researchers conducted one round of experiments without setting expectations. But in the second run, they signalled how hot a sauce people would get using different-coloured chilli pepper shapes. An image of two red peppers, for example, signalled the hottest sauce.

The brain scans showed that, for heat haters, the negative expectation of receiving a spicy sample amplified activity in brain regions that process pain, including the somatosensory cortex, thalamus, insula and amygdala.

"Understanding how expectations influence perception can inform approaches in medicine"

This provides a "critical warning" for how medical patients' negative expectations could intensify pain, says Luana Colloca at the University of Maryland.

By comparison, for hot sauce lovers, the positive expectation of receiving a spicy treat boosted a pleasure signature in the brain – but only for the mild sauce (*PLoS Biology*, doi.org/nms5).

Such disjunction represents "parallel subjective realities" in people's brains, says team member Kenneth Kishida at Wake Forest University in North Carolina. ▮

Jeremy Hsu

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Getting the facts right

There is a dirty secret in publishing: most popular science books aren't fact-checked. Readers deserve better, says **Michael Marshall**

NON-FICTION publishing is failing its readers. It is pumping out books with supposedly game-changing ideas, without bothering to ensure basic accuracy. These tomes have the appearance of academic work, but none of the rigour.

My frustration about this has been building for years and finally exploded when I reviewed Yuval Noah Harari's new book *Nexus*, which is full of ill-supported nonsense, including a hopelessly incoherent definition of the concept of information.

Consider Johann Hari: formerly a journalist at *The Independent*, he was caught plagiarising and resigned. He has since produced a string of unreliable books about medical controversies. *Lost Connections* is about the science of depression and is filled with dubious statistics, which he uses to falsely claim antidepressants don't work in the long term. *Stolen Focus* argues that technologies like smartphones are making it harder to concentrate, even though there are no long-term studies showing changes in attention spans.

Books by academics are similarly shonky. Steven Pinker's *Enlightenment Now* had "serious flaws", according to *New Scientist*'s reviewer, and was eviscerated by historians of the Enlightenment for misrepresenting the ideas of its key thinkers. Jonathan Haidt's *The Anxious Generation* claims smartphones and social media are causing an epidemic of poor mental health in children, despite meta-analyses saying the evidence for harms is weak.

ADRIÀ VOLTÀ

There is an obvious but wrong explanation for these bad books, which is that the authors are writing outside their expertise. Harari is a medieval historian. Pinker mostly studies the psychology of language; Haidt, the emotional roots of morality. You might argue they are engaged in epistemic trespassing. However, it would be ridiculous to say people should only write about topics they have personally researched as academics. On that basis, I could only write about epilepsy.

Besides, many books by subject experts are riddled with errors. Matthew Walker is an eminent sleep scientist, yet independent researcher Alexey Guzey found a laundry list of errors in just the first chapter of his book *Why We Sleep*, notably a false claim that the World Health Organization had "declared a sleep loss epidemic".

And then there is Naomi Wolf, whose 2019 book *Outrages* was pulped by its US publisher after the most toe-curling radio interview in recent memory. Wolf claimed that gay men in England were frequently executed in the 1800s – only to be told she had misread court documents and no such executions had occurred. The book was based on Wolf's PhD.

No, the problem is much simpler, and it is a dirty secret of non-fiction publishing: most books aren't fact-checked. If an author makes a mistake or misinterprets a study, nobody stops them.

In journalism, fact-checking practices vary widely. *New Scientist* has two layers of editors, who each ensure readability and accuracy. Others are even stricter: fact-checkers at *The New Yorker* re-report entire stories. Non-fiction publishing is far more relaxed. Often, there is no fact-checking at all: editors offer guidance on readability, but take factual claims on trust. The UK publishers of my book *The Genesis Quest* did this (though my US publishers, a university press, recruited anonymous peer reviewers).

It is easy to see why this has happened. Nuance is difficult to sell. If your book has a counterintuitive thesis, or simply promotes a moral panic, it is easier to market. Non-fiction authors who are rigorous and careful can't compete. That's why shops are flooded with books about one neat trick for a better life or how everything you know is wrong. But without fact-checking, these books might as well be scrawled in crayon. Publishers must do better. ▮

Michael Marshall is a science journalist and author of *The Genesis Quest*

Field notes from space-time

Nearing the event horizon

What does it mean to "look" at a black hole? General relativity teaches us that it is all a question of perspective – and technique, 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'm currently enjoying Danzy Senna's smart new novel Colored Television.

What I'm watching
It's Halloween season, so I'm rewatching the entire Scream *film series.*

What I'm working on
I'm hiring a new postdoctoral researcher to work on some dark matter calculations with me.

This column appears monthly. Up next week: Graham Lawton

GENERAL relativity teaches us that reality is, in some sense, a matter of perspective. Consider how someone who is "falling" into a black hole sees something completely different to an observer trying to watch that someone cross the event horizon, a black hole's edge.

The person actually making the transition beyond this point of no return won't see anything unusual, although they will notice gravity is getting stronger and stronger. By contrast, the observer will find that no matter how long they watch, the person never seems to actually cross the event horizon.

The reason this disparity is possible is because in the general relativistic picture, space and time aren't separate. Gravity shapes them both by causing the unified entity of space-time to curve. Time flows differently for observers where there is more gravity than for observers where there is less.

Space-time curves most strongly around a black hole and will be less curved further away from it. This means that, if we only take gravitational effects into account, time will be measured as flowing more slowly far away from a black hole than close to it. This effect is known as gravitational time dilation.

If two observers – one on the precipice of crossing the event horizon and one close enough to be watching – can have such different perspectives due to gravitational time dilation, what does this imply for a distant observer, like us here on Earth?

Using the Event Horizon Telescope (EHT), we have, for the first time, observed the event horizon of Sagittarius A*, the supermassive black hole at the centre of the Milky Way, in the radio part of the electromagnetic spectrum. We have also made some exciting observations of other black holes. Over the past decade, the LIGO and Virgo gravitational wave collaborations have used ripples in space-time caused by black hole collisions to test general relativity. (The theory has brilliantly passed all tests, in case you were wondering.)

But how can we look at these black holes and their collisions if what an outside observer sees at the event horizon is stuff that appears close to falling in but never actually does? As an astute *New Scientist* reader wrote to me

"For the first time, we have observed the event horizon of our local supermassive black hole, Sagittarius A*"

to ask: how can we "see" the black holes moving? The answer requires us to think carefully about this issue of observations as a matter of perspective – and technique.

First, let's state the obvious: we can't see light that has already gone beyond the event horizon, by definition. That means that when we are looking at or near an event horizon, we are looking for light signals that were sent out by the source before it went into the black hole. In the case of the EHT, what we actually observe is light that is arriving to us due to space-time bending so much that it behaves like a funhouse mirror.

This phenomenon is known as gravitational lensing, and it occurs when space-time curves strongly enough to distort light signals before they reach the observer. One common example is when we see the same galaxy twice in an image from a telescope. This happens not because a galaxy has a twin, but because a massive galaxy cluster sits in the space-time between the observed galaxy and our telescope, curving space-time and causing weird optical effects.

A black hole can create a similar effect, distorting space-time the way a galaxy cluster might. Black holes are so gravitationally impactful that they not only draw matter into their orbits, but the light radiated from that matter follows a very curved trajectory when it is travelling away from the black hole.

Simulations show that the gravitational lensing signature caused by a black hole event horizon is distinct from lensing signatures from other physical environments, such as massive galaxy clusters. So when scientists use the EHT to look for the event horizons of distant black holes, what they are actually doing is looking for a gravitational lensing effect that produces what they call a "black hole shadow".

Does this undercut the idea that we have seen the event horizon? No. We just have to shift our understanding of what it means to "look" at a black hole.

We can think similarly about the black hole pairs orbiting each other observed with gravitational waves. In that case, we aren't looking at light at all. Instead, we are looking for ripples in space-time itself. The motion of the black holes as they gravitationally interact with each other causes the shape of space-time to change, creating the ripples. Here on Earth, we have special detectors, like LIGO and Virgo, designed to vibrate due to these ripples. Again, looking is a matter of perspective – on what it means to look at objects that are literally made of space-time. ▮

‘Brightling’

Despite its 10.95mm height, the Trident C60 Pro 300 ‘Lumiére’ leaps from your wrist. (Just like it jumped off this page.) Its brightness results from proudly protruding indices and the logo they encircle. Featuring facets finely machined to tolerances of 0.03mm, these mini-monoliths are super-legible in daylight. But it’s the Globolight®, the unique luminous ceramic from which they’re hewn, that produces their astounding, super-brilliance at night. And inspired this timepiece’s name. The light show doesn’t end there. Carved from titanium, the 41mm case incorporates a second sapphire crystal displaying its super-accurate movement. But it’s not the back of this beautiful tool watch you’re buying into. Is it?

Do your research

Christopher Ward

christopherward.com

Thinking big

Photography AlistairVeryard.com
New Scientist Live

THERE were big beasts, big crowds and big ideas at New Scientist Live, an awe-inspiring three-day festival of innovations and discoveries in London last weekend. Visitors young and old enjoyed a huge range of exhibits from leading research groups and companies working in STEM, including King's College London's hospital of the future and a pop-up planetarium.

Thousands of attendees were treated to close encounters with insects, robots and even a fighter jet, not to mention fearsome dinosaurs stalking the show floor. Thanks to virtual reality, there was also the chance to step inside a nuclear reactor, drive a racing car and ride a rollercoaster.

On five stages, there were enlightening talks covering a vast range of subjects, from the birth of the universe to the power of artificial intelligence. The speakers included Nobel prizewinner Venki Ramakrishnan on why we die, TV anthropologist Alice Roberts on ancient epidemics, psychologist Kimberley Wilson on eating for better brain health and statistician David Spiegelhalter on how chance rules our lives.

At the schools' day on 14 October, palaeontologist Mike Benton delved into dinosaur behaviour, biologist Camilla Pang explained how to think like a scientist and psychologist Dean Burnett told students why their parents are hung up on their phones.

In the Future of Food and Agriculture area, visitors learned how science is changing the way we feed ourselves, with cutting-edge techniques for improving soil health, tackling methane emissions from cows and discovering new crop varieties.

Festival-goers even had the chance to come up with their own innovations to protect wildlife and build them from LEGO bricks. Master builders constructed the best ideas submitted to our "save the gibbons" competition, including a fruit-dispensing "social hub" and a solar-powered "skyspeaker".

The festival will be back next year from 18 to 20 October – we hope you can join us for more mind-expanding experiences.

Sam Wong

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2


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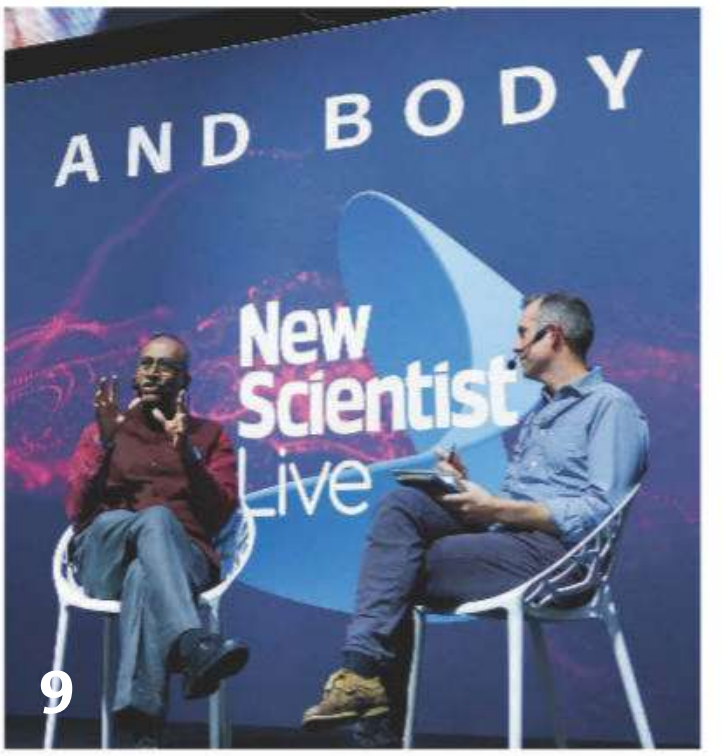
4

1. A friendly face from the Rent a Dinosaur stand welcomes visitors to the show
2. Astrophysicist Jo Dunkley on our quest to understand the big bang
3. A packed audience for the Future Stage
4. Exploring how the brain works at the Medical Research Council stand ›

5

6

7



5. Anthropologist Alice Roberts explores life and death in the Middle Ages
6. Up close with a Red Arrows Hawk aeroplane at the Royal Air Force stand
7. Young visitors share their ideas to protect bees from climate change at the LEGO stand
8. Getting the lowdown on insects at the Royal Entomological Society's stand
9. Nobel prizewinning molecular biologist Venki Ramakrishnan (left) is interviewed by doctor and presenter Chris van Tulleken about why we die
10. Trying out driving skills on the Formula E simulator at the Envision Racing stand
11. Psychologist Kimberley Wilson explains how to eat for better brain health
12. Meeting Middlesex University's selfie robot Baxter

Manifestation on the brain

A neurosurgeon and a neuroscientist separate the "woo" from the work of manifesting in two fascinating new books, finds **Kayt Sukel**

Book
Mind Magic
James Doty
Yellow Kite (UK); Avery (US)

The Neuroscience of Manifesting
Sabina Brennan
Orion Spring (ebook and audio)

DAVID HORNBACK/MILLENNIUM IMAGES

If you manifest it hard enough, might you find yourself here?

EARLIER this year, my daughter moved into college for her first year of university. Amid the boxes lining the hallways, I noticed a bulletin board covered in photos of scrub-clad physicians and inspirational quotes. When I stopped to take a closer look, the mother of the student it belonged to came out to say hello.

"I told my daughter to put her vision board where she can see it every time she sits down to study," she told me. "She has a long road ahead of her if she wants to be a paediatrician. She needs to start manifesting now if she's going to make it happen."

Ever since Rhonda Byrne's bestselling self-help book *The Secret* came out nearly 20 years ago, manifestation, or the idea that you can transform desire into reality by thought alone, has gone mainstream. While many have deemed it nothing more than new-age nonsense, two brain experts – James Doty, a neurosurgeon and founder of the Center for Compassion and Altruism Research and Education at Stanford University, California, and Sabina Brennan, a neuroscientist and psychologist at Trinity College Dublin, Ireland – have written books exploring how to use the brain's own design to help guide your thoughts and perceptions to better achieve your goals.

In *Mind Magic: The neuroscience of manifestation and how it changes everything*, Doty kicks off with what he calls the "real" secret: "The universe does not give a fuck about you." This sets the tone for the book, letting readers know that the following chapters won't offer any advice on how to make the universe bend to our will. Instead, Doty offers a unique primer – and a six-week plan – to help us learn how to adjust our thoughts to better activate parts of the brain to cultivate "a fierce belief in possibility". In doing so, he argues, we can become more resilient, open and intentional.

Doty offers a step-by-step approach to demonstrate that manifesting isn't magic, per se, but a way of clarifying what you truly want, embedding your intention in your subconscious and then releasing your expectations to allow that intention to take root. Along the way, he explains why introducing positive, goal-directed thoughts can help rewire important brain networks to help us pay better attention to the opportunities that will help us realise our potential.

"Doty demonstrates that manifesting isn't magic per se, but a way of clarifying what you truly want"

While a good bit of Doty's six-week plan reads like a meditation guide, complete with instructions to scan your body and let go of unnecessary attachments, he takes the time to explain why manifesting is really about focus. By directing your attention (as well as your time) to what you want, you can get into the right mindset to achieve the things you want most in life.

While Brennan doesn't offer exercises to become a better manifester, she covers much of the same territory as Doty in *The Neuroscience of Manifesting: The magical science of getting the life you want*. Author of two other practical neuroscience books, she has said in interviews that she is inspired to use neuroscience to help people better understand themselves and what they are capable of – and she takes a similar approach in this tome.

Many of us have that one friend who credits manifestation for their success in finding the right job, partner or situation. And Brennan thoughtfully separates the "woo" from the work, providing readers with evidence-based knowledge about how changing your thoughts can alter your behaviour.

She reminds us that our brains are primed to notice the negative by default. After all, by paying greater attention to bad things, our brains can help us avoid danger. But a switch to more positive, intentional thoughts can alter how we perceive the world, as well as filter out the extra noise that so often gets in the way of us achieving our ambitions.

Brennan carefully unpacks the seven Cs of manifesting – curiosity, compassion, connection, change, clarity, coherence and creation. As she does so, she weaves together research on sensory perception, cognitive behavioural therapy, flow states, working memory, visualisation and performance, optimistic dispositions and more to reveal why actively setting an intention can be more than just wishful thinking.

Take the paediatrician vision board my daughter's neighbour created. Brennan devotes a small section of her book to explaining why popular manifestation tools like this can be useful – including the neuroscientific support for them. While this student's collage may not be telling the universe she is MD material, it is reminding her of her goal every time she looks at it. That stimulates the reticular activation system, a brain network involved in focus and attention, to help her identify new opportunities that may help her. It can also encourage activities, like studying or reaching out to the organic chemistry professor, that will help her move step by step towards a white coat.

Both Doty and Brennan's books do a good job of looking behind the curtain when it comes to manifestation, especially in terms of debunking how it is often marketed to the general public. Most importantly, though, they both take the time to remind readers that the real magic of achieving our goals lies within. Our brains can do quite audacious things when we cultivate the right intention and then follow through with changes to our thought patterns and behaviours. ▮

Kayt Sukel is a science journalist based in Texas

A graphic take

Frenetic and funny, this book is a whistlestop tour of the climate crisis, says **Madeleine Cuff**

Book

World Without End

Jean-Marc Jancovici and Christophe Blain

Particular Books (UK, out 24 October); Zando (US, out 11 March 2025)

EVER wondered what your toothpaste has to do with the fossil fuel boom? Or how many Tour de France cyclists it would take to power a vacuum cleaner?

These might seem like flippant questions to ask in a book about global warming. But *World Without End* is no ordinary climate science book. Instead of pages of dense text and graphs, it is a graphic novel, the story of the world's energy challenge told through an extended comic book strip. I said it wasn't conventional.

The book is the brainchild of engineer Jean-Marc Jancovici and artist Christophe Blain, both of whom appear in the book as characters engaged in a Socratic dialogue. Jancovici, a climate expert, guides Blain – the curious, often despairing everyman – through the history of fossil fuels, the basics of economics, the science of nuclear power and more. First published in France in 2021 as *Le Monde sans fin*, it became a surprise bestseller with its sideways take on the biggest crisis of our times.

A guiding theme of the book is that fossil fuels have ushered in a world of energy abundance that made lavish Western consumption patterns an inevitability. There are plenty of neat conceits to help the everyday reader understand complex topics. To illustrate how energy-dense hydrocarbons are, for example, the book converts the energy consumed by fossil fuel-powered machines into "days of slavery". A transatlantic flight has an energy demand equivalent to 5000 days of slavery. A year's worth of car travel? 70,000.

Yet the format does, at times, struggle with the weight of information it conveys. No sooner have you wrapped your head around the competing theories of 18th-century economists than you are getting a one-page explainer on atomic energy. Thankfully, Blain's frenetic art pulls the book back from didacticism. His illustrations are the beating heart of the book, flipping between irreverent humour and stark snapshots of a world creaking under the pressure of our consumption.

I am not sure *World Without End*'s prescription for change (in brief, more nuclear power, less economic growth) will please everyone. But when it comes to understanding the crisis we face, boy, is this a powerful book of cartoons. ▮

Energetic illustrations flip between humour and a stark look at our warming world

JEAN-MARC JANCOVICI AND CHRISTOPHE BLAIN

New Scientist *recommends*

Catherine de Lange
Editor
London, UK

I have to confess, I struggle to watch science documentaries these days – I prefer a bit of escapism from work. But one series I will definitely be tuning in to is the BBC's **Solar System**, presented by Brian Cox (pictured).

I didn't watch Cox's first series on this topic, made 15 years ago, but this latest is well timed. There are currently around 40 probes out there exploring our planetary neighbours, sending back incredible new insights.

I got to watch one episode, *Volcano Worlds*, at a screening at London's Science Museum. Cox kept his feet on the ground as he visited terrains analogous to those of other volcanic worlds, including Saturn's moon Enceladus, with its icy crust and glacial eruptions, and Jupiter's moon Io, bubbling over with sulphurous plumes.

The stunning visual effects painted a picture of these alien worlds. I had read about many of these discoveries for work, of course, but seeing them come to life on the screen gave me goosebumps. Sheer escapism after all.

NICK GAVEN/BBC STUDIOS

Feeling alienated

An understated sci-fi drama traverses themes of immigration and identity as a man discovers his father may be from outer space, says **Miriam Balanescu**

Film

Sky Peals

Moin Hussain

A BFI Player subscription streaming exclusive until 21 October, when it will be on Amazon and iTunes

LISA STONEHOUSE/ESCAPE FILMS

Umer (Faraz Ayub) wonders if he is not of this world

IN FILM and TV, aliens have come in all shapes and sizes. Among them are the seven-limbed floating heptapods of Denis Villeneuve's *Arrival* and, much less ethereal, Adam Sandler's talking arachnoid companion in *Spaceman*. Thanks to the *Alien* franchise alone, onscreen extraterrestrials gained an additional two dozen guises.

It is slightly more unusual for them to assume human form, as is the case in Moin Hussain's debut feature film *Sky Peals*, now released digitally after having screened at the Venice and London film festivals last year to critical acclaim. But any unearthly activity in this understated sci-fi is mostly metaphorical: Hussain, probing themes of mixed-race identity and second-generation immigrants, points to a much broader definition of the word "alien".

The film's marriage of this subject matter and its sci-fi elements makes it unusual, though it shares some of the gritty naturalism and brooding, portentous spirit of Jonathan Glazer's *Under the Skin* – as well as having an alien disguised as an earthling in common. Like Glazer's film, *Sky Peals* has a crackling, cosmically static, pent-up quality that signals the interference of extraterrestrials with our planet.

At the eerily deserted Sky Peals Green service station somewhere in the UK, Umer (Faraz Ayub) works night shifts flipping burgers for straggling travellers. His mother Donna (Claire Rushbrook), who calls him by the more Westernised name Adam, is in the process of relocating to her partner's abode in Hertfordshire. This leaves Umer alone at home, with just a few stray boxes of packed belongings for company.

In the dead of night, he begins to receive out-of-the-blue phone calls from his long-estranged Pakistani father Bilal (Bhasker Patel) – a man always on the move – but he lets them ring through to the answering machine and Bilal's stiltedly polite, cryptic messages sound out into the darkness.

> **"The alien ploy is a clever vehicle through which to unpick the feeling of being torn between identities"**

Whatever comfort Umer clings to in his humdrum routine is thrown into uncertainty when he learns that Bilal has been discovered dead in mysterious circumstances. Uncle Hamid (Simon Nagra), Bilal's brother, arrives on the scene, ready to take care of funeral arrangements and ensure Umer is handed down his father's meagre set of possessions: the car and clothes in which he was found. Revealing that Bilal wasn't his biological brother, but simply showed up in his family's village one day, Hamid is also able to divulge his suspicions – that Bilal wasn't one of them; that he was from outer space.

Reeling from this revelation, Umer starts to wonder whether he too is in the "wrong place". The alien ploy is a clever vehicle through which to unpick much more grounded sentiments on being torn between two different identities.

The fact that further along the line Umer becomes plagued with blackouts and apparently abnormal powers – specifically, an ability to trigger car alarms – feels a tad inconsequential when set against this dense thematic terrain. Plot is less important here than omens and atmosphere, and Hussain makes full use of the symbolic heft of the service station and the surrounding motorways as a location in limbo.

Some of that energy could have been better channelled into rounding out the characters, who can feel flat. This is especially true of Umer's new colleague at the fast-food joint, Tara (Natalie Gavin), who, for reasons unexplained, sets about trying to tease out his fun side. In terms of dialogue, even Umer – albeit an ill-at-ease outsider – is rarely allowed to venture beyond a few monosyllables.

But in its own way, the strange stuntedness of the social interactions contributes to the odd, otherworldly feel of *Sky Peals,* populated by characters seeming to sleepwalk listlessly through existence.

Part sci-fi, part family drama, part coming-of-age tale, whether Umer really is an alien or not is ultimately irrelevant: Hussain's film occupies its own distinctive universe. ▮

Miriam Balanescu is a writer and critic based in Cambridge, UK

Editor's pick

The many facets of common sense

28 September, p 36

From Alwyn Eades, Bethlehem, Pennsylvania, US

When it comes to common sense, it is worth noting that politicians and other public figures often use the phrase in a fairly specific way. In their usage, "it's just common sense" generally means, "I hope you will agree with me although I have no evidence to support my claim and experts in the field say the opposite". For example, it is just common sense that the more guns you have at home, the safer you are.

From Jon Hinwood, Melbourne, Australia

Your piece on "common sense" focuses on what is common, but the primary quantity is sense. Focusing on sense instead explains most of the conflicts reported, since what each person considers sensible depends on circumstance, experience and the level of risk that they accept. Professional associations recognise the roles of each of these factors in their regulations for membership and professional practice.

From Sam Edge, Ringwood, Hampshire, UK

The conclusion appears to be that it would be common sense to agree there is no such thing as common sense. Very Douglas Adams.

We say there is no brain microbiome

28 September, p 32

From Mark Pallen and Aimee Parker at the Quadram Institute in Norwich, Nick Loman at the University of Birmingham, and Alan Walker at the University of Aberdeen, all in the UK

There is no "brain microbiome" in the sense of a resident microbial community present in the brains of healthy individuals. Instead, microbes enter such sterile tissues through the process of infection. While the role of infections such as Lyme disease in eliciting neurological symptoms may be under-recognised, this is distinct from the idea of a resident microbial community in the brain. Claims of up to 100,000 microbial species per sample in the brain are implausible. Contamination remains the most likely explanation for such findings.

Growing your own is still a net gain

21 September, p 44

From Bob Stock, Galashiels, Scottish Borders, UK

James Wong was spot on regarding the poor economics of growing your own produce. But it is important to also consider other, non-economic, factors. These include convenience and flavour – closely linked to freshness. But perhaps most important is the availability of what you want.

More reasons why our cities are getting wetter

21 September, p 15

From Blaise Bullimore, Haverfordwest, Pembrokeshire, UK

There are further factors that could affect city atmospheres and feasibly increase rainfall in urban areas: water vapour released by burning fossil fuels and the use of evaporative cooling.

Multi-megawatt quantities of heat and plumes of saturated air are probably being emitted into ambient air around the clock via cooling towers or evaporative refrigeration condensers. Large air conditioning systems, refrigeration-dependent factories, chilled and frozen bulk cold stores and large data processing sites all contribute.

Maybe we need to rip up the physics dictionary

21 September, p 32

From Alan Giles, Bournemouth, Dorset, UK

Matt Strassler is right regarding words used in physics that can mislead. Changing them might go a long way to clarifying things.

For example, instead of using a word like "particle", give it a new name – "omet" – and then list the characteristics of omets. They are atomic or subatomic in size (although may become larger); they are three-dimensional; they are flexible and stretchable; they vibrate; they spin; they may have an electric charge. When knocked out from its position, an omet can flow through and around other things, such as slits in a grid. It can separate from and merge with others, both bigger and smaller. They can, at times, surround the nucleus of an atom or even be part of the nucleus of an atom.

If you need a picture in your mind to make this work, then think of an omet as a tiny vibrating, spinning smoke ball.

Perhaps solar power could help keep the ISS in space

Letters, 28 September

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

The ideas suggested for keeping the International Space Station aloft aren't realistic, as they would require a lot of fuel and rockets. What might be possible is to set the ISS rotating in a way that when it is moving away from the sun (experiencing "sunset"), its solar panels would be facing the sun, and some 50 minutes later when it is moving towards the sun (experiencing "sunrise"), the panels would be edgewise to the sunlight. This would tend to increase its orbital radius due to photon pressure. But I don't know whether it would be enough to counter drag from the very thin atmosphere where it is.

Could it be that black holes survived a big crunch?

5 October, p 40

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

In the interview with Sophie Koudmani, we read yet again of misgivings about the size of monstrous black holes in our early universe, and concern at the lack of time to reach such proportions. Would it be a silly or outrageous idea that such black holes may have existed before the big bang (perhaps as remnants of previous universes that "big-crunched"), around which our own universe simply expanded and adopted?

A future of artificial food would leave us vulnerable

14 September, p 24

From James Fenton, Clachan Seil, Argyll and Bute, UK

Rowan Hooper's column about a future food revolution paints a seriously worrying dystopian picture. This vision would leave food production in the hands of corporations and subject to the vicissitudes of supply chains, political disruption and so on.

The creation of megafarms already means farming is starting to come under the ownership of such organisations, which is a disaster for both farming and the environment. Chemically produced food divorces us from the natural world completely.

For the record

The man pictured near the Soyuz MS spacecraft is ground crew (5 October, p 26). US astronauts Peggy Whitson and Jack Fischer and Russian cosmonaut Fyodor Yurchikhin are inside the vehicle.

Want to get in touch?

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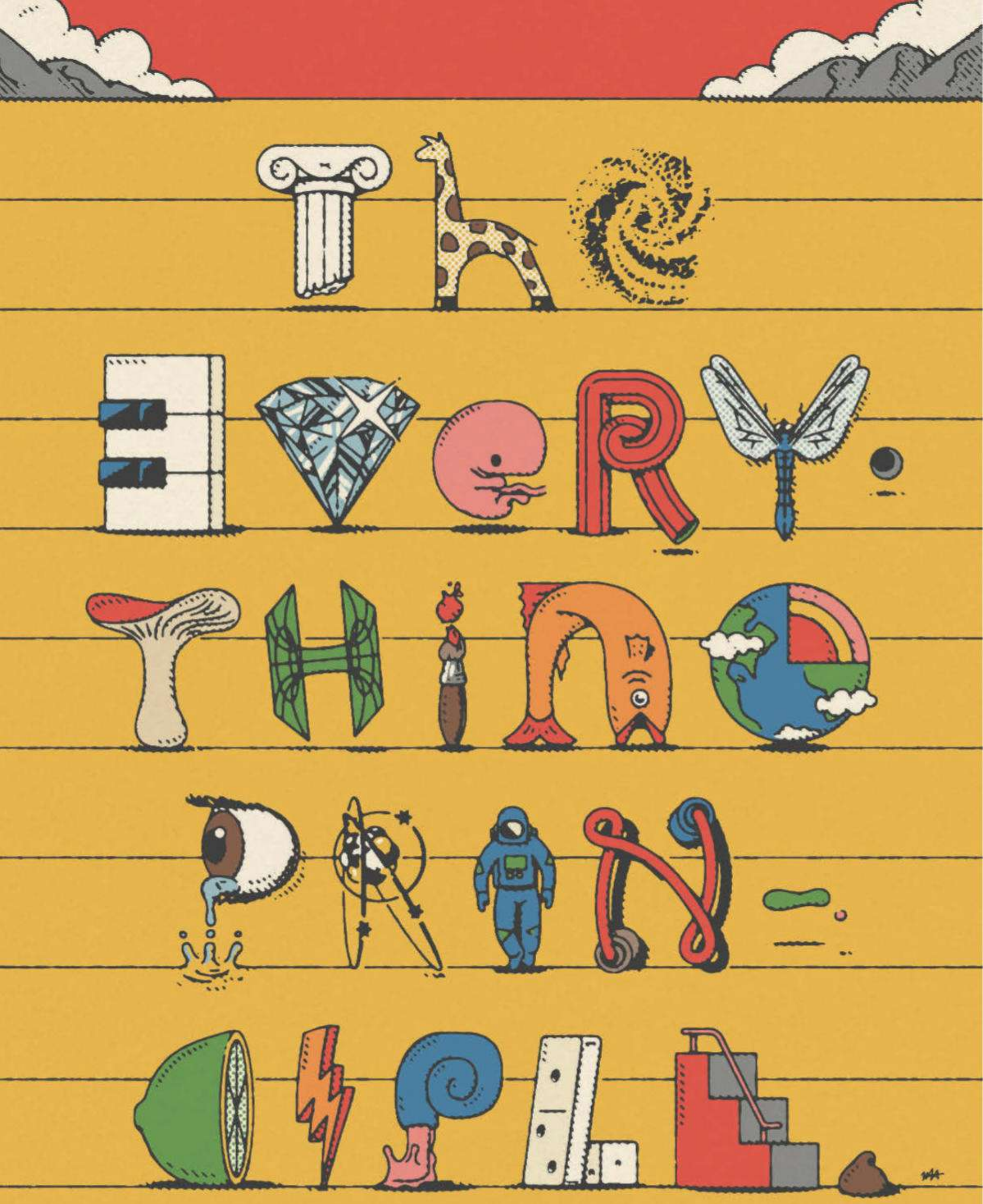


Can this audacious, all-encompassing idea explain the mind, intelligence and what life is in one fell swoop, asks **Elise Cutts**

NEUROSCIENCE seems an unlikely place to find fundamental truths that could apply to everything in the universe. Brains are specific objects that do things that few, if any, other objects in the universe seem capable of. They perceive. They act. They read magazine articles. They are usually the exception, not the rule.

That is perhaps why the free-energy principle (FEP) has garnered so much attention. What began in the early 2000s as a tool to explain cognitive processes like perception and action began to be presented as a "unified brain theory". Then the FEP outgrew the brain, being put forward as a definition of life and, inevitably, as the basis for a new kind of artificial intelligence that can reason. Today, some proponents argue that the FEP even encapsulates what it means for something in the universe to exist at all. "You can read the free-energy principle as a physics of self-organisation," says its originator, Karl Friston at University College London. "It is a description of things that persist."

Yet some researchers are sceptical that the FEP can live up to many of its loftiest promises, having grown frustrated with its shifting scope. "It has been a moving target," says Matteo Colombo, philosopher and cognitive scientist at Tilburg University, the Netherlands.

All of which has made the FEP a source of both fascination and frustration. Its dizzying breadth is key to its enduring appeal, even while it remains famously difficult to get your head around. So, given the claims that it can be used to explain everything in one go, does the FEP really explain anything at all?

Friston, a psychiatrist by training, is by many accounts one of the most influential neuroscientists alive. In 1990, he developed a computational technique called statistical parametric mapping that allows researchers to meaningfully compare images of different brains to each other, despite their varied shapes and sizes. This alone would have earned Friston a mention in the scientific history books. But he went on to develop other tools that made the brain ever more transparent for our digital eyes.

Uniting cognition

However, for all that neuroscientists were learning about the brain in the 1990s, they were left with a stubborn, slippery question: how and why, exactly, do the lumps of wrinkly, fatty tissue sitting in our skulls actually do most of the things we think of as, well, thinking?

Although researchers had some success understanding individual cognitive processes, such as perception or action, the study of the mind had largely remained fragmented, says philosopher and cognitive scientist Jelle Bruineberg at the University of Copenhagen, Denmark.

In the early 2000s, Friston looked to physics and mathematics for a new way to understand cognition. His solution was the FEP.

"The FEP is an extremely universalist approach to the mind," says Bruineberg. Unlike prior ideas, it sought to unite cognition under one principle: the minimisation of surprise.

The FEP does this by casting the brain as a probability-estimating engine. The name of the brain game, the thinking goes, is to develop beliefs about the world that get as close to reality as possible. Together, those beliefs constitute what is known as a generative model – a set of beliefs that can be used to make guesses about the world. This intuitive process can be rephrased with mathematical rigour using "Bayesian inference", a statistical method in which pre-existing beliefs are updated based on new information.

Precisely how a gooey blob of neurons with the consistency of warm butter imprints itself with a generative model isn't important to the FEP – it doesn't care about the mess of biology. What is important is that the brain updates its beliefs when it receives new data via the senses.

Another key aspect of the FEP is that it is focused on the definition of what it means to be something, says Friston. To exist, a thing needs to be distinguished from everything else, he says. In other words, an object must have a boundary.

To divide the brain from the world it models, Friston implemented another mathematical tool: the Markov blanket. This acts as a sort of causal go-between, determining the relevant information that defines a particular brain state (see "What is a Markov blanket?", page 34). Depending on the scale you are interested in, a brain state could be something as granular as whether a particular neuron is firing or as enormous as depression.

In an abstract sense, you can view the universe as composed entirely of nested Markov blankets, says Friston. "There are blankets within blankets within blankets all the way down and all the way up. You have to pick the level at which you want to apply the free-energy principle."

Defining the boundaries of objects by Markov blankets allowed Friston and his ›

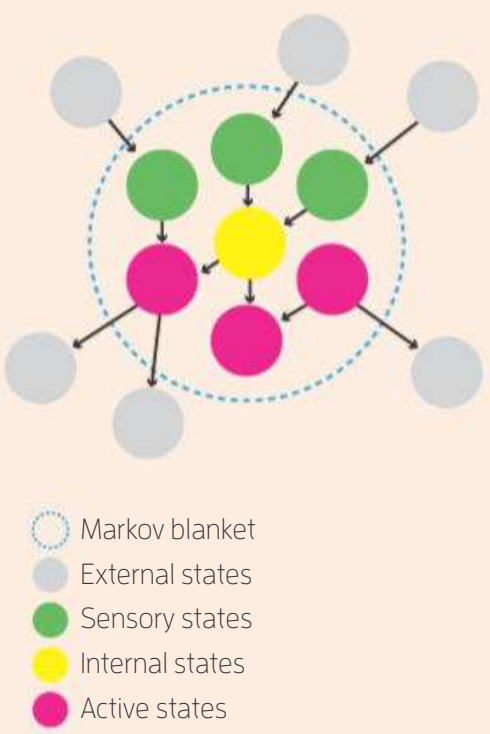
MICHAEL HADDAD

What is a Markov Blanket?

According to the free-energy principle (FEP), entities like brains or organisms are defined by a Markov blanket – an abstract, statistical skin that separates something from everything else.

These blankets aren't necessarily a real, physical border. To draw them, we need to represent a system, such as a brain, as a network of states. Connected in a network, these states influence each other. In a brain, the state of one neuron might influence the state of another, triggering it to fire.

The FEP says that an object persists by changing its internal states (represented by the yellow circle in the graphic below) to create a model about the world beyond, which is represented by external states. The Markov blanket is defined as the smallest set of "blanket states" that can fully predict the internal states. The blanket states are divided into sensory states that receive information from external states, and active states, which usually (but not always) influence external states. Sensing and acting via the sensory and active states allows objects to update their internal states and influence external states to minimise surprise and persist within their environment (see main story).



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colleagues to show that systems that maintain a steady state in time – for instance, staying organised into a cell, brain or human – can be mathematically described as performing Bayesian inference on their environment.

However, doing perfect Bayesian inference is impossible, so Friston proposes that systems use an approximation. This is where the "free energy" of the FEP finally comes in. This isn't the thermodynamic free energy of your high school physics class. It is a quantity from information theory called variational free energy, which you can think of as a measure of surprise. The brain tunes its generative model so that what it perceives lines up with what it predicts, reducing surprise – mathematically, it minimises free energy.

Imagine, for example, you catch the scent of chocolate chip cookies wafting from down the hall. Your brain would then tune its model to include cookies baking in the kitchen.

The FEP wasn't the first framework to cast perception in Bayesian terms. But it went a step further by uniting perception and action within the same conceptual framework. It was also used to explain diverse cognitive processes like attention and learning. All of which eventually led Friston to ask if the FEP was a "unified brain theory" in 2010.

What is life?

The FEP explains action as another way that the brain can minimise the dissonance between its model and its reality. Instead of changing its expectations to match the world, the brain changes the world to match its expectations. It acts to avoid surprise

For instance, if someone is starving, their brain will receive sensory information from the body that it can use to update its model to know it is starving. But that is a surprising state for a brain to be in. If brains expected to receive starvation signals from the stomach, brains wouldn't exist for long. So the brain acts, via the body, to try to change the situation by getting some food, ending the surprising sensation.

Action is the FEP's explanation for how organisms – including their brains – persist. By taking action to avoid the surprise of starvation, a brain persists. Likewise, a fish's model of itself in the world would expect water, but deem air rather surprising – and a fish out of water would take action to change that by flip-flopping back into the ocean. "It effectively says that survival can only happen on the basis of action," says philosopher Michael Kirchhoff at the University of Wollongong, Australia.

The FEP goes further still. Although it was originally explored as a brain theory, in 2013, Friston published a controversial paper called "Life as we know it" that made the leap beyond the brain to all living things. Walling off a system behind a Markov blanket, he suggested, leads to self-organisation, which could then lead to life, or at least lifelike behaviour.

The border between the living and non-living worlds has long remained frustratingly fuzzy – and there is still no widely accepted definition of life. So the idea that the FEP might provide a universal account of biological self-organisation was a tantalising one. "It was very explicit around that time that the point is to get at the differences between living and non-living systems," says Kate Nave at the University of Edinburgh, UK.

Indeed, much of the principle's enduring appeal derives from these lofty claims, says Colombo. But he, Nave and others doubted that the FEP's formal, mathematical definition of what it is to be a thing that persists was up to the task of describing life. Now, some of the hype seems to be fading, says Colombo.

In "Life as we know it", Friston drew a parallel between the cell membrane and a Markov blanket. After that, scientists and philosophers began to discuss Markov blankets as physical boundaries between objects in the real world, says Bruineberg. In 2021, he and his colleagues argued that this was a mistake and that Markov blankets aren't able to delineate the natural boundaries of real objects.

"The Markov blanket stuff is a real mess," says Nave, as it isn't clear what it applies to. For example, it has been argued that a candle flame lacks a Markov blanket because its boundary changes more quickly than its bulk. Nave argues the same is true for living things. "The parts that make them up are in continual turnover, just as much as a candle flame."

Moreover, the FEP rests on assumptions that might not apply to life, says complexity scientist Miguel Aguilera at the Basque Center for Applied Mathematics in Bilbao, Spain. In 2022, he and his colleagues found that only a narrow set of the simple systems they tested could satisfy the FEP's assumptions. These include that a system will visit every possible configuration of its states through time. Keeping in mind how fussy biology must be for living processes to continue working, it isn't clear how something alive could satisfy that assumption without destroying itself.

Faced with criticisms like these, Friston and

USCBRAIN ATLAS

RUSSELL KIGHTLEY/SCIENCE PHOTO LIBRARY

The free-energy principle was originally explored as a unifying theory of cognition, to make sense of how different brain regions (left) operate in unison when we think or act. The same mathematical ideas were later applied to explain how living systems such as plant cells (below) maintain themselves

other proponents of the FEP have backtracked on some of the grander claims, says Bruineberg. Today, Friston discusses the FEP as a general description of what it means for a thing to exist. That sounds quite staggering, but it actually dilutes the FEP's original appeal as a specific description of what is special about the mind, and later as a potential theory of life. Nave says there is a tension between the broader, weaker interpretations of the FEP that accommodate life but don't distinguish it from non-life, and stronger, more specific claims about the nature of biology that don't stand up to counterexamples. In other words, if the FEP can apply to anything, it is questionable whether it is useful to apply it to life.

This shifting scope has been a source of frustration for Nave and Bruineberg. They describe a pattern in which FEP proponents put forward radical claims only to retreat to more defensible, but less-interesting positions when challenged. "[Others working with the FEP] kind of feel they haven't been taken seriously," says Bruineberg.

"You can think of 'free energy' as a measure of surprise"

"The compass of the FEP has certainly increased over time," says Friston. However, he notes that the underlying mathematics has remained the same and that "from its inception, the FEP makes a careful distinction between living and non-living things".

Bruineberg also takes issue with the FEP's original application as a unifying explanation of cognition. One problem, he says, is that the FEP assumes that brains are optimists because they deem anything harmful to be surprising. If you put your hand on a hot stove, your brain could minimise its free energy by updating its model to expect hand-burning sensations. Yet we clearly choose to act instead and pull our hands away from the heat.

"There's a kind of tension there between this optimism bias and learning from experience, because our everyday environments are very unlikely to be optimistic," says Bruineberg.

Truth vs truism

Friston doesn't see a problem. The FEP is tautological, he says: it assumes that things exist, then describes what things do if they exist. If your brain were somehow wired to expect sensations like burning, freezing, starvation or thirst, it wouldn't persist for very long, and the FEP wouldn't describe it. The same goes for brains that easily learn to expect starvation after going without food for a few days. The FEP assumes that brains – and all persisting things – don't act in ways that would cause the dissolution of their very being.

So the optimism bias is there, but Friston would argue that is sort of the point. "The FEP, in and of itself, gets you absolutely nowhere," he says. To apply the FEP to a brain you also need to know "the kind of thing" that brain is – you need to know what the brain expects about itself and its environment. "That's where all the hard work is," he says.

The perceived dissonance between what the FEP might seem to offer and its real limitations may point to a larger pattern. Mel Andrews, a philosopher of science at the University of Cincinnati, Ohio, wonders whether the confusion surrounding the FEP might boil down to a case of unrealistic expectations: perhaps proponents and critics of the FEP have all simply mistaken it for something it isn't.

"It's not right to ask whether it's true in ›

general or true of specific systems – as in true of nature," says Andrews. "By fixating on this question, 'Is it true?', it's generated a lot of literature around this framework that says effectively nothing."

Andrews doesn't believe the FEP is a grand theory explaining life, the universe and everything. It isn't a theory at all, they say, nor it is a hypothesis to be tested. Instead, the FEP is more accurately described as a set of self-consistent assumptions and mathematical tools that offer a scaffold for research – a kind of language for building new theories.

Although Friston has presented the FEP as a theory in the past, he now says that it is best thought of as a tool to apply rather than a truth to debate. "It is not a theory, it's not a hypothesis, it's a principle," he says. The word "principle" is rather slippery, meaning different things to different scientists. But Friston is clear about what it means to him: it is a truism. "That means all you can do with the free-energy principle is apply it. You can't talk about it, you can't admire it, you can't falsify it, you can't critique it."

Every human language smuggles extra layers of meaning and assumptions about what is worth paying attention to into the messages it carries. The same is true for the languages of science. Classical mechanics, general relativity, organic chemistry, genetics – each has its own self-consistent mathematical and conceptual grammar and lexicon that we can use to describe the world. Some are better suited to certain tasks than others. Phrasing the swing of a simple pendulum in the language of general relativity would be clunky overkill. It is possible to make false statements using any of these languages, but, when used carefully, they reveal new facets of the truth.

> **"The free-energy principle is more accurately described as a language for building new theories"**

The FEP's dialect casts existence in terms of information exchange between an observed world and an observing agent. The question researchers should be asking, says Andrews, is what this buys us – if the FEP is new scientific language, is it a useful one?

The many, eclectic applications of the FEP in recent years suggest that it is useful to researchers across disciplines. Over the past year, the FEP has been referenced in papers that study how police officers can improve their hunches, why art touches our emotions and how our ancient ancestors started using hand axes. Yet on closer inspection, while the FEP may have been an inspiration to this research, the extent to which it actually offers explanation is debatable, says Bruineberg. "The question is how much good research the FEP really sparked that couldn't have been done without it."

Free energy and AI

Friston, for his part, thinks the FEP is "extremely useful". In particular, he points to active inference, a concept in machine learning and cognitive science founded on the FEP that is being used to build AIs. "There is a small industry of people that you probably won't find in the philosophy literature. They're just people getting on with the job of applying the free-energy principle."

This "small industry" includes Verses, a company seeking to build computers that simulate human thought processes, where Friston is chief scientist. "We're basing everything on the root of this principle, the free-energy principle," says Verses chief product officer Hari Thiruvengada. The idea is that by replicating the workings of the mind – or at least the mind according to the FEP – its AIs could form hypotheses about the world and, to some extent, reason.

Verses is now assessing its models against AI image-recognition benchmarks as well as the Atari 100k challenge, which tests an AI's ability to play video games. So far, the firm can't announce anything specific, says Thiruvengada. But research published in August by Friston and his colleagues that is yet to be peer-reviewed suggests that models like these need significantly less training data to learn to accurately classify images.

Next to these real-world applications, Friston considers wranglings over the FEP's meaning a spectator sport – one from which physics offers safe retreat. "If one stays close to the physics, there should be no need for proponents or defenders," he says. "Applications of the FEP may or may not be useful. Time will tell." ▮

The free-energy principle has been used to explore why art touches our emotions

CHRIS STEELE-PERKINS/MAGNUM PHOTOS

Elise Cutts is a science journalist based in Graz, Austria

"It's stripping Indigenous people of their heritage"

Archaeologist **Flint Dibble** tells Colin Barras why he is fighting claims that we have overlooked an advanced ancient civilisation – and how best to debunk such ideas

ARCHAEOLOGICAL research has helped us understand the complicated story of our species' past, from the earliest hominins to the dawn of civilisation and beyond. But some people are convinced that it has overlooked an important chapter. They believe there was an advanced global civilisation some 20,000 years ago during the last glacial maximum, often referred to as the ice age – but that it was mysteriously destroyed, with its impressive settlements and monuments drowned by rising seas.

Flint Dibble, an archaeologist at Cardiff University in the UK, is doing all he can to make it clear that such ideas aren't supported by the evidence. Earlier this year, he appeared on *The Joe Rogan Experience* podcast to take part in a high-profile debate with Graham Hancock, a writer who has spent years arguing for the existence of this forgotten society and who discusses the idea in his Netflix show, *Ancient Apocalypse*.

Dibble spoke to *New Scientist* about the reasons for the enduring appeal of mythical lost civilisations, why belief in them can be so harmful, and how to persuade people to reject the ideas promoted by Hancock and others through the use of "truth sandwiches".

PAUL RYDING

Colin Barras: Why do you think the myth of an advanced lost civilisation generates so much interest?

Flint Dibble: That's a tough one. You have to appreciate that Graham Hancock's idea isn't new: it stems directly out of earlier interpretations of Atlantis. And Atlantis has had an enduring appeal for centuries – it is written about more often in English-language books than Stonehenge, than the Sphinx, than any major archaeological site.

Why is that the case? After three years ›

of researching this, I don't have a great answer. But I can speculate. I think the current interest maybe ties in with our obsession with catastrophes. We're very worried about our own civilisation ending due to climate change, an impact from space or a nuclear disaster. Atlantis – and Hancock's story of an advanced ice age civilisation that was destroyed in some sort of cataclysm – feeds into those concerns.

That makes these myths sound relatively harmless. Are they?
Some manifestations are harmless. I mean, right now a *Lord of the Rings* spin-off – *The Rings of Power* – is watched by millions on Amazon Prime Video. In his letters, J. R. R. Tolkien acknowledged that Númenor, an island that's really central to that world, is inspired by Atlantis. But I think it becomes more of an issue when an advanced lost civilisation is believed to have been real.

In Hancock's version, survivors from this civilisation are claimed to be responsible for monumental architecture around the world. That narrative is stripping Indigenous people of their heritage. It's saying that great ancient monuments across the world were not designed and built by local communities.

It sounds like a bizarre idea. Can you explain how it works?
Well, for instance, Hancock will juxtapose images of pyramids from different areas of the world. And it has gut-level appeal: these monuments look similar to the viewer, so the conclusion they reach is that they must be related. That leads to another conclusion: that there was a global diffusion of ideas because survivors of this lost civilisation spread around the world carrying their advanced knowledge with them.

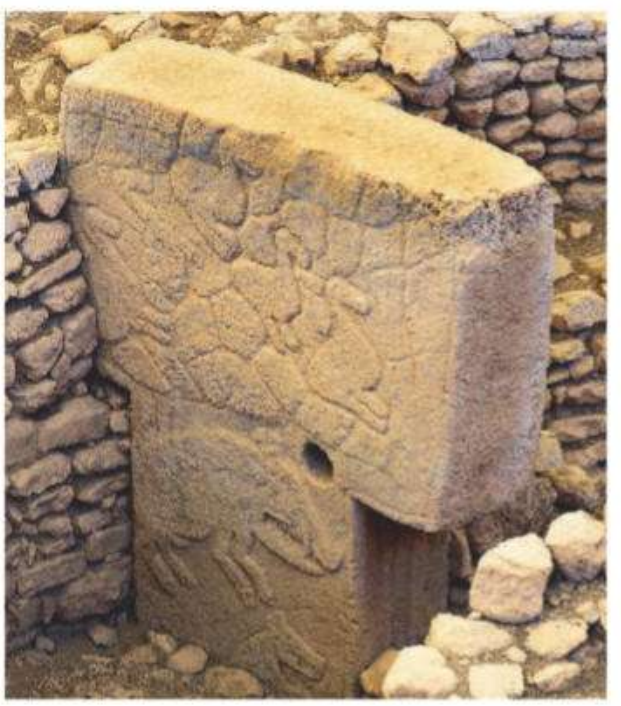
But we know that it's far more complicated than that. For instance, we have material findings from Mesoamerica that tell us the pyramids there are thousands of years younger than the pyramids in Egypt. They're not only separated by an ocean, they're separated by millennia. They can't be related.

So belief in this lost civilisation is only possible if you reject the archaeological evidence?
Yes – belief is viewed as proof that the experts are wrong. We've seen this phenomenon a lot over the past decade or so, this rising trend in anti-intellectualism and anti-expertise.

What can archaeologists do to push back against that?
Let's be honest: academic literature is difficult to access. And some of it might be free, but it's difficult to read and understand because it's filled with jargon. So I think scholars should be trying to do more outreach. It's why I'm active on YouTube and social media.

And that's why you chose to debate Hancock on *The Joe Rogan Experience*. Wasn't there a risk you would do more harm than good?
Well, several of my close friends and colleagues thought I was making a giant mistake, that I was walking into a trap. Hancock has appeared on Joe Rogan's show many times already, and the two of them have a good rapport. All the cards were in his favour; I went in knowing that. But I also went in with a strategy to try to defuse the situation, based on the latest research into tackling misinformation.

What does that research look like?
In past decades, scientists came off badly in debates with pseudoscientists. The old playbook was to put the burden of proof on the pseudoscientist. The problem is that as soon as you do that, you give them the floor. Then you're stuck responding to it and trying to debunk it after the fact. And research has shown that debunking usually doesn't work.



IMAGEBROKER/SHUTTERSTOCK

Carvings at Göbekli Tepe, an archaeological site in Turkey

> "It's time to take back the airwaves and share what we actually know about the past"

What's the alternative?
Pre-bunking is key – getting the first word in. One of my preconditions for appearing on the podcast was that I talked first. Misinformation research also helped me decide how to use that presenting time. Most of us have short attention spans, and what sticks in our brains is often the first thing we hear. So, if you begin a presentation by outlining an idea you want to debunk, it's that misinformation that the audience remembers.

Misinformation research has instead honed in on this idea of a truth sandwich. You start off by saying: Hey, this is something that's real and true. You set the context. Then you introduce and debunk the misinformation. And finally, you end with some more truth that you can build on.

Did your truth sandwich work?
It did. It was really clear from the reaction afterwards. Joe Rogan's fanbase in general was sort of like: wow, archaeology has its shit together. I must have read several hundred, if not thousands, of messages from people who told me that they had previously just loved what Hancock had to say, but that they now realise he's wrong.

What sort of real archaeological truths did you focus on?
As an example, I brought up Göbekli Tepe, this really cool, roughly 11,000-year-old site in Turkey. A lot of people in the public think it was built by a society with farming – and actually that's what the initial excavators thought. But then a careful study of the animal bones and seeds at the site showed they

SHUTTERSTOCK/SKOSTEP

The stepped pyramid at the Mayan city of Uxmal, in present-day Mexico

were all from wild species. The monuments at Göbekli Tepe were built by hunter-gatherers.

Which argues against the idea that survivors of a global ice age civilisation were involved?
Yes. And on that idea, we can look for a signature of that global civilisation. I mean, it's hard to prove a negative: the absence of evidence isn't necessarily evidence of absence. But I strongly believe there are times when we can prove a negative by working from the known to the unknown. For instance, we know from later time periods that if a society is practising large-scale metallurgy, that creates an atmospheric signature that is recorded in ice cores. But there's no signature like that in ice cores from the ice age. That's also my argument with agriculture: it should show up in ice age pollen samples as a spike in grain pollen. Again, there's nothing.

In fact, there's one more reason archaeologists know Hancock is wrong. His idea is that a disaster destroyed evidence of this advanced civilisation. But we know disasters actually preserve archaeological evidence. When a volcano erupts, or an earthquake levels a town and it has to be rebuilt, that locks a phase of occupation in the stratigraphy. Pompeii is a great example of that.

Hancock used some strategies of his own during the debate. One was to point out that scientists can sometimes be dismissive of new ideas. For instance, some of the first archaeologists to argue that the peopling of the Americas occurred much earlier than we thought were ridiculed. But today, many researchers are willing to accept those early dates.
It's true that archaeologists like Jacques Cinq-Mars and Tom Dillehay were treated badly by some people. But at the same time, they were not dismissed by everybody. I think that that's a really important point. We're not talking about renegades from outside archaeology who had uncovered the truth and were being dismissed by academics. We're talking about researchers within the field presenting new ideas – which is what we're all doing.

That said, I think the field has changed in the past couple of decades in the way it reacts to new ideas. Hopefully, most of us have now realised we need to be a little more positive and receptive. Because working in archaeology is tough enough, and we need to recognise we're all on the same side.

Hancock also pressed you on some of your previously published comments. He claimed they would encourage people to view him as racist.
I've never called Graham Hancock a racist. But the thing is that if you trace the history of his ideas, they go back to colonial times. There was this common trope of white-skinned cultural heroes arriving in the Americas in the distant past and bringing civilisation. Those ideas were used to justify claiming lands in the Americas for the Spanish crown. Now, skin colour isn't referred to at all in *Ancient Apocalypse*. That's good, but I don't think it goes far enough. Hancock should acknowledge that his ideas have a clear and problematic history to them. Having said that, this was never the main point of my criticism of his work.

But it's an important point, right?
Yes. For instance, I was in Florida for another podcast just a couple of weeks ago and the taxi driver taking me to the studio told me he was from Peru. When we began talking about the podcast and how I'm trying to explain that these monuments across the Americas were built by Indigenous people, he got very excited. It was just so obvious that he felt it was his heritage, but that it has been taken away.

What have you learned from your debate with Hancock? How will it help you continue to push back against pseudoscience?
Well, I've now been invited on more of these large-audience podcasts. That tells me there's an appetite for real archaeology. And, in fact, I'm helping organise an online archaeology festival in October with that name, Real Archaeology. It'll involve a bunch of YouTube channels, different podcasts and blogs. We're going to put out content at the same time with the same hashtag, and we'll be advertising everything at real-archaeology.com. It's time to take back the airwaves and share what we actually know about the ancient past.

Could you give some examples of real archaeology that excites people?
The reality of being human involves looking at material culture: what we do, the traces we leave as we alter the world around us. And we can find all of these interesting stories there. For instance, we can analyse the weight and style of a set of ancient footprints to forensically start putting together the story of a journey taken by a mother and child across a dried-up lake bed. Or we can tell the story of ancient potters – their age and sex – just from studying the fingerprints they left in the wet clay. That's the goal of archaeology: to take something that has no words attached to it and then tell its story. And when people hear these stories, they are always impressed. They do find them really cool. ▮

Colin Barras is a writer based in Ann Arbor, Michigan

THE VERY WORST OF FRIENDS

Love-hate relationships are surprisingly bad for you, but knowing your frenemies is the first step to improving things, says **David Robson**

WHEN I contemplate the members of my social network, I am mostly filled with unadulterated feelings of love and warmth: I simply can't wait to see them again, in the knowledge that we will bask in mutual affection and support.

A handful, however, arouse quite different emotions – a mixture of eagerness and dread. They promise encounters that are the conversational equivalent of Russian roulette. In the right mood, these individuals can deliver a fun-filled evening, but if I catch them at the wrong moment, they can drain me of all my goodwill. There is simply no knowing what is to come.

If this sounds familiar, then you too have frenemies. Psychologists call them "ambivalent relationships" and they don't just have the potential to ruin a good party, they also have surprising consequences for your well-being. According to a wealth of research, these love-hate relationships are often more stressful than interactions with people who are consistently nasty. They can damage your mental and physical health. They might also be prematurely ageing you.

Knowing this, the simple solution would seem to be to cut ties with these people. But our relationships with frenemies aren't simple, and ditching them isn't always possible or even desirable. However, a deeper insight into your ambivalent relationships will help you deal with them more effectively. It could make you a better friend, too. Because, when you know the signs to look out for, you might discover that the frenemy in some of your relationships is you.

Since the 1970s, huge studies examining thousands of people over extended periods have shown that those with more vibrant social networks tend to live longer and are less susceptible to a host of different illnesses – from the common cold to Alzheimer's disease and heart attack. Many of these studies focus on the sheer size of people's social circles: those with larger networks appear to live longer than those with smaller ones.

Over time, however, it has become clear that the quality of our relationships can matter as much as the quantity. After all, the benefits of social connection come from feeling well understood and supported: if we know that others will have our back when we are threatened and vulnerable, life is less stressful. But not all our acquaintances leave us feeling like this. Not only do some fail to protect us from life's slings and arrows – they will sometimes slide the knife in themselves.

To capture these interpersonal dynamics, Julianne Holt-Lunstad and her colleagues at Brigham Young University in Utah have designed a simple scale that identifies four broad categories of relationship. You can try it for yourself. Pick a couple of people within your social network and answer the following two questions on a scale of 1 (not at all) to 6 (very much). When you are feeling in need of advice, understanding or a favour, how helpful is your connection? Likewise, how upsetting is your connection?

People who score 1 on both questions are your indifferent relationships – a neighbour, perhaps, who is rather bland company with neither good nor bad qualities. Those who score highly on the first question, while getting the lowest possible rating on the second, are your supportive social ties – the people who are an unalloyed good in your life. Others are the mirror image, with the lowest score on the first question and high marks on the second. These are purely aversive relationships. You will probably do your best to avoid talking to them unless you are forced to interact, such as in a business meeting or at a family gathering. Finally, there is the fourth category: people who are both nice and nasty. Anyone with a score of 2 or more on both scales is considered an ambivalent connection – your frenemies. They may be incredibly generous when you ›

MARIANA CASTEL/MILLENNIUM IMAGES, UK

have a problem yet can also lash out with a bitter put-down when they feel envious or threatened.

Ambivalent connections could include a friend, parent, sibling, colleague or even a spouse – anyone with whom you have a love-hate relationship. And their ambivalence can come in many forms: it might be a lack of interest in your life rather than overt disrespect, or a general unreliability that means they are often unavailable when you need their support. It could be a partner who love-bombs you one day, but who is fiercely critical the next, leaving you unsure about their true feelings.

We might hope that in such relationships, the good would outweigh the bad, with a net positive to our overall well-being. At the very least, you would expect them to be better for us than our aversive relationships. Unfortunately, the research suggests things aren't so simple. Holt-Lunstad's team, for example, hooked 102 people up to portable blood pressure monitors for three days. During any social interactions, the participants could press a button to trigger the device, and after they had finished the conversation, they recorded who they had met and rated them on the scales above. As you might expect, people's blood pressure was higher when they met an ambivalent tie compared with when they met someone who was uncomplicatedly supportive. Surprisingly, however, the ambivalent ties also provoked a stronger reaction than aversive ones.

It gets worse. In another study, Holt-Lunstad and her colleague Benjamin Clark, also at Brigham Young University, found that simply knowing that an ambivalent connection was in the next room as participants prepared to give a speech was enough to send their blood pressure rocketing. It also slowed their recovery after the task. The frenemy didn't need to say a word to evoke anxious feelings. In fact, even subliminal reminders of a frenemy can shatter our peace of mind.

A team led by McKenzie Carlisle at the University of Utah asked people to take a reaction-time test. She found that rapidly flashing the name of an ambivalent connection on the computer screen – so quick that it couldn't be consciously detected – amplified their stress response. Seeing the name of an entirely unpleasant

"Frenemies can put extra strain on your heart and can raise levels of inflammation"

MARTIN PARR/MAGNUM PHOTOS

The nasty behaviour of frenemies can be enough to make your hair curl

MARTIN PARR/MAGNUM PHOTOS

The unpredictable nature of our interactions with frenemies is what makes them so bad for our health

connection failed to create such a large effect.

It seems that our frenemies have us in a kind of stranglehold. We may depend on their support and try our best to please them, but that emotional investment makes their occasional nastiness especially hurtful. Moreover, the uncertainty about which side of them we are going to see – Dr Jekyll or Mr Hyde – only compounds the stress of meeting them, so that we feel anxious before they have even opened their mouths. Contrast this with our aversive social ties, which mean very little to us: if we know someone is a jerk, we can more easily discount their unkind behaviour.

The long-term effects of ambivalent connections may be just as bad as having few connections. Through the stress they create, regularly interacting with frenemies can put extra strain on the heart and raise levels of bodily inflammation – both of which have been associated with an increased risk of mortality.

The effects have even been seen in measures of cellular ageing. At the end of our chromosomes, we have protective caps called telomeres that prevent DNA from being damaged when cells replicate. As we age, our telomeres slowly wear down and, when they become too short, cells may start to malfunction or die. Shorter telomeres are thought to put us at greater risk of many of the diseases that come with ageing – and our ambivalent connections appear to contribute to their decline. If you live with someone who often makes you feel like you are on a knife edge, or if you regularly see friends who leave you feeling that way, you are more likely to have shortened telomeres, relative to other people of a similar age.

It isn't just our physical health that is at stake. Good relationships with our colleagues are one of the best predictors of job satisfaction and resilience against burnout, so it should be little surprise that toxic dynamics can be a serious cause of workplace distress. Ambivalent bosses can be especially damaging. A recent survey examining 993 employees from 27 work groups found that bosses who provide unreliable support and sporadic unkindness can take a serious toll on their employees' mental well-being, raising the risk of depression, anxiety and emotional exhaustion.

The paradoxical nature of our ambivalent connections means that there is no simple solution. If you feel someone has become too toxic a presence in your life, you may decide to cut off contact – but that may not be possible if they are your boss or a family member, or if they are so deeply integrated into your social network that you would also risk losing supportive relationships with other people. So, what can be done?

Am I the frenemy?

Simply being aware of the ambivalent nature of a relationship might offer some protection. Personally, I have found that knowledge of this research helps me to manage my expectations and mentally prepare myself for the mixed feelings that interacting with frenemies might bring. This allows me to focus more on the good in these people and to feel compassion for their more unpleasant streaks, while also attempting to reduce contact when I feel that they may only add to the stresses I am facing in other areas of my life.

Just as importantly, this research has prompted me to consider my own behaviour – are there relationships in which I am the frenemy? The truth isn't always easy to swallow. Unlike my worst frenemies, I don't tend to lash out with barbed comments and sarcasm, but I do often fail to show others the appreciation and respect I feel for them – accidental neglect that could be taken as a sign of indifference. I am surely not alone in this. Studies show that we often fail to express our gratitude as regularly as we could, either through thoughtlessness, shyness or the assumption that the other person will already know how important they are to us.

I am resolved to be a little more mindful of my interactions with all my ties – indifferent, aversive, ambivalent and supportive. What's more, I now know who to hold at arm's length and who to keep close. ▮

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The problem with frenemies is that they are inconsistent, sometimes full of smiles and fun

David Robson is an award-winning science writer and the author of *The Laws of Connection*

The back pages

Mathematics of life

Form an orderly queue

From shops to ride-share apps, queuing is everywhere. **Peter Rowlett** explains how maths can make it more efficient

Peter Rowlett is a mathematics lecturer, podcaster and author based at Sheffield Hallam University in the UK. Follow him @peterrowlett

I IMAGINE that you may, at some point in your life, have been in a queue that wasn't run entirely efficiently. Despite allegedly loving to line up and wait for things, Brits like me have an array of stories about badly run queues.

Luckily, maths can give us insight into queues and answer questions like how many staff are needed to help them run efficiently. We can gather data on a real queue and use the average arrival rate to calculate the probability of someone joining. This is just an average, of course: if I told you an average of six people were going to enter your shop every hour and six arrived in the first few minutes, would you assume no one else would enter for the rest of the hour? No, because customers don't arrive in average numbers at all times.

Rather than assume the average number of arrivals, we calculate probabilities for numbers of arrivals based on the average using the Poisson distribution, named for mathematician Siméon Denis Poisson (1781-1840). This uses an exponential curve to calculate lower probabilities away from the average – so, for example, if you expect the next person to join the queue in 2 minutes, it isn't unthinkable that they take longer, but it gets increasingly unlikely for longer times.

This maths is useful in working out how many cashiers you need in your shop. But queuing goes a lot further than this.

Your queue need not be a physical one: you may have been held in a queue online waiting to buy tickets, or on a phone where "your call is very important to us".

JEFF J MITCHELL/GETTY IMAGES

Or your queue may be part of a computer process. Typing this text caused a queue of operations to be sent to a computer processor, which worked through them one at a time. When you upload a video to social media, it gets divided into data packets that form a queue to be reassembled.

Some queues have more complicated dynamics. In a supply chain, a shop might be queuing to receive products from a factory, which is waiting in turn to obtain raw materials. A ride-share app operates a two-ended queue, with customers waiting to be served and drivers queuing for jobs.

Sometimes queues don't serve people in the order they joined. Should a lift move to the next person who pressed the button, or pick up other people it passes on the way? There are also queues with ordering based on urgency of need, such as triage systems in hospitals or maintenance jobs.

I am writing this on a slightly delayed train. If we miss our slot at a station, should we be prioritised, potentially delaying another train, or be made to wait?

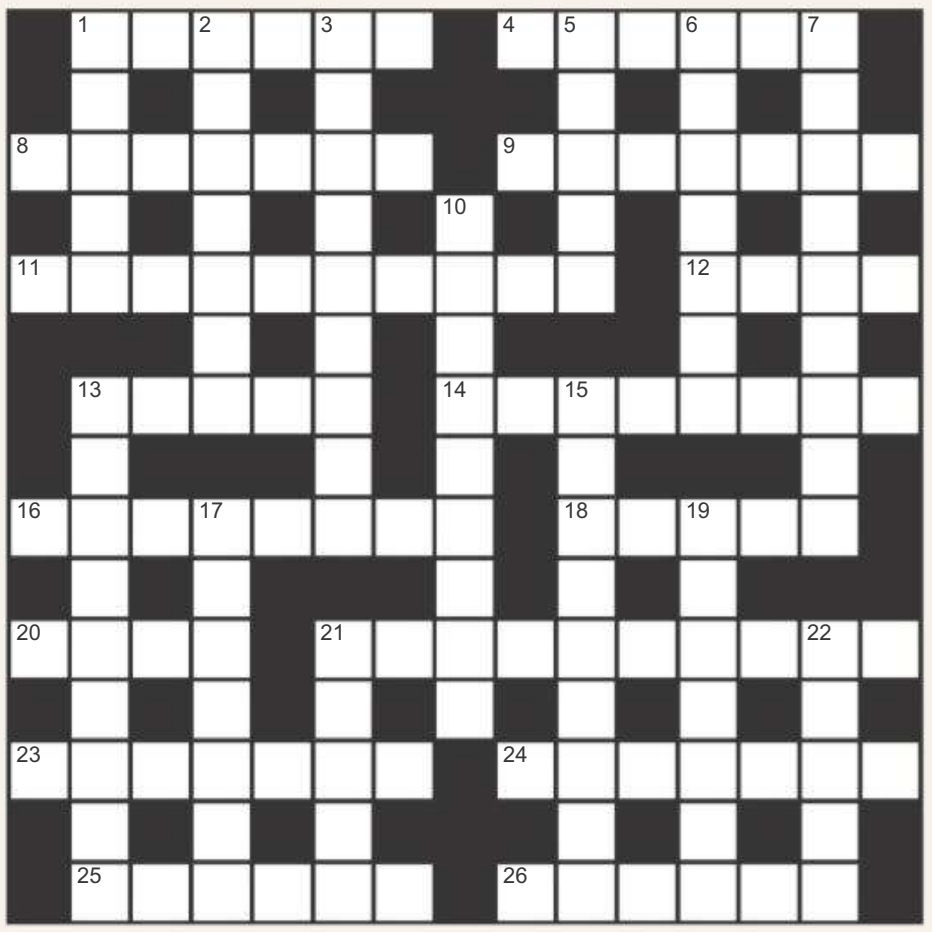
We can gain insight into a great many processes by thinking of them as queues, and using maths like the Poisson distribution helps us create more realistic models and understand how to run those queues more efficiently. ▮

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

Mathematics of life appears monthly

Next week
Debunking gardening myths

Quick crossword #169 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 1.8288 metres (6)
4 Lose the sense of hearing (2,4)
8 Office appliance (7)
9 Hinged section of an aircraft wing (7)
11 Having an aspect ratio >4:3 (10)
12 Philip K. ___, sci-fi writer (4)
13 Lifeless (5)
14 1995 pandemic thriller (8)
16 Online alternatives to TV and the press (3,5)
18 Hours of darkness (5)
20 Pottery oven (4)
21 Viral disease first described in Nigeria (5,5)
23 Field that combines engineering and the natural sciences (7)
24 Ethanol, for one (7)
25 Shipping company founded in 1904 (6)
26 Tropical biting fly (6)

DOWN

1 Enrico ___, Italian-American physicist (5)
2 Citrus hybrid (7)
3 $C_{18}H_{34}O_2$ (5,4)
5 Constellation (5)
6 Kindle, perhaps (1-6)
7 Process diagram (9)
10 Hormonal fluctuation, typically in older women (9)
13 Am (9)
15 Grasping organs of an octopus, say (9)
17 Sea cow (7)
19 Dimming of vision (7)
21 Set of points, such as a curved line (5)
22 Wear away (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #274
set by Bethan Ackerley

1 What name is given to the factor by which time, mass and length change for an object as it moves?

2 The breakdown of the membrane of a cell is known as what?

3 Which astronomer discovered the relationship between the period and luminosity of Cepheid variable stars?

4 Olibanum is better known by what name?

5 What is the most abundant excitatory neurotransmitter in the human brain?

Answers on page 47

BrainTwister
set by Peter Rowlett
#42 Persistence

A number's persistence is given by the steps needed to reach a single-digit whole number by repeatedly multiplying all its digits together. For 39, for example, we start with 3×9 to give 27, then 2×7 is 14 and 1×4 is 4. This took three steps, so the persistence of 39 is 3. We ended up with 4, so we say the root of 39 using this rule is 4.

What are the persistence and root of 77?

What is the smallest number with a persistence of 1?

What is the largest persistence of a two-digit number?

Solution next week

Round in circles

Would it be possible for an intelligent species to develop an advanced technological civilisation without the wheel?

Pat French
Longdon-upon-Tern, Shropshire, UK
The development of advanced technology without the wheel would rely upon so many different things, starting with a definition of "advanced technology". What sort of intelligent organism, inhabiting what kind of world, would be seeking what kind of technological solutions? Does a fish need a bicycle?

The only technology we understand is that of our own species, which may or may not be "advanced". We have reached our current technological level at the end of a long timeline. Our technology started with the tools of the hunter-gatherer and spent a long time developing alongside agriculture, architecture and warfare before eventually reaching centralised manufacturing within cities. Only comparatively recently has technology involved electrics, electronics and digital devices. At every stage, our technologies were considered to be advanced.

"Without inventing the wheel, we would need rockets to power aircraft, so rocket technology would develop quickly"

Generating transmitted energy from wind, water, steam, fossil fuel and nuclear sources all requires rotation at some point. If these power sources are essential to deliver technological solutions, then the concept of the wheel would also seem essential.

Machinery for the manufacture of our technological hardware uses wheels to redirect, utilise and store energy as well as for transport. It is hard to imagine a species developing far into a mass manufacturing age without developing the wheel. Given so many mechanical examples, its usefulness for overland transport would surely be obvious long before industry developed an electric technology.

Alex McDowell
London, UK
It certainly would be possible and may help such a society to develop space travel quicker!

Without the wheel, we would need rockets to power aircraft. Hence rocket technology – which is essential for space travel – would develop rapidly.

Roads could have a slippery surface upon which rocket-powered sledges could run. Ramjets would be developed too. Runways could also have slippery surfaces on which aircraft with skis could land and take off or seaplanes could be used. Maglev trains would be developed more quickly as well.

The wheel is found in most engines, but it isn't essential. Early steam engines, which mainly drove pumps, lacked wheels. Internal combustion engines with parts that only move forwards and backwards, known as reciprocation, would be feasible and it would be easy to produce electricity by using reciprocating magnets inside coils.

Screw threads would be hard to produce without lathes, so such a society would have to rely on nails and rivets as fasteners. It would be impossible to drill holes in thick metal objects, so they would have to be in the original casting.

TWENTY47STUDIO/GETTY IMAGES

This week's new questions

Play on **Presumably music is an essential part of human evolution or it wouldn't be there, but why?** ***John Grant,*** *Caloundra, Queensland, Australia*

A killing blow? **Some worms regenerate when cut in half laterally, but what would happen if they were cut in half longitudinally?** ***Keith Marshall,*** *London, UK*

Is music an essential part of human evolution? And if it is – then why?

Many people think that the rocks for Stonehenge and the pyramids were pulled on sledges by humans or animals.

Atlant Schmidt
Nashua, New Hampshire, US
It is virtually inconceivable that a civilisation could become technologically advanced without employing the wheel. This basic machine is fundamental to so many other technological advances. And it is an obvious invention or discovery, as anyone who has ever slipped on an acorn or a round stick can attest.

On the other hand, it is possible that a species can be intelligent without possessing the wheel. Our own planet's aquatic mammals may eventually attest to that.

Hillary Shaw
Newport, Shropshire, UK
The Aztecs used no wheels because they lived in a mountainous area where llamas or humans were better at transporting things. However, they did have wheeled toys.

Suppose they had good local access to many minerals, were isolated and safe from conquest, and had developed a simple character alphabet and the Gutenberg press (this printing press made cheaper books widely available and arguably kicked off advances in schooling and many technologies).

On this basis, the Aztecs could have developed chemistry, physics and biology. They could have discovered electricity and invented solar panels for energy and magnetic levitation-type transport. They could have developed explosives and maybe the hydrogen bomb, and gone on to conquer the Americas and beyond. Rockets and spacecraft need no wheels.

But once they overran flatter areas where people did use wheels, they are likely to have seen their

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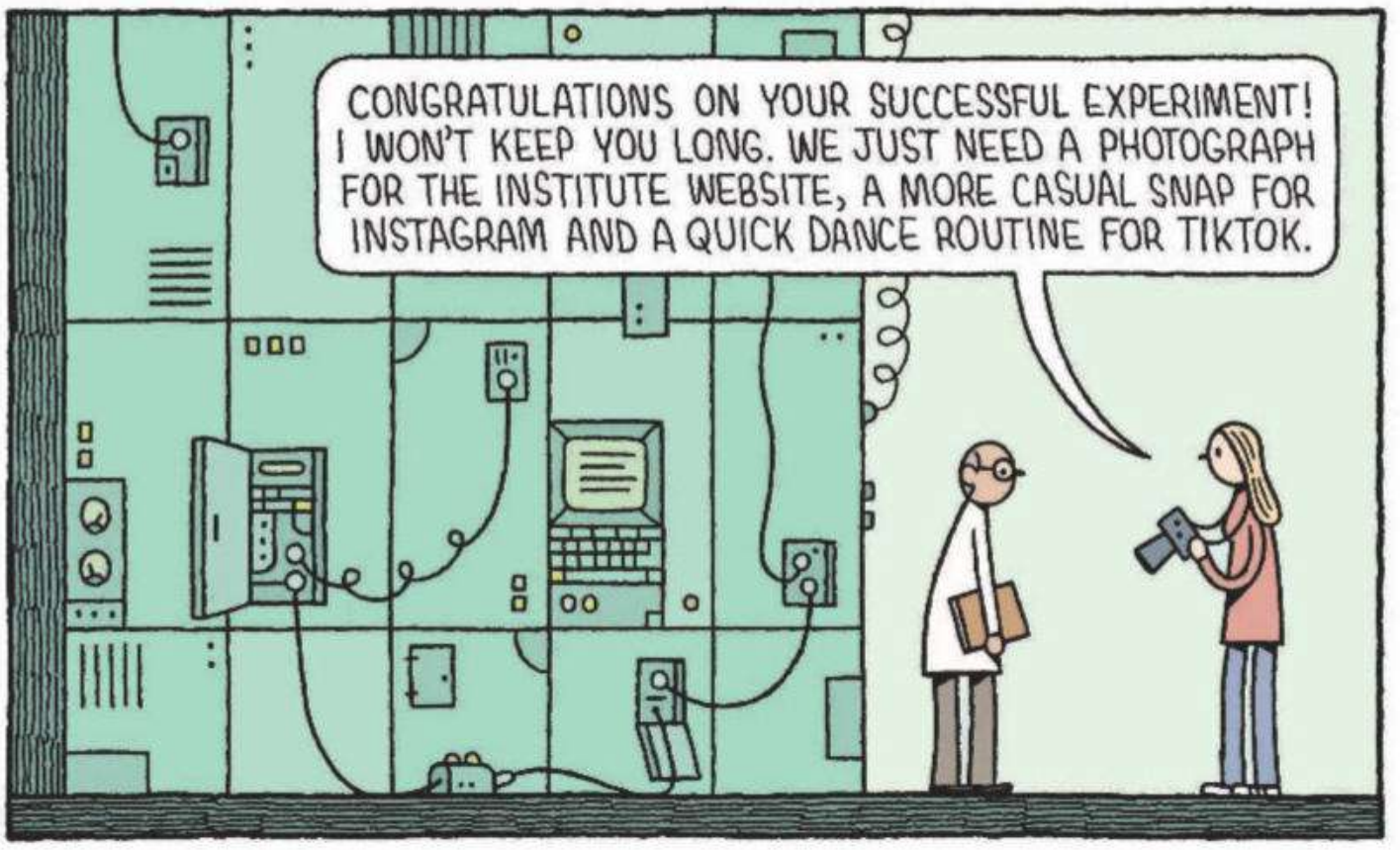


efficiency and adopted the technology of the colonised.

Adding up

Did abstract mathematics, such as Pythagoras's theorem, exist before the big bang? (continued)

Richard Swifte
Darmstadt, Germany
I would lump mathematics in a similar category to language, art, music, etc. – inventions of the human mind that are highly relevant and meaningful to our species, but have no reality otherwise. It is amazing that the evolving human brain happened to gain the ability to think up abstract mathematics (going beyond the simple practical ability to count objects), since this has no obvious survival value to our species.

However, what a useful invention mathematics has been, essential to developing scientific theories and in technical calculations. Without it, we would never have acquired our knowledge of the structure of the solar system and our subsequent ability to accurately send spacecraft to investigate it.

"There is simply no circumstance in which 2 + 2 doesn't equal 4, not even in a universe containing fewer than four particles"

But while geometrical examples such as Pythagoras's theorem are precise, we should regard mathematical equations in science as good approximations to truth rather than 100 per cent precise. Consider, for example, that Isaac Newton's beautifully simple equation describing gravity became accepted as perfectly accurate until slight observed anomalies in planetary orbits showed its imprecision, corrected by Albert Einstein's more complicated general theory of relativity. Time will tell whether the latter is yet another approximation to the truth.

Mathematics is a highly useful tool invented by the human mind – and probably by other intelligent alien species – that has been essential for developing our modern society and knowledge. But if it weren't around, the rest of the universe (pre or post-big bang) would simply keep on existing and evolving in the same way.

Luce Gilmore
Cambridge, UK
Maths is eternal, that is to say, its rules are unaffected by time. They don't wear out and they can't be overloaded by excess use. There is simply no circumstance in which 2 + 2 doesn't equal 4, not even in a universe containing fewer than four particles. Maths isn't invented; it is discovered. This is the Platonic stance, popular among mathematicians. Pythagoras's theorem is easily proven by simple arithmetic, so it is eternally true.

If anything at all existed "before" the big bang, it would be maths. The absence of mathematicians would be entirely irrelevant. ▮

Answers

Quick quiz #274 *Answers*

1 The Lorentz factor
2 Lysis
3 Henrietta Swan Leavitt
4 Frankincense
5 Glutamate

Cryptic crossword #146 *Answers*

ACROSS 1 Mineral, **5** Medic, **8** Drone, **9** Unleash, **10** Leap second, **13** Plasma, **15** Entrap, **17** Fingernail, **21** Bronchi, **22** Pshaw, **23** Xenon, **24** Rapidly

DOWN 1 Mudflaps, **2** Neonatal, **3** Reeks, **4** Launch, **5** Melanin, **6** Draw, **7** Coho, **11** Broached, **12** Spillway, **14** MRI scan, **16** Uglier, **18** Rip up, **19** Ibex, **20** Mown

#41 There are three prisoners *Solution*

If the prisoners pick one of them to speak, and to guess randomly, they have a 50 per cent chance of success. To win 75 per cent of the time, they agree that any of them who can see two blobs the same colour will guess the opposite colour, but those seeing two differently coloured blobs won't guess. This will guarantee success except when all three blobs are the same colour (25 per cent probability). After overhearing this strategy, the guards will use the same colour of blob. To beat this, the prisoners agree they will treat the blob of a prisoner who flips heads as the actual colour, but the blob of one who flips tails as the opposite colour, thus randomising the blobs in a way the guards can't control. The prisoners then follow the usual rules using the modified colours. If any prisoner guessing has flipped tails, they need to reverse the final answer too.

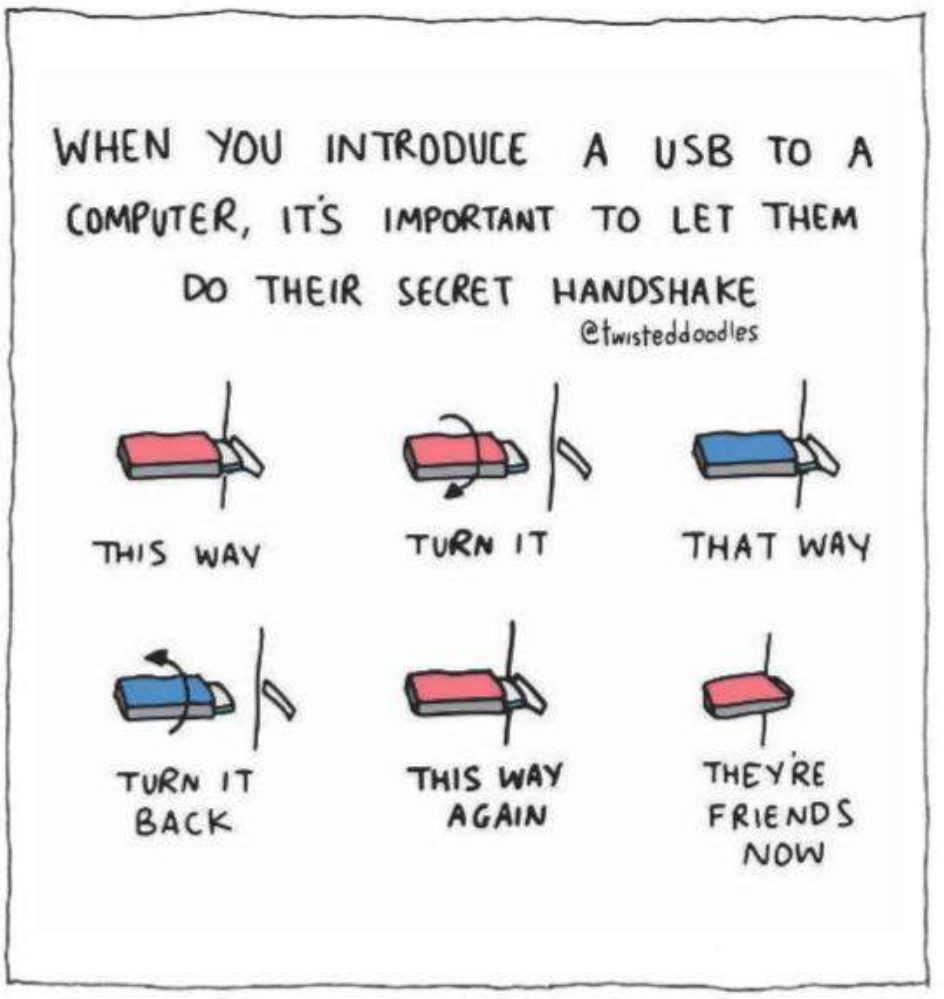
Flash on the pate

While research in Ireland suggests that hats can protect scalps from the sun (see Feedback, 13 July), research in Germany suggests that letting rain soak your head might – just maybe – help you survive if and when lightning strikes your pate.

The researchers used a wetted artificial head, having chosen not to experiment with a wetted genuine human head. Their report, called "Rain may improve survival from direct lightning strikes to the human head", aimed to "measure the influence of rain during high-energy direct lightning strikes on a realistic three-compartment human head phantom".

René Machts and colleagues say they found "a lower number of perforations and eroded areas near the lightning strike impact points on the head phantom when rain was applied compared to no rain".

Twisteddoodles *for New Scientist*



Homeopathic comeback?

Peter Billard showed his son-in-law some of Feedback's collection of remarks by doctors as to whether their job sometimes involves entertaining the patient while nature does the healing. The son-in-law works in a paediatric ward in Germany. He responded that "often enough it is easier and faster to prescribe something than to explain and argue why nothing is needed. That is definitively true for antibiotics but also counts for anti-cough agents."

Billard's son-in-law mentions some risks that come with taking antibiotics – eventual antibiotic resistance, possible diarrhoea and other side effects, et cetera – then says: "However I have some understanding for colleagues... who sometimes follow the parental wish/push for antibiotics."

Billard himself muses: "Wouldn't it therefore be possible to just fob off concerned parents and patients by offering homeopathic remedies? It was obviously a good alternative when it was conceived at the turn of the 19th century – no effective treatment was a massive improvement over the conventional medical treatment back in those days. Perhaps it's time for a comeback!"

Got a story for Feedback?

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

Dishonesty questioned

If you worry about honesty, affix your seat belt and eyeglasses, and read this item.

Just eight days before Feedback commented on the difficulty of getting an honest appraisal of research about dishonesty (Feedback, 28 September), the *Journal of Marketing Research* (*JMR*) published an "expression of concern" about an article called "The dishonesty of honest people", which *JMR* published in 2008.

The letter explained – though in terse, not-exactly-easy-to-understand language – that a large group of researchers had examined the "dishonesty of honest people" paper, leading them to question its accuracy and honesty.

This brouhaha is a clash of award winners. Dan Ariely is the most prominent of the several co-authors of the disputed 2008 paper. In that same year, he was awarded an Ig Nobel prize for a study "demonstrating that high-priced fake medicine is more effective than low-priced fake medicine".

The study criticising Ariely's "dishonesty" study was done by an international group of researchers, two of whom – Bruno Verschuere and Laurent Bègue – had themselves been awarded Ig Nobel prizes. (Verschuere won his in 2016 for a study "asking a thousand liars how often they lie, and for deciding whether to believe those answers". Bègue won his in 2013 for a study "confirming, by experiment, that people who think they are drunk also think they are attractive".)

The study Feedback noted on 28 September ("The untrustworthy evidence in dishonesty research") was published by František Bartoš, who was awarded an Ig Nobel prize this year for a study showing, "both in theory and by 350,757 experiments, that when you flip a coin, it tends to land on the same side as it started".

Bartoš's "untrustworthy evidence" paper explicitly questions research done by Ariely. One of those papers was a 2020 follow-up, called "Signing [one's name] at the beginning [of an official report] versus at the end does not decrease dishonesty", to a 2012 paper called "Signing at the beginning makes ethics salient and decreases dishonest self-reports in comparison to signing at the end".

Ariely's 2012 signature-at-top-or-bottom paper was retracted in 2021. Observers speculate as to whether his 2020 signature-at-bottom-or-top paper will be retracted in 2029.

That's four Ig Nobel prize winners, with the three most recent questioning research published by the earliest. Ig Nobel prizes honour things that make people laugh, then think. Those criteria say nothing as to whether a thing is correct or incorrect, good or bad, important or trivial. Feedback is personally acquainted with all four of these Ig Nobel prize winners and can honestly report that all four are – as people – thoughtful, charming and warm. This four-threaded tangle epitomises the research-community condition: it is messy, contentious, sometimes funny, sometimes disturbing, very thought-provoking and very human.

Final item

Marc Abrahams has written the Feedback column every week for the past two years. This is his final Feedback column. You can follow his other writings and activities at improbable.com. ▮

Marc Abrahams

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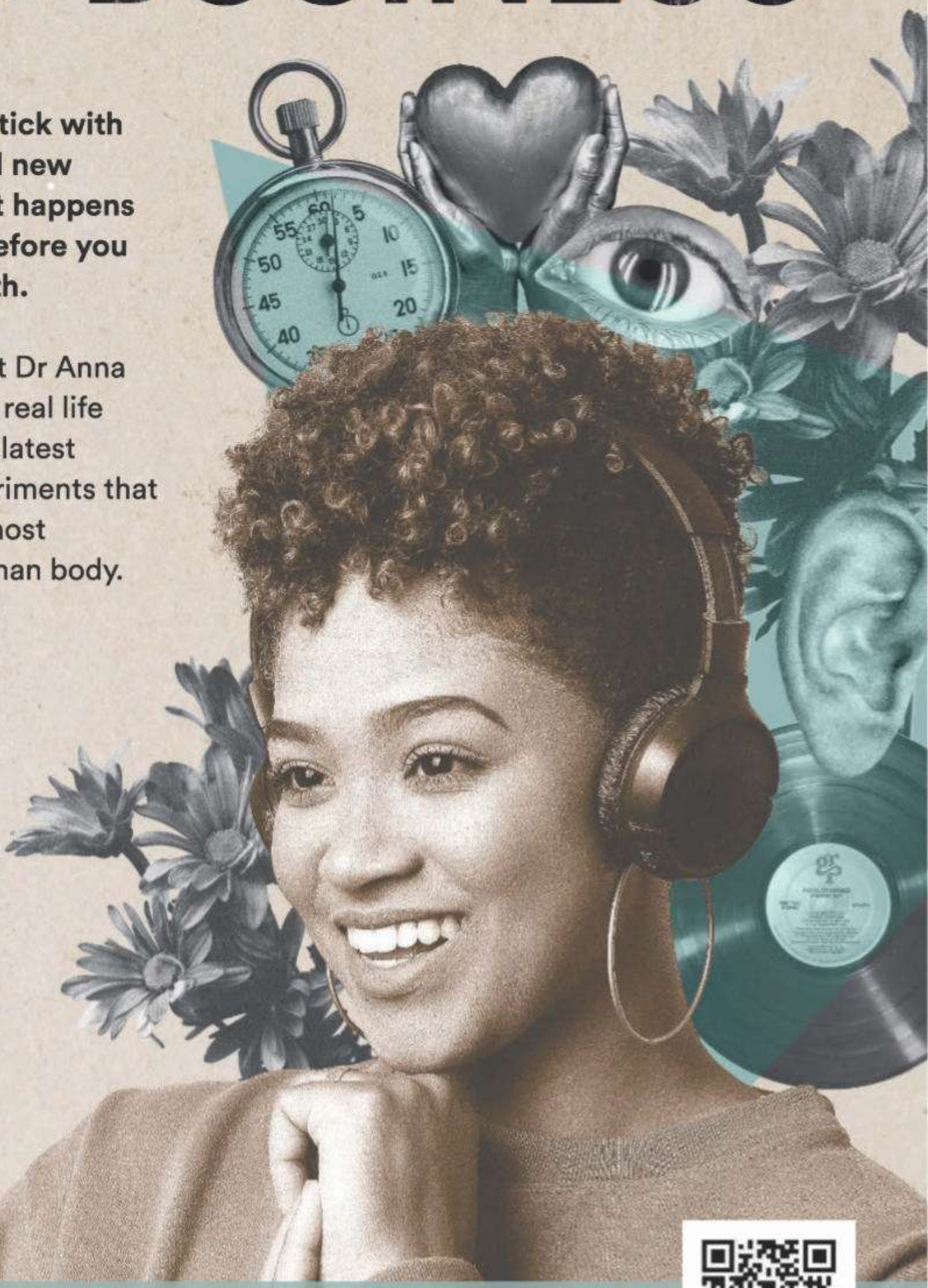

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