New Scientist

WEEKLY July 8 - 14, 2023

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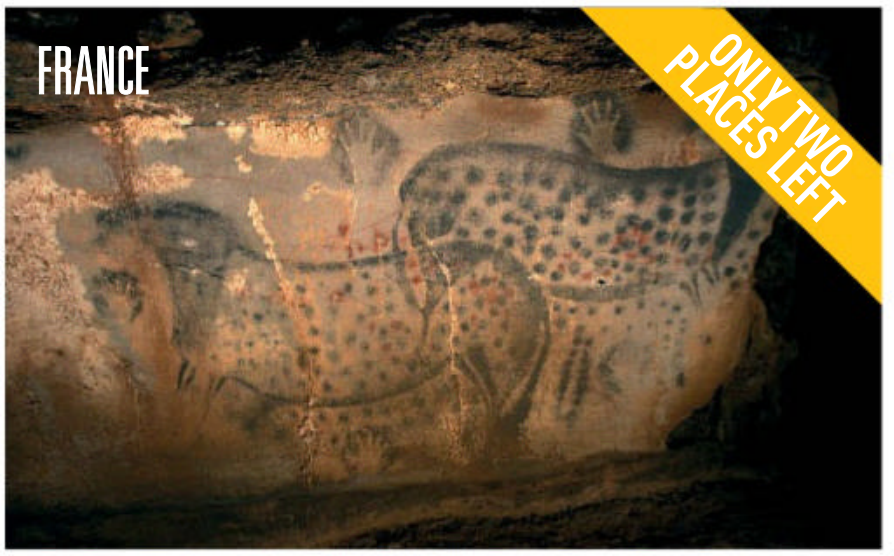

Neanderthal origins: Southern France

1 September 2023 | 10 days

Step back in time on a journey to the key Neanderthal and Upper Palaeolithic sites of southern France between Bordeaux and Nice with palaeolithic archaeologist and author Dr Rebecca Wragg Sykes. See some of the oldest traces left by archaic humans: stone tools, art objects, cave paintings and skeletons that have changed the way we think about Neanderthals.

Science of the Incas: Peru

17 September 2023 | 10 days

Immerse yourself in the Inca civilisation's most important archaeological sites, science and history while exploring the beautiful Sacred Valley.

On this unique expedition, you will learn how the Incas developed a complex society and used their extensive grasp of science and technology to expand rapidly. They displayed a mastery of stone-cutting, astronomy and mathematics as they created buildings for living and worshipping, and their irrigation, aqueducts and precision control of water supported their high-altitude farming on steep slopes.

Renaissance astronomy in Kepler's Prague: Czech Republic

10 September 2023 | 6 days

Discover the giant legacy of the Renaissance period astronomers Johannes Kepler and Tycho Brahe in Prague, the city of a hundred spires, where astronomy, maths, music and art connect.

Accompanied by astronomer and historian Martin Griffiths, you will journey to the heart of early science, exploring Prague's medieval marvels and walking the streets as Kepler and Brahe did while Martin and the local guides share tales of Renaissance history.

Learn how to be an archaeologist at Mycenae: Greece

18 September 2023 | 8 days

An interactive tour offering you a unique opportunity to get "behind the ropes" at Mycenae, one of the most important historical and archaeological sites in Greece.

The trip offers a unique archaeological experience at a 1 acre dig simulator. Follow every single step of the dig process, learn many of the techniques and use specialist technology. The dig simulator facilitates intensive, interdisciplinary "hands-on" education and practical field training in real conditions.

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New Scientist Discovery Tours

A desert adventure: Landscapes and cultures of Utah, USA

19 September 2023 | 9 days

Southeastern Utah holds a wealth of fascinating geological and cultural stories. Join two experienced geologists, Russell Davies and Janok Bhattacharya, to learn about the rocks and their influence on the history of the area.

During the nine days of this tour, you will visit and learn about the geological history of amazing national parks and monuments, including Colorado and Bear Ears national monuments and Capitol Reef, Arches and Canyonlands national parks.

Iron age archaeology in Talayotic Menorca: Spain

16 October 2023 | 5 days

Menorca boasts some of the best archaeology in Europe with some 1,574 sites throughout the island. This wonderful tour takes you to some of the best, as well as more recent sites that reflect periods of more recent occupation. A delightful climate, the charming village of Es Castell and the historic town of Ciutadella will add to the experience.

The archaeological wonders of Jordan

3 October 2023 | 8 days

Explore archaeological remains and the living history of Jordanian sites inhabited from Neolithic and Bronze ages through to the Roman and Byzantine periods. Enjoy varied archaeology sites influenced by many intersecting pilgrims, traders, cultures and societies and experience the historic capital of Amman to castles, caves, mosaics and excavations.

Total Solar Eclipse 2024: USA

1 April 2024 | 10 days | Albuquerque to San Antonio

3 April 2024 | 8 days | Houston to San Antonio

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This week's issue

On the cover

30 Rebuilding reality
A bold new way to think about how the universe fits together

Vol 259 No 3446
Cover image: Radachynskyi/iStock

38 Features

"After having the CRISPR therapy, no cancer cells could be found in Alyssa's body"

News

Views

TOMMY TRENCHARD/PANOS PICTURES

Features

The back pages

Elsewhere on New Scientist

Tour

Space: The history and future of space exploration

Explore key sites in space history, from NASA's space centres to the Very Large Array and Virgin Galactic's Spaceport America, before heading to the Mount Wilson Observatory in California. You will learn about the first rockets, iconic missions and the developing space tourism industry, accompanied by leading academics. This 12-day tour will take place in 2024. Register your interest now to receive further information.

newscientist.com/tours

NS Live

Great moments in future science

Join scientist and broadcaster Karl Kruszelnicki, or "Dr Karl" as he is best known, on 9 October as he discusses some of the scientific mysteries that will be solved in the next century. Discover what feats of engineering, physics, maths or biology will most affect our daily lives in ways we may struggle to conceive of today.

newscientistlive.com

Podcast

Weekly

This edition of the podcast comes from our new hosts in New York, who discuss a law attempting to make AI less racist and sexist. They also explain why a new gravitational wave discovery is making physicists giddy with excitement. Plus (of course), there are some beatboxing orangutans.

newscientist.com/nspod

DZMITRY KLIAPITSKI/ALAMY

We have lift-off! Explore space history at the Kennedy Space Center

CARLOS VILLOCH/ALAMY

Dreams in colour Watch how a sleeping octopus changes colour

Video

Octopus dreams

When asleep, octopuses replay skin patterns that they use to stay safe when they are awake. By looking at electrical signals that these animals produce in their brains while they snooze and while they are awake, researchers have gathered the best evidence yet that the cephalopods dream during a REM-like sleep state. Watch the colour-changing dreams of an octopus in action.

youtube.com/newscientist

Newsletter

Fix the Planet

Environment reporter Madeleine Cuff discusses the hot rocks beneath our feet – are they our ticket to a clean-energy future? Last week, the UK's first deep geothermal well project in 36 years opened at the Eden Project in Cornwall. Cuff explores the potential of geothermal energy around the world.

newscientist.com/fix-the-planet

A note from the editor

Dear reader,

The PPA awards are the UK's most prestigious magazine prizes and competition is stiff. I was therefore really delighted that my colleague Graham Lawton won Writer of the Year at the awards last week. As regular readers will know, Graham is a world-class journalist and he brings huge heft to what we do at this magazine week in, week out. Many congratulations, Graham.

But that wasn't the only good news last Wednesday night. *New Scientist* also won Consumer Media Event of the Year for our flagship live show in London. New Scientist Live, led by my brilliant colleague Adrian Newton, is a huge team effort. Many congratulations to Adrian and everyone else involved.

This year, the event kicks off at ExCeL London on Saturday 7 October. There will be the usual wall-to-wall talks from the world's most exciting scientists, environmentalists and technologists, as well as a huge show floor of activities and exhibits.

Everyone is welcome on the Saturday and Sunday, while Monday will be a dedicated schools day. If visiting in person isn't an option for you, by the way, then the show can be attended virtually. For any and all further information you may desire, please visit newscientistlive.com.

I hope to see you there!

Emily Wilson
New Scientist editor-in-chief

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All about the price tag

Astronomical fees for new CRISPR therapies will stop them reaching those in need

LITTLE more than a decade ago, a new technology was revealed to the world: CRISPR, a way to change DNA inside cells in a more precise way than ever before. The news triggered a storm of media coverage and earned its developers a Nobel prize in 2020. This year, the first genetic therapy based on CRISPR is set to be approved.

This is for sickle cell disease, a condition in which a faulty protein causes red blood cells to form an abnormal "sickle" shape, which can lead to blocked blood vessels, agonising pain and even organ damage. The CRISPR approach activates a gene that can make the correctly-shaped blood cells. This one-off treatment can relieve a lifetime of hardship. Yet there is a catch. Although a price for the therapy, made by Vertex Pharmaceuticals, hasn't been announced, analysts predict it could be between $1 million and $3 million per person.

Sickle cell disease is one of the most common conditions to have been successfully targeted by a genetic therapy and the treatment therefore has a huge potential market. But of the approximately 100,000 people with the condition in the US, where Vertex Pharmaceuticals is based, many are on publicly-funded Medicaid. That set-up can't afford this treatment. It would be a tall order for any healthcare system in the world to be able to offer it to all those who could benefit. And this is just one of many CRISPR therapies in development (see our feature on page 38).

"Analysts say a new gene-editing therapy for sickle cell disease could cost $3 million per person"

It is unclear how authorities will react. There are solutions, including streamlining regulatory processes to make it cheaper to test the efficacy and safety of these therapies, as well as the promise of "off-the-shelf" CRISPR treatments that will significantly reduce costs. But until then, celebrations over CRISPR's incredible clinical potential need to be tempered with the knowledge of its limitations. We don't just need to figure out how to create new medicines – but also how to get them to everyone who needs them. ▮

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News

ERNESTO RYAN/GETTY IMAGES

Environment

Uruguay faces severe drought

This dry expanse is part of the Santa Lucía river in Uruguay, which has been drained by several years of drought. The river feeds Paso Severino reservoir, which supplies drinking water to 60 per cent of the country's population and is now at below 2.5 per cent of its capacity. The shortage means many residents of Montevideo, Uruguay's capital, are having to buy bottled water to drink.

Physics

Listening to the hum of the universe

Astronomers have found signs that suggest huge gravitational waves create a background rumble across the universe, discovers **Alex Wilkins**

THE very fabric of the universe is constantly rippling, according to astronomers who say they have discovered a background rumble of gravitational waves permeating space-time. This may be down to supermassive black holes merging across the cosmos, but could also have more exotic origins, such as leftover ripples in space-time created shortly after the big bang.

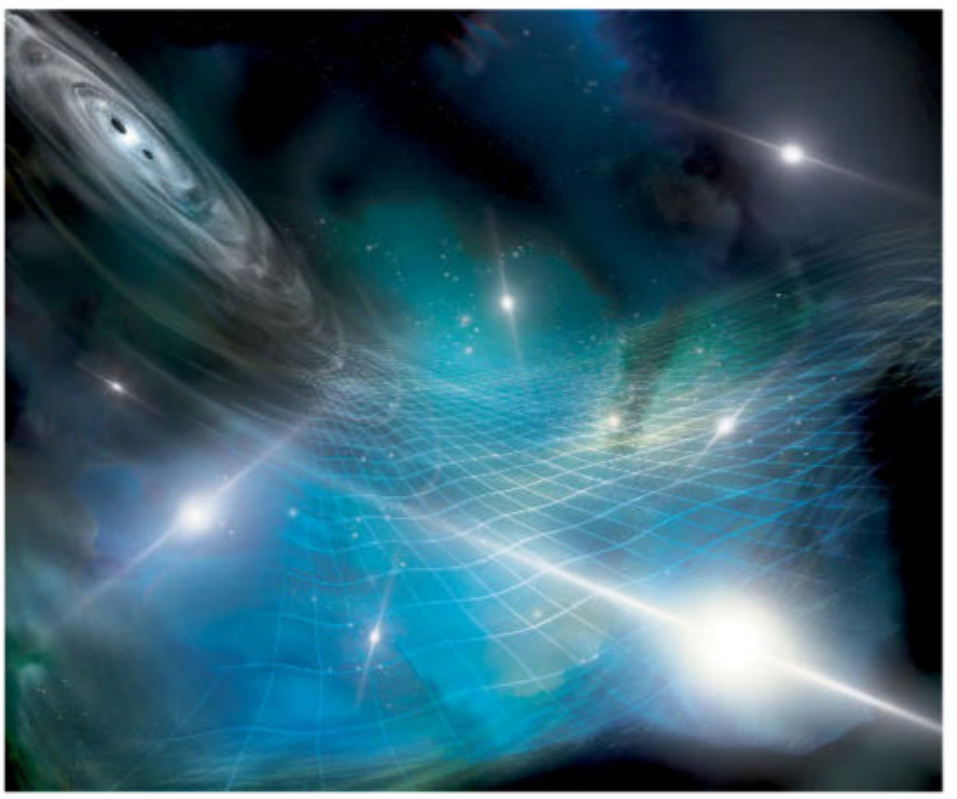
Pinning down the true nature of these waves could tell us about how supermassive black holes grow and affect their host galaxies, or even about how the universe evolved in its first moments.

To find this mysterious hum, astronomers have been tracking rapidly rotating neutron stars called pulsars that blast out light with extreme regularity. By looking at different pulsars across the Milky Way, astronomers can effectively use them as a galaxy-sized gravitational wave detector called a pulsar timing array.

While individual gravitational waves, which are ripples in space-time created by massive objects colliding, have been seen regularly since they were first detected back in 2015, the focus of this search is different.

Those previous gravitational waves all have a localised origin and rise and fall hundreds of times a second, but the newly discovered signal is more like a gravitational wave background that would pervade the entire universe at much lower frequencies, similar in concept to the cosmic microwave background, which is radiation left over after the big bang that is seen all over the universe today.

In 2021, there were the first hints that the North American Nanohertz Observatory for Gravitational Waves (NANOGrav), a US-based collaboration that began in 2007 and that uses a pulsar timing array, had been able to detect this gravitational wave background with the use of radio telescopes.



NANOGRAV

Pulsars have helped reveal ripples in space-time that fill the whole universe

By measuring the light signals from pulsars as they arrive at Earth and checking for tiny time fluctuations that may have been caused by ripples in space-time, it should be possible to spot the background waves. Astronomers thought they had found signs of this. However, they lacked a telltale signature to the signal that is predicted by Albert Einstein's general theory of relativity and that would confirm this really was the cosmic-scale hum they sought.

Now, after a total of 15 years of observations, the NANOGrav team has seen this signature in the signal for the first time, across a range of different gravitational wave frequencies. The collaboration announced the results on 29 June. "It's gone from a tantalising hint to something that is very strong evidence for the gravitational wave background," says team member James McKee at the University of Hull, UK.

This hasn't passed the statistical threshold that scientists need to call it a definite detection of the gravitational wave background, but astronomers are comfortable calling it very strong evidence, at a 3-sigma level of statistical significance, meaning the odds of such a signal cropping up in the absence of the gravitational wave background are around 1 in 1000.

"It's gone from a tantalising hint to strong evidence for the gravitational wave background"

Three other pulsar timing array collaborations, consisting of Europe and India (EPTA), China (CPTA) and Australia (PPTA), also released their results at the same time. The CPTA claims to have found the gravitational wave background at an even higher confidence level than NANOGrav, but for only one frequency, while both EPTA and PPTA are seeing hints of it at a slightly weaker statistical level.

"They're also starting to see this very characteristic correlation signal in their data," says NANOGrav team member Megan DeCesar at George Mason University in Virginia. "We're kind of all seeing it, which is very exciting because that suggests that it is probably real."

But confirming these signals and gaining more confidence in them isn't straightforward, says Aris Karastergiou at the University of Oxford. "It's on an enormous scale, with incredibly difficult data to work with."

The gravitational wave background is minuscule – the strength of the signal that astronomers need to extract compared with the noise that is also picked up at the same time equates to one part in a quadrillion, while the gravitational waves themselves stretch around a light year – more than 9 trillion kilometres – over one wavelength.

That is why pulsars, which are suitably spaced and are some of the most sensitive clocks in the universe, are key to this search. If a constant background of such gravitational waves is distorting all space-time, then it should also be affecting all the pulsars' light pulses, but measuring this isn't easy, due to the many other factors that might affect the timing of the signals from each of these spinning stars in the array.

"We have to be able to account for all of them and that takes a long time," says McKee. "It takes a lot of years of observations, it takes a lot of understanding the noise properties of spin irregularities, the interstellar medium, things like that."

It is only now that pulsar timing array teams feel confident enough

in their data to be able to spot the distinctive pattern within the signal that is predicted by general relativity. As astronomers track pairs of pulsars in the sky, the timing differences in the light from them should become broadly less similar as the angle between them grows. This is because the light from pulsars that appear close in the sky will have travelled a similar route to Earth, meaning it experiences a similar path through the gravitational wave background, while light from those that appear further apart will take different paths.

Thanks to a quirk of general relativity, this relationship actually reverses for pulsars that are very separated, with the timing differences becoming more similar as you compare pulsars on opposite sides of the sky. This full pattern can be described using a graph called the Hellings-Downs curve, and it is this pattern that NANOGrav was missing in 2021.

"They couldn't characterise it specifically and say, yes, it's gravitational waves," says Carlo Contaldi at Imperial College London. "But now that they've measured this Hellings-Downs curve, that's really just a smoking gun."

Competing explanations

So, assuming the signal remains as astronomers gather more data, what is causing the gravitational wave background?

The leading explanation involves pairs of merging supermassive black holes, cosmic giants with masses millions of times that of the sun that are found at the centre of many galaxies. Once these are locked into orbit around each other, as so-called binaries, their extreme masses should bend space-time in the same frequency range that the pulsar timing arrays seem to be measuring for the gravitational wave background. Because these events happen throughout the universe, both in time and space, the waves they produce should knit together to create a distinctive hum that pervades the cosmos.

"It is inevitable that those [pairs of] supermassive black holes are going to be brought together, eventually, to form binaries," says team member Laura Blecha at the University of Florida. "It's just a question of the timescale on which they would actually come together close enough to produce these gravitational waves that NANOGrav and other pulsar timing arrays could observe."

Although this explanation makes the most sense, when Blecha and her colleagues modelled a gravitational wave background caused by merging supermassive black holes across the universe, they saw a slightly different signal to that found by NANOGrav, suggesting that these gargantuan objects are either more massive or more common in the universe than previously thought. If true, this could change our understanding of both galaxy formation and how the universe is structured on large scales.

One way to shore up the supermassive black hole explanation would be to see a gravitational wave background signal growing in strength in a specific portion of the sky, which might be caused by a nearby merger. The PPTA is seeing hints of this in its analysis, but it is still too early to tell.

"We're all seeing this signal, which is very exciting because that suggests it is probably real"

There is enough uncertainty in the NANOGrav signal that the door is open for other explanations, says Nelson Christensen at Carleton College in Minnesota. "We're going to have hundreds of papers from theorists in the coming days where they're going to be presenting other models."

One possibility is that the background waves come from defects in the very early universe as it changed phases. The idea is that this left an imprint in space-time, like the cracks that form when water freezes into ice. Another is that the background in fact comprises long-theorised primordial gravitational waves, produced by the universe rapidly expanding shortly after the big bang during a period known as cosmic inflation.

The view that the data isn't precise enough to rule out one scenario or the other, is echoed by Pedro Ferreira at the University of Oxford. "The problem with this topic is, yes, it could be any number of types of new physics, but you can't really distinguish between them," he says.

To solve that, we need more data. Recently built telescopes like FAST in China and MeerKAT in South Africa, as well as the Square Kilometre Array, the world's largest telescope that is under construction in Australia and South Africa, will allow us to measure the pulsars more often and with much greater precision. Discovering new and more regular pulsars to measure will also help, says McKee.

Combining data gathered by the various groups so far into a global collaboration, too, will allow for a more detailed analysis. There are some pulsars that only Australian telescopes can see, others that can only be glimpsed by European ones. An analysis combining all of the results is already under way, says DeCesar, and should be released in the coming years.

"This is a golden era for gravitational waves," says Christensen. "Within about eight years, not only have we detected gravitational waves on the ground, but now we've detected them with a completely other method at a very different frequency – this is just super exciting." ▮

NANOGrav used the Green Bank Telescope in West Virginia

NANOGRAV

Mind

How our brain works to overcome negative emotions

Moheb Costandi

PATTERNS of brain activity may show when a person is working to overcome negative emotions. This could help to identify people who have trouble doing this.

A reduced ability to control emotional responses, known as emotional dysregulation, has been linked with conditions such as anxiety and depression. To investigate what happens when people try to modify their emotional response, Jared Rieck at the University of Colorado, Denver, and his colleagues scanned the brains of 82 people as they looked at 15 neutral images, such as a photo of an umbrella, and 30 emotionally negative images, such as a photo of someone ill in hospital.

They then asked the participants to try to think less negatively about half of the emotionally negative images while they looked at them, for example by thinking about how the person in hospital is receiving the medical care they need. This allowed the team to use machine-learning algorithms to identify the brain regions that were activated when the participants did this.

The researchers pinpointed a network of structures in the brain. Some, such as the insular cortex and regions of the prefrontal cortex, had already been linked with emotional regulation while others hadn't, such as parts of the visual cortex.

Next, the team scanned the brains of another 40 volunteers as they viewed the same images and found that the algorithms could detect whether these people were just viewing a negative or neutral image, or when they were trying to reduce their response to a negative image, with 82.5 per cent accuracy (bioRxiv, doi.org/khn2).

This could help to identify those at risk of mental health conditions and help assess treatments such as cognitive behavioural therapy, says team member Joshua Gowin. ▮

Environment

US set to nearly halve emissions by 2035, but that isn't enough

James Dinneen

SERGIO FLORES/BLOOMBERG VIA GETTY IMAGES

The number of solar power projects in the US is continuing to grow

THE US is on track to cut its greenhouse gas emissions nearly in half, compared with 2005 levels, by 2035, according to an analysis looking at the impact of the Inflation Reduction Act (IRA).

Just a year after this law – which has a heavy focus on promoting green energy – took effect, climate progress in the US is improving, but the analysis shows the act won't be enough for the nation to hit its target of a minimum 50 per cent emissions cut by 2030.

With climate-related tax credits and funding amounting to nearly $400 billion, the IRA is the most significant spending on this sector in US history and it is already influencing the path of US decarbonisation, which was accelerating even before the law was passed.

"There's been a ton of announcements in clean-energy manufacturing, battery manufacturing, EV [electric vehicle] manufacturing," says Robbie Orvis at Energy Innovation, a US think tank. Requests from wind and solar projects to connect to the grid are growing and people are buying record numbers of EVs and heat pumps, he says.

But a year is hardly enough to gauge the impacts of such a sweeping law, says John Bistline at the Electric Power Research Institute, a non-profit organisation in California.

To assess its long-term effects on emissions, he convened 17 groups, including Energy Innovation, to compare nine economic and energy models. "There's a flurry of modelling released and it's challenging to understand where the models agree, where they disagree, and why," he says.

2030

Year by which the US needs to cut its emissions by 50 per cent

The groups found that the models' latest projections range from a 43 to 48 per cent emissions reduction compared with 2005 levels by 2035, a significant jump from the 25 to 31 per cent reduction the models say would happen without the law.

All the models show that decarbonising the electricity sector is responsible for the greatest share of emissions reductions due to the law (*Science*, doi.org/gsd7cc).

"There's general agreement that this is a big deal for the US," says Ben King at Rhodium Group, a research firm in New York that contributed modelling used in the analysis.

However, those reductions aren't enough to meet US targets under the 2015 Paris Agreement, which require a cut in emissions of at least 50 per cent by 2030. Failing to meet the 2030 target would mean even steeper cuts will be needed to achieve the US goal of net-zero emissions by mid-century.

"Life gets substantially more difficult each year we're not making massive strides in decarbonisation," says King.

Bistline says closing that gap will require some combination of actions by the private sector, state governments and federal agencies to expand clean energy, improve energy efficiency and electrify everything. It is an "all-hands-on-deck situation", he says.

Steps like the US Environmental Protection Agency's recent move to place strict limits on emissions from existing power plants and mandate sales of more EVs can help, says King, as would tighter rules on methane emissions from the oil and gas industry.

With further action, it should still be possible for the US to meet its climate targets, he says. "But there's a lot that has to go right for us to get there." ▮

Astronomy

The past appears to run slower

Cosmological time dilation means the early universe's events seem five times slower to us

Chen Ly

TIME seems to have ticked more slowly when the universe was young, according to observations of ancient astronomical objects that appear to evolve at a fifth of the rate we see today.

The idea that time seems to be slower in the past sounds odd, but it is a direct consequence of the expansion of the universe since the big bang. This expansion means that light from ancient cosmic events must travel increasingly longer distances to reach Earth, and therefore takes more time to arrive.

As a result, cosmic events that are extremely distant or far back in time appear to unfold more slowly than the same event happening nearby, right now. That isn't to say the early universe was in slow motion, however – anyone present billions of years ago would have seen time passing normally.

Since the 1990s, astrophysicists have observed this celestial time warp in distant supernovae – powerful stellar explosions – with the oldest one going back to around half the age of the universe and appearing to evolve at 60 per cent of the speed we see today. Now, Geraint Lewis at the University of Sydney, Australia, and Brendon Brewer at the University of Auckland, New Zealand, have detected a more extreme, earlier version.

The pair looked at quasars, which are objects at the centre of some galaxies comprised of a supermassive black hole inside a disc of hot plasma that spit out high energy particles. They are among the oldest objects in the universe, with the earliest we have seen emerging just 600 million years after the big bang.

An artist's impression of a quasar. These seem to demonstrate time dilation

SMILE_RANIE/SHUTTERSTOCK

In theory, this age makes quasars suitable for probing time dilation in the early universe, but their unpredictable nature makes that difficult, unlike with supernovae.

"Imagine you've got a firework, it's bright but it fades away over a few seconds, that's like a supernova," says Lewis. "Now, imagine you're looking at a firework display, the brightness varies and there can be lots of stuff going on." By watching lots of firework displays, however, a pattern emerges, he says.

That is exactly what Lewis and Brewer did by analysing the data of 190 quasars. The duo compared quasars that they thought would behave similarly by grouping them by brightness and how red-shifted they appeared – this is because the light from distant objects is stretched into longer, redder wavelengths.

They then compared the quasars within a group with each other and found they had similar patterns of activity over a certain time period.

Using these patterns like a clock, the duo found that the earliest quasar, which is at a distance putting it about 1 billion years after the beginning of the universe, appeared to run five times more slowly than quasars from today (*Nature Astronomy*, doi.org/khj2).

This is our earliest ever observation of cosmological time dilation, says Lewis. ▮

Environment

Humans exploit one-third of all vertebrate species

NEARLY one-third of all known vertebrate species across the world are used or traded by humans.

"We've become this kind of super-predator," says Rob Cooke at the UK Centre for Ecology & Hydrology. Cooke and his colleagues have analysed data from the International Union for Conservation of Nature on 46,755 species of vertebrates, which includes all known mammals, birds, amphibians, reptiles and fish.

The records show how people use each species. This includes killing them for food, clothing, specimen collections and recreational hunting, as well as taking them from the wild to be pets or to display in zoos.

The team found that 14,663 species, around a third of the total, are used or traded. About 55 per cent of these are killed for food and 40 per cent are kept as pets.

Nearly half of ray-finned fish and bird species are used or traded, which makes them the most exploited groups, while reptiles and amphibians are the least exploited. Of all the exploited species, 39 per cent are threatened due to human use or trade (*Communications Biology*, doi.org/gsd65q).

Cultural reasons may be why the other two-thirds of vertebrate species aren't used, says team member Boris Worm at Dalhousie University in Canada. "Rarity and accessibility are not really an issue because we're exploiting some incredibly rare and hard-to-find species." Thousands of rodent and bat species aren't used because they are seen as unclean, he says.

"If you take an animal, it's gone from the wild. It can't reproduce there and can't sustain the population"

The researchers hope the work will raise awareness of how humans exploit animals. "If you take an animal, it doesn't matter what you do with it. It's gone from the wild, it can't reproduce there and it can't sustain the population," says Worm.

The study shows the scale of the problem facing biodiversity and the urgent need for action, says Pedro Jaureguiberry at the National University of Córdoba, Argentina. ▮ CL

Evolution

Ape family tree hints human ancestors weren't that violent

Soumya Sagar

THE last common ancestor of humans, chimpanzees and bonobos wasn't especially prone to violence, according to a study trying to reconstruct the evolution of warlike behaviour in apes. But researchers say its conclusions are speculative.

Whether violence is integral to human nature has been debated for centuries. Biologists have tried to find an answer by looking at chimpanzees, which, along with bonobos, are our closest living relatives.

All four subspecies of chimpanzee engage in violence between groups. Some biologists have noted parallels with human warfare, suggesting that the common ancestor of humans and chimps must have been violent and aggressive.

But this focuses on only one of our closest relatives, leaving out bonobos, says Kit Opie at the University of Bristol, UK. "Different groups of bonobos usually get on very well and one of the ways they resolve conflict is by having sex."

To get a broader view, Opie and his colleagues collected data from 301 primate species on 13 traits linked to lethal violence, such as infanticide and male alliances. They traced these behaviours across the primate evolutionary tree and performed a statistical analysis to identify which traits were relevant to intergroup violence.

They found that encounters between groups in the common ancestor of humans, bonobos and chimpanzees probably weren't always hostile.

In chimpanzees, only females leave their social groups when they reach maturity. Opie and his colleagues think this makes intergroup violence more likely, because groups are dominated by males with strong bonds. But, by inferring ancestral behaviour using the dispersal patterns in existing primates, they found that the females and males of our common ancestor were equally likely to leave their social group after puberty.

13

Number of behavioural traits linked to lethal violence

"If anything, it may have been more like gorillas and modern humans, who can vary the dispersal patterns," says Opie.

The three other traits that the researchers learned were important in influencing violence in primates were male coalitions, males being dominant over females and males being exclusively responsible for defending the group – features that are also seen today in chimpanzees.

Opie and his colleagues found that the most recent ancestor we share with chimps was probably the first ape that showed cooperation among unrelated females. They conclude that violence in males was kept at bay by such female alliances and the males having to cooperate to form coalitions (OSF Preprints, doi.org/khgw).

Using evolutionary trees to reconstruct the behavioural traits of ancestral species is highly speculative, says Michael Wilson at the University of Minnesota. "Even with a fossil record, inferring the social behaviour of extinct species poses tremendous challenges."

The study's conclusions are plausible, says Steven Pinker at Harvard University, but he also thinks they are speculative.

Comparisons with humans' closest relatives show there is an inherent propensity for violence in social-living species, says Martin Surbeck, also at Harvard University. But many factors determine whether those traits are selected for and manifest in a species or context, he says. ▮

SERGEY URYADNIKOV/ALAMY

Bonobos aren't usually violent towards other groups and get on well

Health

Genetic marker found for severity of multiple sclerosis

Grace Wade

A STUDY of more than 22,000 people with multiple sclerosis (MS) has identified a genetic variant associated with the condition's severity. It was seen in people who experienced quicker progression of the disease, and the finding could lead to better treatment.

MS is a neurodegenerative condition that causes brain lesions and leads to difficulties with walking, memory and other bodily functions. Some people with it can lead relatively normal lives with treatment, while others experience rapid disease progression.

To investigate this disparity, Adil Harroud at McGill University in Canada and his colleagues performed a genome-wide association study using data from more than 22,000 people with MS. Such studies use statistical analysis to pinpoint genes associated with certain characteristics.

After analysing almost 8 million genetic variants, the researchers found one that seemed linked to a score that measures disability in people with MS. On average, people with the marker required walking assistance 3.7 years earlier than those without it.

The researchers then examined brain tissue samples collected from a separate group of 290 people with MS who had died. On average, those with the marker had nearly twice the number of lesions in the outer layer of their brain and in their brainstem than those without it (*Nature*, doi.org/kg6j). This indicates that the variant has a connection to the neurological injuries that trigger the progression of MS, say the researchers.

The finding could help doctors identify which people with multiple sclerosis are more likely to have severe disease and adjust treatment plans accordingly, says Violaine Harris at the Tisch MS Research Center of New York. ▮

Archaeology

A 40,000-year-old rope-making kit

Stone tools found in caves in the Philippines seem to have been used for processing plant fibres

Soumya Sagar

THE prehistoric inhabitants of the Philippines could make ropes and baskets from plant fibres almost 40,000 years ago, according to an analysis of stone tools. The find suggests the people living then may have been able to construct more sophisticated things, such as boats and buildings, than previously thought.

"Mastering fibre technology was a very important step in human development. It allows people to assemble different objects together and to build houses, make composite objects, hunt with bows," says Hermine Xhauflair at the University of the Philippines Diliman. "Eventually, the existence of ropes allows people to attach a sail to canoes and create boats that can be used to go very far away."

Because of this, archaeologists are keen to study ancient fibres, but their organic nature means few have been preserved – the oldest ever found is a 50,000-year-old piece of string thought to have been made by Neanderthals.

This lack of specimens means archaeologists often have to rely on indirect evidence for textile-making, such as depictions in art, the seeds of fibre plants or signs of fibre processing on stone tools.

Xhauflair and her colleagues have done just that, by analysing 43 stone tools dating from 33,000 to 39,000 years ago that had been excavated from the Tabon caves on Palawan island in the Philippines.

To see if these tools had been used to make textiles, Xhauflair first learned fibre-processing techniques from modern-day Indigenous inhabitants of the island, the Pala'wan people. She then used replicas of the tools, made from a stone known as red jasper, to thin the fibres from bamboo, palms and other plants. The researchers used a microscope to examine these replica tools for patterns of wear created by plant processing, then compared these marks with the ancient tools.

Three stone tools from the cave showed similar marks, which suggests that they were once used for transforming rigid plants into supple strips. These signs included a brush stroke-type pattern of striations, micro-polish and micro-scars on the surface of the tools. The researchers also found that a cave tool had residues on it from a plant in the Poaceae family, of which bamboo is a member (*PLoS One*, doi.org/gsd7t8).

HEMIS/ALAMY

Inside the Tabon caves in the Philippines, a treasure trove of ancient discoveries

Xhauflair isn't sure what the prehistoric Filipinos did with these supple strips. Today, the Pala'wan people use them to make baskets and traps or to tie objects together, so they may have had the same use in the past. "What we can conclude is that prehistoric people had the capacity to do all these things as soon as they knew how to process fibres," she says.

"The study is intriguing as it opens the door to investigating aspects of past human behaviour that is typically not preserved in archaeological sites," says Ben Shaw at the Australian National University. "Even though the plant remains are long gone, [the team's] detailed approach has made them visible by looking at the tools used to process them." ▮

Marine biology

Atlantic cod may be five species rather than one

THERE are five species of Atlantic cod, researchers have claimed after conducting a genetic analysis of the fish. "What we thought was a single species is actually more species," says Einar Árnason at the University of Iceland. "It's important in terms of biodiversity." Not everyone agrees with the findings, though.

Árnason and his colleagues have sequenced the genomes of nearly 1700 Atlantic cod, currently regarded as a single species called *Gadus morhua*, from across the Atlantic Ocean. For comparison, they also sequenced the genomes of several related species, including Pacific cod and Greenland cod.

They found the Atlantic cod genomes could all be put into one of five distinct groups. "They are not interbreeding," says Árnason.

There is a lot of overlap in the geographic areas where the five cod groups are found. But the researchers think each group lives in distinct habitats at different depths.

"They are habitat specialists, and they are breeding in the habitat that they choose to live in," says Árnason. "The sea is three dimensional. They can be separated out even though they reside at the same coordinates."

For instance, the researchers call one of the groups SS, because it lives on shell sands. Another, known as S, is found mostly around the Baltic Sea and appears to be adapted to brackish water (bioRxiv, doi.org/khhw).

"The five species are habitat specialists, and breeding in the habitat that they choose to live in"

Árnason and his colleagues have yet to give the five groups scientific names and are now investigating the questions raised by their discovery, such as whether there are previously unnoticed physical differences, and whether any of the five groups are threatened.

But other researchers are yet to be convinced. "I am a bit surprised about the conclusion that there exist five cryptic [hidden] species," says Kjetill Sigurd Jakobsen at the University of Oslo, Norway, whose team was the first to sequence the genome of the Atlantic cod. ▮

Michael Le Page

Health

Iceman's health claims assessed

Wim Hof's claims that breathing and cold exposure have widespread benefits lack evidence

Carissa Wong

THERE is little good-quality evidence to support Wim Hof's claims that controlled breathing and cold exposure have widespread health benefits. Also known as The Iceman, Hof claims his so-called three pillars – controlled breathing, cold therapy and "commitment" – can benefit everything from our immune health and energy levels to sleep quality and creativity.

In the first review into the Wim Hof Method, researchers have found that just a few small studies support his claim that these techniques lower inflammation, with other experiments failing to back up that his methods improve athletic performance.

To investigate, Lucy Hammond and Omar Almahayni at the University of Warwick, UK, reviewed eight studies that had been published in peer-reviewed journals and had what they deemed to be a good design. The first four of these explored Hof's breathing and cold therapy techniques, while the other four tested only his breathing methods – generally defined as taking 30 to 40 deep breaths, holding the final exhale for as long as you can and then holding the next inhale for around 15 seconds, repeated three to four times.

Of the first four studies, two linked Hof's methods to reduced inflammation, specifically to lower levels of inflammatory proteins. But the two studies only analysed inflammation over the short term and didn't look at the important aspect of immune cell activity, says Jonathan Peake at Queensland University of Technology, Australia. "There is no evidence that the Wim Hof Method reduces chronic inflammation, and more research is needed that includes individuals with different types – and severities – of inflammation."

Of the four studies that assessed whether Hof's breathing method alone enhances our ability to exercise, none found an effect on how much air entered and left the participants' lungs while exercising, which is sometimes used as a marker of athletic performance (medRxiv, doi.org/kg54). And "none of the studies compared the Wim Hof Method with other methods of enhancing exercise performance, such as a warming up", says Peake. Hof's other claims, such as improving sleep quality, weren't assessed in the studies.

More than 80 per cent of the studies' participants were male, making it hard to generalise the results to the wider population, say Hammond and Almahayni.

Overall, the evidence to support Hof's approach is "not strong at all, in my opinion", says Peake. From a safety perspective, cold therapy has been linked to amnesia and cold burns. "There could be medical risks associated with extreme cold exposure for people with pre-existing risk factors," says Peake. For example, sudden exposure to extreme cold temperatures can increase the risk of heart-related events in particularly at-risk people, he says.

Hof didn't respond to a request for comment. ▮

KIN CHEUNG/AP PHOTO/ALAMY

Wim Hof at an event to raise awareness of climate change in Hong Kong in 2010

Zoology

Female frogs croak to tell horny males to cool off

MALE frogs often force females to mate with them, but in one species, a croak from the female seems to persuade males to leave her alone.

"In general, male frogs are known to jump on even inorganic objects if they are female-like," says Makoto M. Itoh at Nagoya University in Japan. "However, this species [stops attempting] such holding behaviour at the sound of a female's call. I consider it rather gentlemanly."

Most frog calls are produced by males as they try to attract mates. A few years ago, Itoh discovered that female black-spotted frogs (*Pelophylax nigromaculatus*) call quietly as well.

To investigate the purpose of the female calls, Itoh captured 15 males and 27 females from ponds in Kyoto during the frogs' annual breeding season. Fourteen of the females had maturing eggs in their ovaries, suggesting they were fertile.

In his lab, he introduced each female to up to six males, one at a time, in a test tank. All but one of the females without eggs and half of those with eggs called out at the males – especially when the males took a hop towards them.

The calls were low volume and seemed to be a communication to the male, says Itoh. Sometimes, the males called back – and when that happened, half of the females called back at them again.

Following these calls, none of the males attempted mating, says Itoh. For the most part, they turned and hopped away. Successful mating only occurred when the female remained silent (*Behavioural Processes*, doi.org/kg58).

"The males stop holding on at the sound of a female's call. I consider it rather gentlemanly"

Although some of the vocal females had eggs, Itoh says the calls may have been an honest signal about their fertility status, as the eggs might not have been mature.

"The results do definitely suggest that females emit calls to deter male coercion, but I do not think the data are quite robust enough to say that with 100 per cent confidence," says Derek Coss, a frog communication researcher. ▮

Christa Lesté-Lasserre

Exercise

Muscle fibres warp as we get older, but we can restore them

Michael Le Page

AS WE age, our muscle fibres become misshapen, but resistance training seems to at least partially restore them.

Casper Søndenbroe at Copenhagen University Hospital in Denmark and his colleagues have looked at samples taken from the thigh muscles of about 200 people aged between 20 and 97. The researchers gave the muscle fibres a score based on how much their cross-sectional shape deviated from a circle. Healthy muscle fibres deviate slightly because they have a pentagonal or hexagonal shape, scoring about 1.2.

Misshapen fibres may have an elongated or "squashed" shape, with extremely askew ones scoring around 1.9. For each sample, the scores of fibres were averaged to get an overall figure.

In the slow-twitch muscle fibres used for endurance activities, there was a small, gradual increase in misshapenness with age, the team found. In the fast-twitch muscles used for powerful movements, such as lifting weights, there was a bigger increase, rising from 1.4 around age 20 to 1.6 by age 90.

Misshapenness correlated with muscle performance as well or better than muscle size did, measured by the cross-sectional area of muscle fibres, says Søndenbroe.

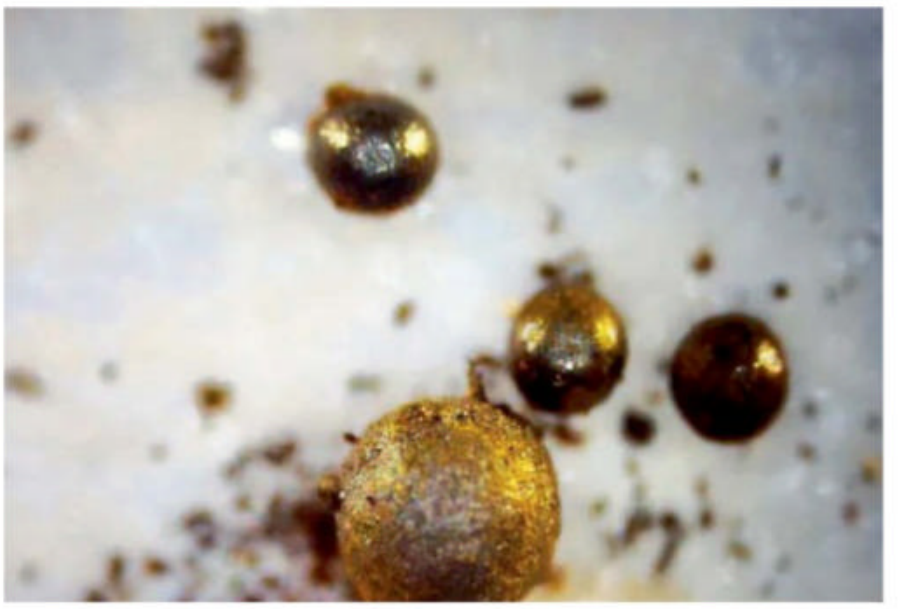
He and his colleagues then got about 60 of the people to do at least three months of heavy resistance training three times per week.

Afterwards, the researchers took further muscle samples and found a decrease in misshapenness in fast-twitch fibres in both younger (aged 20 to 36) and older (aged 60 to 80) volunteers. In the older group, the average score fell from around 1.5 to 1.45, for instance. The results have been posted as a preprint, but aren't yet peer reviewed (bioRxiv, doi.org/khf4). ▮

Space

Are these the remains of an interstellar meteor?

Leah Crane



AVI LOEB

A microscope image showing some spherules found in the Pacific

TINY flecks of an interstellar meteor may have been found at the bottom of the ocean. Researchers mounted an expedition to the Pacific Ocean just north of Papua New Guinea to hunt for fragments of the meteor, which entered Earth's atmosphere in 2014, and they say their search has been successful – but other scientists remain sceptical.

Avi Loeb and Amir Siraj at Harvard University identified the meteor as potentially interstellar in 2019 based on its recorded velocity, which they claimed was fast enough to indicate that it hurtled into our solar system from interstellar space. The data they used came from classified US government sensors, so there wasn't enough information to prove their claim, but the government released a statement confirming the high velocity. The pair nicknamed the object Interstellar Meteor 1, or IM1, although many astronomers remain unconvinced that it is truly interstellar.

2014

When "Interstellar Meteor 1" entered Earth's atmosphere

Using the sparse data the government did release, Loeb and Siraj traced the area where the meteor exploded in the atmosphere, and Loeb and his colleagues headed out on a privately funded voyage.

They dragged the sea floor under the area using a magnetic sled to pick up bits of iron, as well as a sieve similar to those used to pan for gold, and they have found 40 of what they say are fragments of IM1.

The fragments are in the form of tiny iron spherules, each less than a millimetre across.

This in itself isn't particularly surprising. "Micrometeorites should be found all across the sea floor due to their constant accumulation by the Earth, so if you're thorough enough, you're bound to find something," says Alan Fitzsimmons at Queen's University Belfast in the UK, who wasn't involved with this work.

However, Loeb says that they only found these spherules in the area under where the explosion is thought to have happened, not in the other spots they visited as controls.

He also claims to have found strange compositions upon preliminary analysis.

"The composition didn't look like anything that is Earth-like – I will not go into detail until we do the complete analysis on land, but we find composition patterns that deviate from what was reported in the past," Loeb told *New Scientist*. "Some elements are abundant that are extremely rare, and some are not present at all."

One of the elements that seems to be missing is nickel, which usually makes up between about 5 and 10 per cent of iron meteorites. That may be unusual, but it isn't enough to convince some astronomers that the spherules are interstellar.

"The allusion is that it's not like the other spherules, but we don't know that yet – and, in fact, there's a big dispersion in nickel abundance in the others, especially those in the ocean," says David Jewitt at the University of California, Los Angeles.

Loeb and his colleagues plan to do a more detailed analysis of the spherules as soon as they get back from their expedition, so there should be results within weeks.

If they show that these tiny marbles have a very different make-up to those from within the solar system, or that they are far older than the solar system, that could finally be conclusive proof that IM1 truly is interstellar – and that these are the first fragments of an interstellar rock ever recovered. ▮

Humans

The myth that men hunt while women forage is wrong

Michael Le Page

ANDREY GUDKOV/ALAMY

A woman from the Dani tribe in Indonesia with a bow and arrow

THE idea that men hunt while women stay at home or forage is almost completely wrong, a review of foraging societies around the world has found. In fact, women hunt in 80 per cent of the societies looked at, and in a third of these women hunt big game over 30 kilograms as well as smaller animals.

The findings are likely to be representative of foraging societies past and present, says Cara Wall-Scheffler at the University of Washington in Seattle. "We have nearly 150 years of ethnographic studies sampled, we have every continent and more than one culture from every continent, and so I feel like we did get a pretty good swathe of what people do," she says.

There was already evidence that women hunted in past cultures. For instance, a 2020 study found that of 27 people discovered buried with hunting weapons in the Americas, nearly half were women. Yet some have been reluctant to conclude that these women were hunters.

"There is a paradigm that men are the hunters and women are not the hunters, and that paradigm colours how people interpret data," says Wall-Scheffler. Her team looked at a database called D-PLACE that has records on more than 1400 human societies worldwide made over the past 150 years. There was data on hunting for 63 of the foraging societies recorded and, of these, 50 described women hunting.

80%

Proportion of foraging societies looked at in which women hunt

For 41 of these societies, there was information on whether women's hunting was intentional or opportunistic – that is, whether they were going out to hunt rather than catching animals they stumbled on while gathering plants, say. In 87 per cent of cases, it was intentional. "That number was higher than I expected," says Wall-Scheffler.

The team also looked at data on the size of animals hunted by women, which was recorded for 45 societies. In 46 per cent of cases it was small game such as lizards and rodents, 15 per cent medium game and 33 per cent large game. In 4 per cent of the societies, women hunted game of all sizes. The study didn't include the equivalent data for men (*PLoS One*, doi.org/gsdzbr).

The analysis found that women's hunting strategies were more flexible than men's. "Women use a wider range of tools when they go hunting, they go out with a wider variety of people," says Wall-Scheffler.

They may hunt alone or with a male partner, other women, children or dogs, for instance, says Wall-Scheffler. While the bow and arrow was commonly used by female hunters around the world, she says, women also used knives, nets, spears, machetes, crossbows and more.

This greater flexibility could be a result of women's mobility varying when they are pregnant or breast-feeding, she says. In at least some cases, women hunted with babies strapped to their backs, for instance.

In some societies there were taboos on women making or using specific tools or weapons, says Wall-Scheffler, forcing them to find alternatives.

"This paper represents a much-needed meta-analysis," says Randy Haas at Wayne State University in Michigan, whose team carried out the study of burials in the Americas. "The findings, coupled with related archaeological findings, convincingly show that division of subsistence labour is much more variable than previously thought," he says. ▮

Physics

IceCube detector finds neutrinos from the Milky Way

Leah Crane

AFTER more than a decade of searching, the IceCube neutrino detector in Antarctica has found high-energy particles from within our galaxy, the Milky Way.

The disc of the Milky Way is bright in every wavelength of light – particularly in gamma rays, which tend to be accompanied by neutrinos. But any neutrinos from within our galaxy have historically been overwhelmed by stronger signals from other galaxies, so we haven't been able to observe them.

"It took us 10 years to find the galactic plane in neutrinos," says IceCube head Francis Halzen at the University of Wisconsin-Madison. "It's totally counterintuitive. It's like if you went outside at night and saw a sky bright in active, distant galaxies, but no Milky Way."

The IceCube collaboration applied a machine-learning algorithm to the data the detector gathered between 2011 and 2021. This allowed the researchers to flag many signals as worth investigating that were previously discarded as noise.

They found a glow of high-energy neutrinos that seem to come from within our galaxy (*Science*, doi.org/gsd4js). Generally, neutrinos form when cosmic rays – high-energy particles travelling through space at nearly the speed of light – collide with other matter and create showers of particles and radiation.

Where cosmic rays originate and how they get such high energies is controversial. Many astrophysicists think they come from huge black holes devouring material, but that can't be the source for the cosmic rays that created the neutrinos IceCube saw. "We don't have an active supermassive black hole in our galaxy," says Halzen.

"Cosmic rays seem to dominate the high-energy structure of our galaxy," he says, and finding them could help us determine how they shape the universe. ▮

Food

Soya beans get a portion of pork

Moolec's transgenic "Piggy Sooy" beans are a quarter pig protein rather than plant protein

Michael Le Page

MEAT substitutes could be about to get a lot more meat-like. A UK-based company called Moolec says it has created genetically modified soya plants that produce beans in which a quarter of the soluble proteins are pig proteins. It has named its plant "Piggy Sooy".

Moolec is also creating pea plants that contain beef proteins. It claims its products will be able to provide a similar taste, texture and nutritional value as meat, but without the high costs associated with cultured meat.

The company won't yet say which pig genes have been added to soya to produce Piggy Sooy. "At this point, we can't disclose that, for intellectual property reasons," says Amit Dhingra at Moolec.

However, photos of the Piggy Sooy beans show they have a pinky tinge (see photo, right). This means it is likely that one of the added genes is for a protein with an iron-containing haem group such as myoglobin. Myoglobin gives red meat its colour and also contributes to its flavour.

Impossible Foods already adds a plant haem protein called soy leghaemoglobin to its burgers to give them a more meat-like look and taste. Leghaemoglobin is naturally found in the roots of soya plants, but to obtain enough, Impossible Foods manufactures it in genetically modified yeast.

Another company called Motif produces beef myoglobin as an additive called Hemami for meat substitutes. Motif began manufacturing it in modified yeast, but plans to make it in maize to scale up production.

These "Piggy Sooy" soya beans can contain 25 per cent pig protein

MOOLEC

Dhingra says the added proteins in Piggy Sooy have been chosen to give the right "feel in the mouth" after food is cooked, but wouldn't comment when asked if myoglobin was one of them, nor would he say if anyone has tasted Piggy Sooy beans yet.

Products such as Piggy Sooy could help make our food supply more sustainable, says Dhingra.

Environmental writer Mark Lynas thinks similarly. "It should also be much more environmentally sustainable, and also avoid the unpleasantness of intensive animal farming," he says.

Lynas has argued that the "yuck factor" associated with transgenic plants – those whose DNA has been modified using genetic material from something else – is what led to the opposition to genetically modified crops. He isn't sure how Piggy Sooy will go down with the public.

"I really have no idea how this will land. It's interesting that they have gone all-out for the 'piggy' thing – there is no attempt to sweeten the pill," says Lynas. "Of course, scientifically it's just a protein, and we already engineer lots of plants and microbes to make desirable proteins."

Moolec points out that 98 per cent of all soya grown in the US is genetically modified, and says the success of Impossible Foods shows that consumers aren't deterred by genetically modified products.

The company is now seeking the approvals necessary to grow and sell Piggy Sooy in the US, says Dhingra. ▮

Sexual health

Vibration neurons in clitoris and penis play key role in sex

MYSTERIOUS neurons in the clitoris and penis turn out to respond to vibration and light touch, and seem crucial for healthy sexual function. The finding may explain why vibrators are sexually stimulating.

Lijun Qi at Harvard University and his colleagues used staining techniques to examine clusters of nerve endings from the clitorises and penises of mice, known as Krause corpuscles. They were discovered in humans in 1860, but their function was unclear. The team found the corpuscles were densely concentrated in the clitoris and more sparsely spread in the penis of mice.

Next, they applied stimuli to male and female mouse genitals. The neurons inside the Krause corpuscles were most responsive when the genitals were touched with a vibrating device or stroked with a paintbrush, as determined by measuring their electrical activity.

"When they shone blue light on the penises of five of these males, they all developed erections"

To explore further, the researchers genetically engineered male mice so their Krause corpuscle neurons would be activated by light, rather than touch. When they shone blue light on the penises of five of these males, they all developed erections.

The researchers also genetically engineered female mice to lack Krause corpuscles and found they tended to be less receptive to sexual advances and ended intercourse earlier than unmodified females.

Similarly, males without Krause corpuscles took longer to initiate sex, withdrew earlier and were less likely to ejaculate than typical males (bioRxiv, doi.org/kg3g).

The findings suggest that stimulation of Krause corpuscles is key for motivating sex and sexual function, possibly by producing pleasurable sensations, says Qi.

The corpuscles probably serve a similar role in people, because of anatomical similarities, says team member Michael Iskols. Vibrators used for sexual stimulation often vibrate at the same frequencies as those that most strongly activated mouse nerves: about 40 to 80 hertz, he says. ▮

Alice Klein

Insects

Baby bugs eat adults' poo for a bacterial boost

Alice Klein

SHORTLY after hatching, young squash bugs go on a mission to find and eat adults' faeces so they can acquire bacteria they need to survive. They are forced to do this because they don't inherit the vital bacteria from their parents.

Squash bugs (*Anasa tristis*) are agricultural pests that commonly attack courgette, also known as zucchini, and pumpkin crops in North and Central America.

The bugs have a symbiotic relationship with *Caballeronia* bacteria, which live in their guts and are crucial for their growth, development and survival.

Other species that require symbiotic bacteria, like stink bugs, get immediate access at birth because their mothers leave bacteria-rich faeces on their eggs.

However, squash bugs aren't left the same inheritance, says Scott Villa at Davidson College in North Carolina. "They basically leave it up to each generation to find it on their own in the environment."

Villa and his colleagues have discovered that newborn squash bugs, also referred to as nymphs, do this by seeking out and feeding on the faeces of adult squash bugs, which are packed with *Caballeronia*.

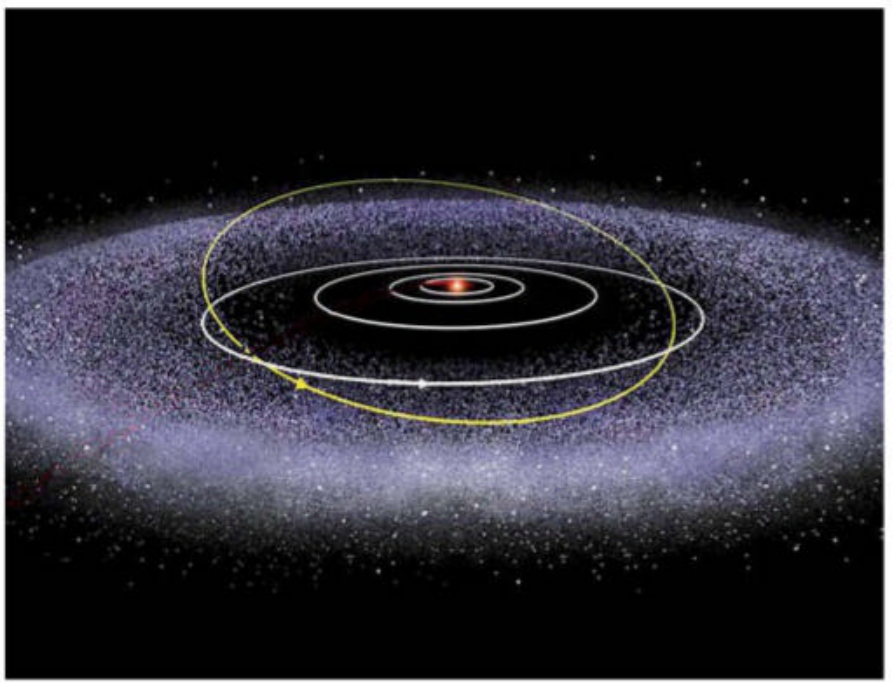
They found that nymphs choose to move towards and eat adult faeces even when provided with ample summer squash to munch on. Only once the nymphs had acquired the *Caballeronia* did they concentrate on eating the squash (*Current Biology*, doi.org/kg2b).

The researchers hope the findings will lead to new strategies for eliminating the pests from crops. "Squash bugs can be a devastating pest, and we now know a key vulnerability in their life cycle," says Villa. If we can somehow break their ability to find their bacteria, we might be able to halt population growth, he says. ▮

Space

Planet the size of Uranus could be hiding in our solar system

Leah Crane



NASA

We know little of what is beyond the doughnut-shaped Kuiper Belt

THE solar system could be hiding an extra planet in its outermost reaches. It is possible that a giant planet lurks in the Oort cloud, which begins hundreds of billions of kilometres beyond dwarf planet Pluto and has typically been considered the domain of comets.

Most multi-planet systems, especially those with giant worlds like our own solar system, undergo what is called a dynamical instability at some point in their lifetime, wherein the planets interact gravitationally and violently swing past one another. Often, this is thought to result in one or more of these worlds being hurled out of the system entirely.

Sean Raymond at the University of Bordeaux in France and his colleagues performed a series of simulations of these instabilities, taking into account the gravity from the galactic environment of the systems.

They found that up to 10 per cent of the exiled planets may actually hang out at the edges of their systems, refusing to be banished altogether. "Unless we don't understand gravity at all, lots of planets should be ejected, and it turns out some of them might not quite be ejected at all," says Raymond.

These planets would follow a strange, elongated orbit, spending most of their time at extraordinary distances from their stars and then plunging briefly inwards.

7%

The probability a world the size of Uranus lurks in the Oort cloud

"Most of the time, it's this frozen ice ball and all you see is stars, and then once in a while one star starts to get brighter and brighter and it gets hotter and hotter and all of a sudden it's roasting," says Raymond. "It would be very dramatic."

The researchers found that given our best models of our solar system's history, the probability of a world like this, about the size of Uranus, in the Oort cloud is about 7 per cent. It is unlikely there would be anything bigger out there, but the probability of a smaller planet is even higher (arXiv, doi.org/gsdn7p).

Unfortunately, confirming the existence of such a world would be tough. Astronomers have already spent a decade looking for a theorised world called Planet 9 or Planet X – which, if it exists, should be about 10 times closer than the nearest possible Oort planet – but without any success because of the huge distances involved.

"I think if you're talking about an Earth-mass planet, it's pretty much impossible that it could ever be observable," says Scott Tremaine at the Institute for Advanced Study in New Jersey. "However, if you're talking about something larger, a Uranus or Neptune, it might be observable with future technology."

Raymond likens such a search to "the hunt for Planet 9, on steroids". If we did find Planet 9, it would rule out the existence of an Oort planet, because each of these possible worlds requires the solar system's major dynamical instability to have happened at a different time.

"This relatively high probability of a currently hidden planet – and one that is completely separate from the theorised Planet 9 – demonstrates how little we know about the furthest reaches of even our own solar system," says Dimitri Veras at the University of Warwick, UK. Such a world would be far closer to us than any of the thousands of exoplanets we have spotted so far – and yet, paradoxically, far harder to find. ▮

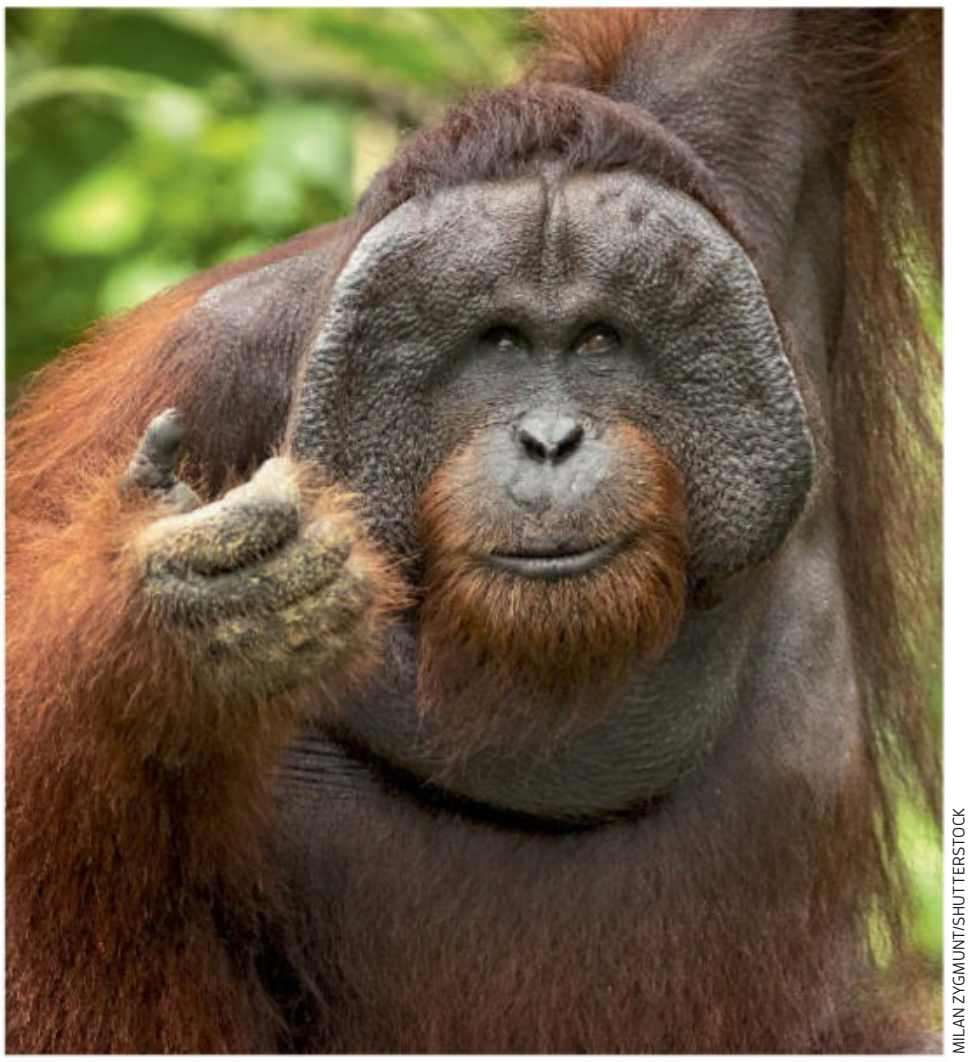
Health

Opioids don't help short-term back pain

WHEN it comes to relieving short-term lower back and neck pain, opioids are no more effective than placebos. This type of discomfort affects up to 500 million people globally and doctors commonly prescribe opioids as painkillers for it. Yet opioids can be addictive, which may lead to drug abuse.

Andrew McLachlan at the University of Sydney and his colleagues have studied 347 people with acute lower back or neck pain, in which half took the opioid oxycodone daily and half took a placebo. They also gave everyone typical pain management advice, such as keeping active.

After six weeks, both groups rated their pain as having reduced the same amount, suggesting that the opioid and placebo were as effective as each other (*The Lancet*, doi.org/kg3m). **Chen Ly**



MILAN ZYGMUNT/SHUTTERSTOCK

Technology

Transforming robot rolls, crawls and flies

A ROBOT can change its wheels into propellers and hands, giving it a huge range of movements.

Morteza Gharib at the California Institute of Technology and his colleagues drew inspiration from the animal kingdom to create the Multi-Modal Mobility Morphobot, or M4 for short. It has four appendages that can turn into wheels, thrusters, legs and hands.

By shifting between different modes, it can fly, roll, crawl, crouch, balance, tumble, scout and pick up objects. In scouting mode, inspired by the way meerkats stand on their hind legs, the robot becomes upright to get a better view of its surroundings (*Nature Communications*, doi.org/gsdssv).

Such mobile robots could be useful for exploring other planets, delivering packages in hard-to-reach locations or aiding search-and-rescue operations. **CL**

Zoology

Orangutan talents include beatboxing vocal skills

GREAT apes in South-East Asia have been heard making calls that are akin to beatboxing. They can produce vowel and consonant sounds at the same time – a complex feat even for us – shining light on the evolution of human speech.

Adriano Lameira at the University of Warwick in the UK and his colleagues recorded two groups of orangutans in two distinct locations in Indonesia for about 3800 hours. The researchers found that female orangutans in Sumatra simultaneously make consonant-like kissing sounds and vowel-like hu-hooing sounds to warn their group if predators are around. Similarly, males in Borneo have a call that uses both mouth chomping and guttural grumbles that come from the larynx at the same time (*PNAS Nexus*, doi.org/kg3j).

The sounds are striking and complex, says Lameira, comparing them to beatboxing. While two separate, far-away populations of orangutans are both employing these "bi-phonations", it is unclear whether all orangutans use these types of calls and whether this is a learned or innate facet of language, he says.

Research like this is "opening our eyes to the diversity" of speech patterns and abilities in species other than ours, says Marco Gamba at the University of Turin in Italy.

"The traditional view is that great apes have very little interesting things to teach us about vocal communication," says Lameira. "But with every new observation we actually start to build the most concrete image we ever had of what our own ancestors were doing and how it ultimately leads to us speaking right now." Sofia Quaglia

Really brief

DILLON TRAVIS

Non-native bees worse for plants

Honeybees are no friends to some of the plants they visit. Native plants pollinated by non-native, wild honeybees produce seedlings that are far less likely to survive and reproduce than those from plants pollinated by native pollinating insects (*Proceedings of the Royal Society B*, doi.org/gsdxvb).

Climate change is turning snow to rain

A shift from snow to rain due to climate change is making extreme rain and flooding more severe in many regions dominated by snow. In the Himalayas, Alps and Sierra Nevada, the intensity of extreme rainfall has increased by an average of 15 per cent for each degree of warming (*Nature*, doi.org/kg5k).

Low iron levels in US young women

Nearly 40 per cent of girls and young women, aged 12 to 21, in the US have insufficient levels of iron in their blood, which can lead to fatigue and hair loss. Of these, 16 per cent have iron deficiency anaemia. Rising rates of veganism and vegetarianism may be a factor behind this (*JAMA*, doi.org/gsdzcf).

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The next small step

The dawn of a new age of space exploration is thrilling. But there is a gap in our preparation for space flight, warns **Elisa Raffaella Ferrè**

NASA has named its first astronaut crew bound for the moon in more than 50 years. "There are three words that we keep saying in the Artemis program and they are 'we are going'," said commander Reid Wiseman last April. Promising advances in rocket technology are ushering in exciting opportunities for space exploration. But, as a cognitive neuroscientist focusing on the effects of non-terrestrial gravity on the human brain and behaviour, I have to ask: are we ready to take on the challenges to human health posed by this new age of space travel?

Let's be clear – going to space isn't like taking a transatlantic flight. Space is a hostile environment for us. Ionising radiation, the lack of atmospheric pressure, extreme temperatures, confinement and isolation are just some of the stressors that space travellers encounter.

Another is exposure to non-terrestrial gravitational environments, such as weightlessness or partial gravity on the moon or Mars, which leads to dramatic changes in human physiology. While the detrimental effects of such gravity on cardiovascular and musculoskeletal systems are well-documented, very little is known about its impact on the human brain and behaviour.

Upon entry into weightlessness, pressure is removed from bodily tissues, causing a migration of fluids from the legs towards the upper part of the body and head. Neuroimaging studies have demonstrated structural changes after weightlessness exposure, including an upwards shift of the brain, an enlargement of the ventricles in this organ and differences in its white matter.

MICHELLE D'URBANO

These lead to behavioural alterations. Astronauts have anecdotally reported shifts in their spatial orientation, perception, postural control and balance. Changes in psychological, cognitive and socio-emotional abilities have also been observed. Recent studies, including my own, have described effects of non-terrestrial gravities on decision-making, risk-taking behaviour and even aesthetic preferences.

How does gravity influence human behaviour more generally? It is hard to imagine a more ubiquitous aspect of life on Earth than gravity. The vestibular otoliths, which are sophisticated organs in the inner ear, detect gravitational acceleration. When the head moves with respect to gravity, the otoliths shift with the direction of gravitational acceleration, moving the vestibular receptors and signalling to the brain where the head is with respect to the direction of gravity.

The brain then combines the vestibular signals with sensory inputs from vision, visceral organs and skin, forming an internal representation of Earth's gravity, known as a gravity prior. Our lifelong experience with terrestrial gravity makes the gravity prior highly reliable and optimal for Earth. Put simply, we can lift a glass of water with no effort because our brain knows exactly how to overcome the 9.8 metres per second squared of gravitational acceleration we experience on Earth. During space flight, conflicts arise between the unusual gravitational information sensed by the vestibular otoliths and the gravity prior, leaving astronauts disoriented and cognitively debilitated.

A huge gap in human preparation for space flight is evident. It is time to reconsider our sci-fi-based idea of astronauts: they are humans, and their brains demand time and effort to adapt to different gravity environments.

Our commitment to space exploration shouldn't merely focus on improving rockets and flight manoeuvres. A clear understanding of how gravity affects human psychology and cognition is key to space success. Let's use our brains to get ready for the next "small step". ▮

Elisa Raffaella Ferrè is a reader in cognitive neuroscience at Birkbeck, University of London

Lost in Space-Time

Proving it

Proofs, the central tenet of mathematics, occasionally have errors in them. Might computers be able to prevent this from happening, asks **Emily Riehl**

Emily Riehl is a professor at Johns Hopkins University, where she works on category theory, a subject about the relationships between mathematical objects.
Sign up to *Lost in Space-Time*, a monthly email newsletter from the frontiers of the cosmos, at newscientist.com/lost-in-space-time/

Emily's week

What I'm reading
Advanced Marathoning *by Pete Pfitzinger and Scott Douglas while preparing for the Baltimore Marathon.*

What I'm watching
Nothing, as I'm travelling to various summer mathematics conferences, but before I left home I stayed up late to finish season 2 of Yellowjackets.

What I'm working on
Formalising the results from an old joint paper of mine on infinite-dimensional category theory in a new experimental computer proof assistant called rzk.

ONE miserable morning in 2017, in the third year of my job as a mathematics professor, I woke up to a worrying email. A colleague had questioned the proof of a key theorem in a paper I had co-authored. The proof, he noted, appeared to rest on a tacit assumption that wasn't warranted.

Much to my alarm, I realised immediately that he was correct. After an anxious week working to get to the bottom of my mistake, it turned out I was very lucky. The theorem was true; it just needed a new proof, which my co-authors and I supplied in a follow-up paper. But if the theorem had been false, the whole edifice of consequences "proven" using it would have come crashing down.

The essence of mathematics is the concept of proof: a combination of assumed axioms and logical inferences that demonstrate the truth of a mathematical statement. Other mathematicians can then attempt to follow the argument for themselves to identify any holes or convince themselves that the statement is indeed true. Patched up in this way, theorems originally proven by the ancient Greeks about the infinitude of primes or the geometry of planar triangles remain true today – and anyone can see the arguments for why.

Proofs have meant mathematics has largely avoided the replication crises in other sciences, where the results of landmark experiments haven't held up when repeated. But as my experience shows, mistakes still occur. Ideally, a false claim would be caught by the peer review process. In practice, however, peer review in maths is less than perfect – not just because experts can make mistakes too, but because they often don't check every step in a proof.

MARSHALL CLARKE

This isn't laziness: theorems at the frontiers of mathematics can be dauntingly technical, so much so that it can take years to confirm the validity of a proof. Vladimir Voevodsky, who received a Fields medal, the discipline's highest honour, noted that "a technical argument by a trusted author, which is hard to check and looks similar to arguments known to be correct, is hardly ever checked in detail". After several experiences in which mistakes in his proofs took over a decade to be resolved, Voevodsky's crisis of confidence led him to abandon his "curiosity-driven research" to develop a computer program that could verify the correctness of his work.

"Theorems at the frontiers of maths can be so technical it can take years to confirm the validity of a proof"

This is known as a proof assistant, though it might be better called a "proof checker". It can verify that a string of text proves the stated theorem. The proof assistant knows the methods of logical reasoning and is equipped with a library of proofs of standard results. It will accept a proof only after satisfying each step in the reasoning process, with no shortcuts of the sort that human experts often use.

Computer proof assistants can be used to verify proofs that are so long human referees are unable to check every step. They can also be used to verify results in subfields so technical that only specialists understand the meaning of the central concepts.

Fields medallist Peter Scholze, for example, spent a year working out the proof of a theorem he wasn't quite sure he believed and doubted anyone else would have the stamina to check. To be sure his reasoning was correct, he posed a formalisation challenge in December 2020. The mathematics involved was so cutting edge it took 60,000 lines of code for the last five lines of the proof – but nevertheless this project was completed and the proof confirmed this past July by a team led by Johan Commelin.

Could computers just write the proofs themselves, without involving any humans? At present, large language models like ChatGPT can fluently generate mathematical prose. However, the logic of these "proofs" tends to be nonsense. Researchers at Google and elsewhere are looking to pair large language models with automatically generated formalised proofs to guarantee the correctness of the mathematical arguments, though initial efforts are hampered by sparse training sets. But while machine capabilities are relatively limited today, auto-formalised maths is surely on its way.

In thinking about how the human mathematics community might wish to collaborate with computers in the future, we should return to the question of what a proof is for. It has never been solely about separating true statements from false ones, but about understanding why the mathematical world is the way it is. While computers will undoubtedly help humans check their work and learn to think more clearly – it is a much more exacting task to explain mathematics to a computer than it is to explain it to a kindergartener – understanding what to make of it all will always remain a fundamentally human endeavour. ▮

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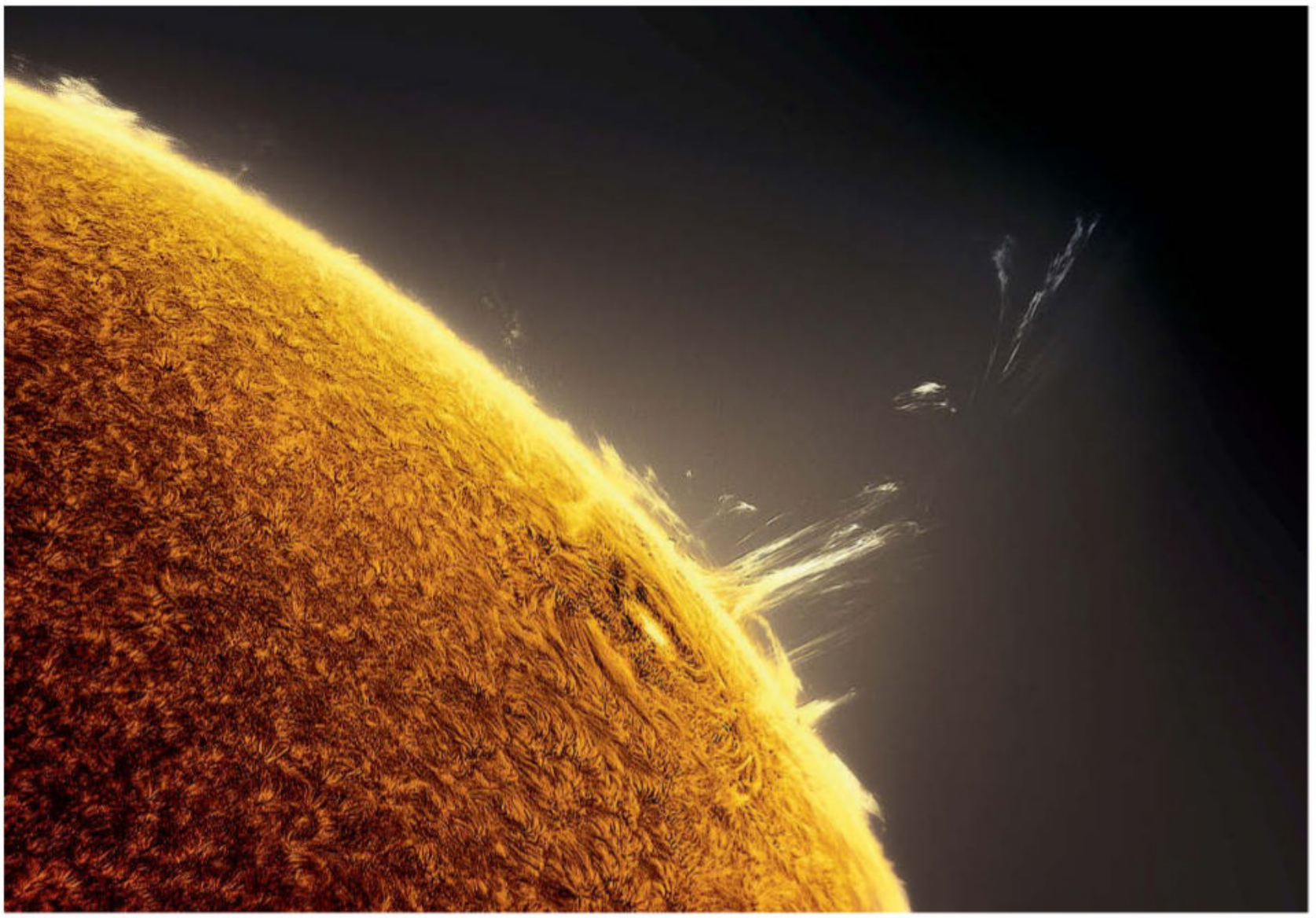

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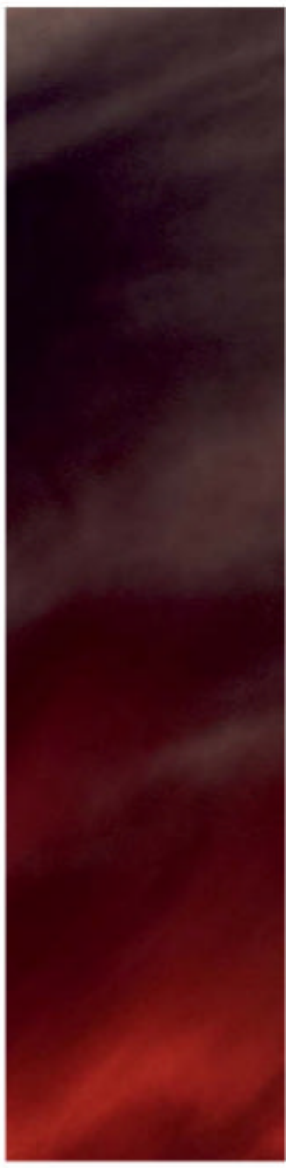

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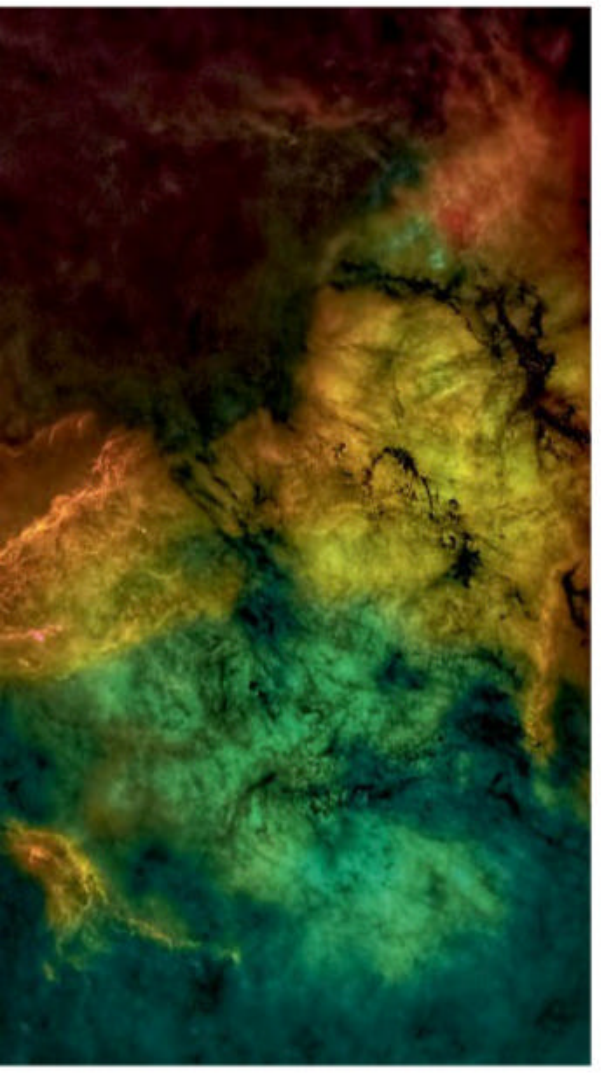


ANDREAS ETTL

Heavens above

FEW sights are as dazzling as those that can be glimpsed when we look up. These astronomical images are some of those shortlisted for this year's Astronomy Photographer of the Year competition, which is organised by the Royal Observatory in London, UK.

The characteristic twist of a solar flare (top left) – a result of an explosive release of energy from the sun's magnetic fields – was captured by Miguel Claro at the Dark Sky Alqueva reserve in Portugal in April 2022. The reserve often offers an incredible spectacle thanks to its combination of low light pollution and frequent cloudless skies.

At top right is an entry from Eduardo Schaberger Poupeau, which shows a crescent moon surrounded by red-tinted clouds above Rafaela, Argentina. Poupeau created this image by combining three separate shots.

The bottom row of images (left to right) shows: the Milky Way, taken by Jeff Graphy from the top of the Pain de Sucre mountain in France; Peter Larkin's shot of the Jellyfish Nebula, a cloud of space dust and gas named for its unique bulbous structures, which is located in the Gemini constellation around 5000 light years away; and, lastly, Andreas Ettl's photograph of an auroral substorm in Hamnøy, Norway. This phenomenon is more violent and short-lived than the northern lights, occurring when Earth's magnetic field is disrupted.

The competition winners will be announced on 14 September and exhibited at the National Maritime Museum in London from 16 September.

Gege Li

When viruses cure

Replacing antibiotics that no longer work costs money and time. A gripping book makes the case for revisiting an alternative, says **Michael Marshall**

Book

The Good Virus

Tom Ireland

Hodder & Stoughton

EVERY so often I remember that I should be scared, not just of climate change and creeping authoritarianism, but also of antibiotic resistance. As bacteria acquire the ability to fend off ever more antibiotics, we risk returning to a time when a simple bacterial infection could mean death.

To tackle the threat, some researchers are developing new antibiotics to replace the old ones that no longer work. It is expensive and time-consuming. What if there was a simpler solution? What if we could use viruses to cure bacterial infections?

That is the premise of science journalist Tom Ireland's debut book, *The Good Virus: The untold story of phages: The most abundant life forms on Earth and what they can do for us*. (Full disclosure: Ireland and I are represented by the same literary agency.) Many of us are still feeling the impacts of covid-19, which was caused by a virus, but this book is a reminder that not all viruses are dangerous to our health.

The good viruses of the title are called bacteriophages, or simply phages. They can only reproduce by infecting bacteria, injecting their own genetic material into the cells and taking over their internal machinery. Ireland explains that "a never-ending microbial war between viruses and bacteria is going on in the world around us, every minute of every day". This even happens in our bodies, every bacterium on our skin and in our guts is under attack from phages.

"Phage medicine came to be associated with crank ideas pushed by such pseudoscientists as Trofim Lysenko"

The notion of using phages to cure bacterial infections goes back decades. Ireland begins his book, arrestingly, in 1942 during the siege of Stalingrad, in the then Soviet Union. He writes: "Soviet scouts were crossing the front line daringly to steal certain German corpses, before squirrelling them back down into a secret laboratory hidden deep beneath the city." These raids were part of a project led by Soviet researcher Zinaida Yermolyeva to treat outbreaks of cholera, a bacterial infection, by harnessing the phages that attack the cholera bacteria. These phages were most readily found in the corpses of those who had recently died from cholera.

Stories like this reflect the excitement many microbiologists felt after the discovery of phages in the early 20th century. However, the research from that time was largely ignored, and phages have been neglected. The core premise of *The Good Virus* is that medical and virological research has paid too little attention to phages, despite their enormous promise.

Ireland's account of the early history of phage research is richly detailed and absorbing, and well balanced between the biological details and the personalities and scientific politics involved.

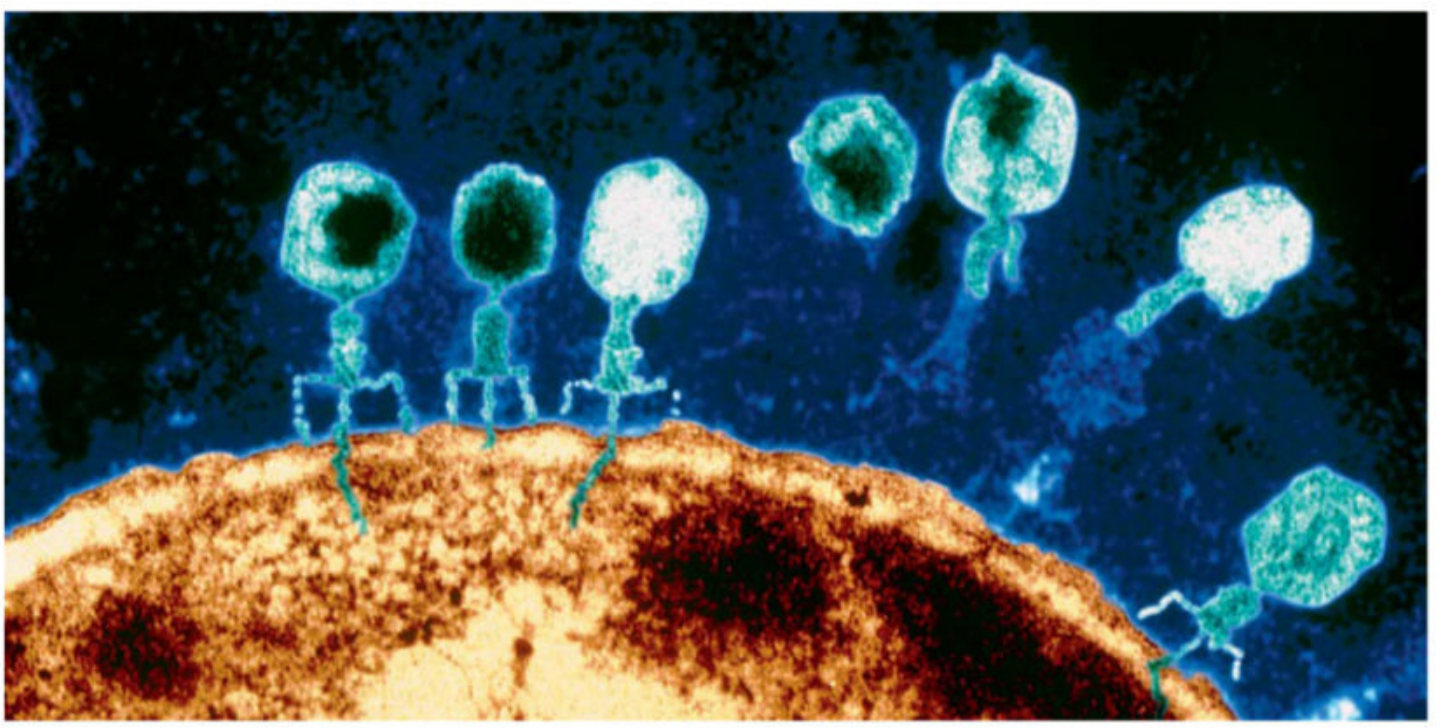
He argues that phage medicine came to be associated with the crank ideas pushed by Soviet pseudoscientist Trofim Lysenko, among others, explaining why it has been little studied in the West. For many years, almost the only place to get phage therapy was at the Eliava Institute in Tbilisi, Georgia – and many people with chronic bacterial infections made the journey to receive treatment.

The tables finally turned in 2016, when epidemiologist Steffanie Strathdee used phage therapy to save her husband's life. Tom Patterson had a bacterial infection that had resisted all known antibiotics. In desperation, Strathdee recruited a team to develop a phage therapy after reading about the idea online. The pair tell their story in their book, *The Perfect Predator*. Ireland retells it, setting it in its full context.

Readers may be wondering why phages aren't regularly prescribed. The difficulties are largely procedural. Phage therapies typically involve a cocktail of phages, freshly sourced for each infection, ruling out conventional controlled studies in which the same treatment is given to many patients. This could surely be overcome by ingenious experimental design, but the stigma attached to the idea means regulators have been slow to act.

A later section of the book explores the role of phages in ecosystems. Fascinating as this is – it turns out phages kill about half the bacteria in oceans – it interrupts the narrative and might have been better as an epilogue. But this is a minor complaint. *The Good Virus* is original, eye-opening and grippingly told. ▮

Michael Marshall is a writer based in Devon, UK



Bacteriophage viruses attacking an *E. coli* bacterium

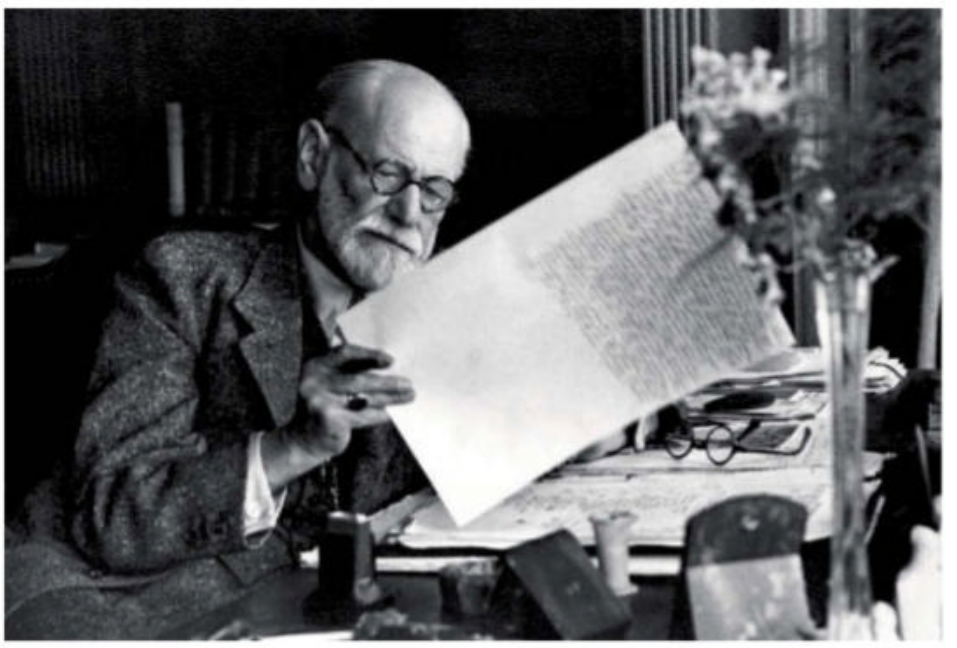
EYE OF SCIENCE/SCIENCE PHOTO LIBRARY

Return of the superego

Could the ideas of the psychoanalyst Sigmund Freud help us understand the internet, asks a new book. **Simon Ings** explores

Book

The Age of Guilt
Mark Edmundson
Yale University Press



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IN HIS Freudian analysis of what we might loosely term "cancel culture", Mark Edmundson wisely chooses not to get into simplistic debates about which of the psychoanalyst Sigmund Freud's ideas have or haven't been "proved right". What would that even mean? Psychology isn't so much science as it is engineering – applying ideas and evidence to a purpose. In *The Age of Guilt: The super-ego in the online world*, Edmundson, a literary scholar, simply wants to suggest that Freud might help us better understand our cultural moment.

In the centre of Freud's model of the personality sits the ego, the conscious bit that thinks – and therefore is. Bracketing the ego are two components of the personality that are inaccessible to conscious awareness: the id and the superego. The id is the name Freud gave to all those drives that promote immediate individual well-being. Fancy a sandwich? A roll in the hay? That's your id talking.

Much later, in an attempt to understand why so many of his clients gave themselves such a hard time (beating themselves up over trivia, calling themselves names), Freud conceived the superego. This is the bit of us that warns against misbehaviour and promotes conformity to social norms. Anyone who has seen the uninhibited behaviour of chimps will understand why such machinery might have evolved in an animal as ultra-social as *Homo sapiens*.

Casual descriptions of Freud's model often characterise the superego as a sort of wise uncle, paternalistically ushering the Sigmund Freud believed we have a powerful, unrelenting superego that controls our behaviour **cadet ego out of trouble. This, says Edmundson, is a big mistake. A power that, in each of us, watches, discovers and criticises all our intentions isn't to be taken lightly.**

He argues that key cultural institutions evolved not just to regulate our appetites, but also to provide direction and structure for the superego. A priest might raise an eyebrow at your gluttony, but that same priest will relieve you of your self-hatred by offering you a simple atonement: performing it wipes your slate clean.

Edmundson wonders what, in the absence of faith, can corral and direct the fulminations of our superego – which, for him, is no fount of idealism, more a petulant, unrelenting and potentially life-threatening disciplinarian.

The result of unmet superego demands can be severe. "The super-ego punishes the ego and turns it into an anxious, frightened creature, a debilitatingly depressed creature, or both by turns," writes Edmundson. He quotes a Pew Research study showing that, from 2007 to 2017, the percentage of 12 to 17-year-olds in the US who said they had experienced a major depressive episode in the previous year rose from 8 per cent to 13 per cent. Are these teenagers with depression "in some measure victims of the wholesale cultural repudiation of Freud", he asks.

Arguments from intuition need a hefty health warning, but I defy you not to agree with more than a few of Edmundson's denunciations: for instance, how the internet has become our culture's chief manifestation of the superego, its loudest users "immune to irony, void of humour, unforgiving, prone to demand harsh punishments".

In 1973, the anthropologist Ernest Becker wrote *The Denial of Death*, which hypothesised many connections between society, behaviour and consciousness. Becker's informed and closely argued speculations inspired a few young researchers to test his ideas and thereby revolutionise the field of experimental psychology. In a culture growing so pathologically judgmental, condemnatory and punitive, I wonder: can *The Age of Guilt* perform the same valuable trick as Becker's book? I do hope so.

Simon Ings is a writer based in London

New Scientist *recommends*

Grace Wade
Reporter
New York

In honour of Pride Month, I went to see ***Love + Science*** by cell biologist David Glass, performed at New York City Center.

The play follows the lives of two gay medical students (pictured) during the AIDS crisis in 1980s New York and offers a stark reminder of how furiously the queer community had to fight for AIDS to be taken seriously.

It also reflects some of the emotions we all remember from the early days of the covid-19 pandemic, such as the

fear of inadvertently spreading the disease and the anxiety of waiting for a vaccine.

I am currently reading *The Price of Peace: Money, democracy and the life of John Maynard Keynes*, a biography of the famous economist by Zachary D. Carter.

It is a meticulously researched retelling of economic events from the early 20th century, and Carter's prose is so enjoyable that it makes notoriously dense topics such as monetary policy an absolute delight to learn about.

JEREMY VARNER

The TV column

A beautiful life Marnie is like any 13-year-old – except she has a severe form of muscular dystrophy. A four-part drama, *Best Interests,* is an empathetic and nuanced story about terrible choices, says **Bethan Ackerley**

Bethan Ackerley is a subeditor at *New Scientist*. She loves sci-fi, sitcoms and anything spooky. She is still upset about the ending of *Game of Thrones*. Follow her on Twitter @inkerley

BBC/CHAPTER ONE/SAM TAYLOR

Marnie (Niamh Moriarty) and her friend George (Lenny Rush)

THERE is a line in *Best Interests* that haunts me. In the first episode of this four-part BBC drama, a doctor (Kevin Eldon) tells Nicci and Andrew Lloyd that their baby daughter is unlikely to lead a long life. "Please don't assume that Marnie's story is going to be any less beautiful," he says. "It'll just be different, and you have to adapt to that difference. And you'll find such joy if you do."

Marnie (Niamh Moriarty) has a severe form of muscular dystrophy, a degenerative condition with no cure. She has grown into a funny, sweet-tempered 13-year-old. When Marnie is in good health, Nicci and Andrew (Sharon Horgan and Michael Sheen) are two big kids who seem settled in their love.

Returning from a rare holiday away from Marnie and her older sister Katie (Alison Oliver), they find Marnie has developed a life-threatening chest infection and their hard-won peace unravels.

Marnie's doctor Samantha (Noma Dumezweni) tells the Lloyds that Marnie's body is failing and further treatments will be ineffective and unpleasant. Nicci and Andrew are forced to consider whether Marnie should be allowed to die. While Nicci decides to take the hospital to court, Andrew wrestles with his growing belief that Marnie is in a lot of pain. Their marriage begins to buckle.

This is, naturally, a devastating series. But *Best Interests* isn't inspiration porn or a maudlin morality play built on a pitying view of Marnie and her disability. Flashbacks show moments of great joy as Marnie learns dance routines and watches make-up tutorials, races her mother in her wheelchair and covets her sister's poster of actor Daniel Kaluuya.

"TV is a way to provoke discussion, bring joy and tell the stories of those too often dismissed"

Crucially, writer Jack Thorne – himself a disability activist – has shown that her world is enriched by having other people with disabilities around her, such as her cheeky friend George (Lenny Rush), who asks her on a date to the cinema. Such depictions are vanishingly rare on television.

Marnie's life has been full of pleasure and love, and she has brought delight to all around her. But her family have been living with the same question for more than a decade: when will they have to mourn Marnie?

Horgan and Sheen are terrific, giving layered, subtle performances, but it is Oliver who is particularly affecting. Katie is ebbing away. Treated as an emotional equal by her parents, she must bear their pain without expressing her own. Moriarty, too, who has cerebral palsy in real life, paints a vivid picture of Marnie despite her restricted screentime.

The series is a project of great nuance all round. Nicci's cruel words to her husband that he has always wanted Marnie dead don't detract from her fiercely loving side; Andrew's cowardly tendencies and his anger at Katie when she asks for support don't stop him from being a good father.

There are no villains here except for the effects of systematic underfunding on UK medical systems, particularly during the covid-19 pandemic. What begins as a personal story crystallises into a condemnation of the ways people with disabilities have been failed time and again.

But *Best Interests* also offers sympathy to all involved in the difficult decisions about Marnie's care. More importantly, it shows the capabilities of TV as what Thorne called "the empathy box", a way to provoke discussion, bring joy and tell the stories of those who are too often dismissed. ▮

TV
Best Interests
BBC iPlayer

Bethan also recommends...

Then Barbara Met Alan
BBC2 film
Netflix
Based on the true story of Barbara Lisicki and Alan Handsworth, who met, fell in love and were among the founders of the Disabled People's Direct Action Network in the 1990s.

Am I Being Unreasonable?
BBC iPlayer
Lenny Rush (see main article) won a BAFTA for his scene-stealing role as Ollie in this comedy-thriller. Daisy May-Cooper is his mother, hiding dark secrets from her mysterious new friend.

Editor's pick

The moment is upon us to change tack on the climate

24 June, p 8

From Michael Graham, Peterborough, Cambridgeshire, UK

As Madeleine Cuff reports, 2023 is shaping up to be the hottest year on record: global warming is being exacerbated by El Niño conditions and the temperature of the oceans is particularly alarming. The case for intervention is only growing.

Steuart Campbell's letter (24 June) cites Stephen Salter's idea of marine cloud brightening. This is a safe form of geoengineering using seawater sprayed from ships to brighten clouds. It could be turned off instantly and the effects would be gone in a few days.

You can judge Salter's presentation to the UK's Royal Meteorological Society for yourself, as it is available online under the title "Marine cloud brightening as an emergency brake on climate disaster".

Evolved fear of heights fails when on a flight

17 June, p 19

From Alan Stennett, Sydney, Australia

You report work on brain circuits involved in the fear of being high off the ground, an evolved reaction almost everyone has.

There does seem to be an exception to this for a lot of people. I think I have an average fear of being on high structures, but being high in various aircraft doesn't worry me. I have a couple of times been in a helicopter with the door removed, I have also been in hot air balloons and sat in the open cockpit of a Tiger Moth plane.

Masturbation isn't just a solo activity

17 June, p 14

From Guy Cox, Sydney, Australia

Researcher Matilda Brindle is quoted as calling masturbation a seemingly "costly sexual behaviour that's very much a solo activity". Female masturbation doesn't lead to ovulation so how can it be costly? Male masturbation does lead to loss of sperm, but males produce sperm continuously so the cost is trivial.

And it absolutely isn't just a solo activity. Everything I have read about bonobos emphasises how mutual masturbation is vitally important in maintaining same-sex social bonding in their society.

No getting away from generational thinking

17 June, p 28

From David Shaw, Perth, Western Australia

Elle Hunt, in discussing Jean Twenge's book *Generations*, says the reason generational thinking persists, despite its downsides, is that it helps us articulate our own experience so that we might be understood by others.

I agree. Generational-ism has a simplistic appeal owing to identification, for good or bad, with common experiences. For example, the "silent generation", born between 1925 and 1945, experienced global depression and war with conscription for millions. It is easy to understand and communicate with someone who has similar experiences and understands the consequences and importance of them.

On the reasons why farms continue to pollute rivers

24 June, p 36

From John Crofts, Nottingham, UK

Having worked decades ago for the UK's then Ministry of Agriculture, Fisheries and Food, I can say that many agriculture-related river pollution problems stem from the fact that some farmers want a "quick fix" for their own issues.

Take the control of rushes with MCPA, an example you raised. This has long been used as a herbicide, but it is very soluble in water. Under wet conditions, it will soon end up in the local watercourse.

A much more effective, long-term solution would be to improve land drainage. This wouldn't just get rid of the rushes permanently, but also improve productivity of the land and double its capacity to store water during extreme weather. Admittedly, the loss of grants to farmers has been a factor.

Quake lake may also offer an opportunity

17 June, p 15

From William Hughes-Games, Waipara, New Zealand

If the dry lake in California is indeed delaying the rupture of the San Andreas fault – possibly leading to a worse eventual quake – perhaps Californians should flood the lake themselves.

This might release the strain before it builds up to an even more dire event. At least if they flooded Lake Cahuilla themselves they would have a good idea when the fault is going to let loose and could prepare for it.

Aliens will probably be just as flawed as we are

Letters, 17 June

From Geoff Willmetts, Bridgwater, Somerset, UK

Bob Denmark's description of humankind as prone to violent conflict and conquest could equally apply to any alien we communicate with. Intelligence doesn't rule out the predatory instinct, and in-species warring could be a lot more common in the galaxy than we anticipate.

Having advanced technology doesn't necessarily mean violent instincts will go away, a fear that Stephen Hawking expressed.

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

We seem to always imagine alien civilisations will be homogenous, and hence unlike us. That is possibly because pretty much every sci-fi story I can think of, from H. G Wells and his Earth-invading Martians to the Dan Dare tales in the *Eagle* comic, portrays aliens as single planetary cultures.

Can worms turn coffee grounds into safe stuff?

17 June, p 44

From Cos Harnasz, Budapest, Hungary

James Wong describes the detrimental effects of caffeine on plants as a result of putting used coffee grounds on the soil of one's garden. I place my used grounds on the compost heap and have noticed that, when I lift some of the decomposing vegetable matter and dig into the heap, there are sometimes dense clusters of worms where I had put the grounds. It is as if they are enjoying the coffee and perhaps being stimulated by the caffeine!

Is caffeine broken down by earthworms (and other creatures) in the process of composting? The grains have a texture that seems so beneficial for the soil and it seems a shame not to use it.

Ancient Egyptians tried 'new' cancer treatment

24 June, p 40

From Alex McDowell, London, UK

Fighting cancer with bacteria predates even William Coley's work of the late 1800s. Around 2600 BC, Imhotep (an Ancient Egyptian polymath) noted that making incisions into tumours and applying a poultice to induce an infection could cause them to shrink. ▮

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Reality reconstructed

It's time to ditch the idea that everything is always made of smaller stuff – and instead think of the universe as a single, quantum whole, says physicist **Heinrich Päs**

IMAGINE you could see through everyday objects to the stuff they are made of. If you zoomed in on the arm of a chair, say, you would see that it is made of atoms. Zoom in again and you would see that those atoms contain subatomic particles called protons, neutrons and electrons. Zooming further still, you would see that the protons and neutrons are composed of quarks.

These are the layers of reality, and this is how physicists understand the universe: by breaking everything down into its constituent parts, an approach known as reductionism. As a particle physicist, I grew up on this philosophy. It has brought physics a long way – it is how we built our current picture of matter and its workings, after all. But now, with further progress stalling, I am convinced we need to go about things differently from here.

Rather than zooming ever further inwards, I think we need to zoom out. In doing so, we may see that everything there is, including such seemingly fundamental things as space and time, fragment out of a unified whole. This might sound like philosophy or mysticism, but it is in fact a direct result of applying quantum mechanics to the entire cosmos. When you do that, you realise that the universe isn't fundamentally made of separate parts at all, but is instead a single, quantum object.

It is a radical idea, and one we are just beginning to test experimentally. But if it is correct, it could help solve some of the most puzzling mysteries in physics and upend the way we think about the universe.

For almost a century, physicists attempting to understand the most fundamental layers of reality have been inadvertently describing systems without knowing what is going on inside them. In the 1930s, when Enrico Fermi worked out how a neutron decays into a proton and spits out an electron – known as beta decay – he did so only by considering the electrons, protons and neutrons involved. Only decades later, when physicists discovered an intermediary particle called the W boson, did they realise there was a deeper layer of interactions playing out at tinier scales.

From today's perspective, Fermi's description is the prime example of an effective field theory (EFT), a mathematical framework that allows us to divide reality into different size scales and analyse them separately. In this way, physics behaves like a set of Russian Matryoshka dolls, where you can understand the outer doll without knowing anything about the dolls inside.

An EFT is the name given to any work that exploits this idea. Whenever physicists want to describe effects beyond an established but incomplete theory, without specifying what the new physics is, they use EFTs. "Everything is an EFT," says Cliff Burgess, a physicist at McMaster University in Hamilton, Canada, who has written a book about the approach.

Crucial to EFTs is the concept that the different size scales of the universe correspond to different energies. At the largest distances are the lowest energies, while the tiniest parts of reality are associated with the highest energies. Fermi didn't have a particle accelerator like the Large Hadron Collider (LHC), so he couldn't reach the high energies needed to reveal the smaller-scale reality of the W boson.

RADACHYNSKYI/ISTOCK

Fermi's description works well for nuclear physics, though, and was an approximation of an even better, more fundamental theory: the standard model of particle physics, our best picture of matter and its workings. Now we know that the standard model is also incomplete, since it doesn't include gravity, a particle for the universe's enigmatic dark matter or a mechanism to generate the perplexing masses of subatomic particles called neutrinos. When this became clear, physicists realised that the standard model itself was also an EFT.

For all the convenience they provide, EFTs might be obscuring a truer understanding of the universe. This is because they introduce problems. One that particle theorists have been worried about for years involves the Higgs boson, the particle responsible for giving mass to quarks and electrons. In theories like the standard model, particles can temporarily change into short-lived particles, known as virtual particles, only to quickly decay back into the original particle. In a quirk of quantum mechanics, the rules that govern the world of particles, these fluctuations contribute to a particle's mass. The extent of this contribution depends on the highest energy the virtual particles may have.

Importantly, working out the contributions to a particle's mass depends on the boundaries of energy within which the standard model applies – or the size of the Russian doll. As far as we know, the upper energy threshold is the Planck scale, the smallest scale there is and the point at which gravitational effects become important and the standard model must be replaced by something that unites gravity ›

and quantum mechanics. According to this idea, the mass of the Higgs boson is expected be determined by the Planck scale. But the prediction is 17 orders of magnitude larger than the actual mass we measured when the particle was eventually discovered at the LHC.

The only way around this conundrum is to accept that totally unrelated contributions to the Higgs mass from fleeting virtual particles just so happen to almost completely cancel each other out. This makes the conditions we see in our universe as unlikely as a pencil balancing on its tip. It is known as the fine-tuning problem.

Hidden dimensions

A similar puzzle crops up in cosmology, too. This one involves dark energy, the mysterious force that propels the accelerated expansion of the universe. The expansion is thought to be caused by the energy stored in the vacuum of space. But here, our observed reality differs even more from prediction: the value of the vacuum energy we measure is some 30 orders of magnitude too small.

There have been some attempts to solve these two puzzles. An approach known as supersymmetry, for example, predicts new particles that cancel the quantum fluctuations produced by standard model particles. An alternative solution involves additional dimensions of space-time. This idea – proposed by Nima Arkani-Hamed, now at the Institute for Advanced Study in Princeton, New Jersey, and his colleagues – says that gravity may leak out into these extra dimensions, making it look weaker than it actually is. Models based on this idea predict a lower Planck scale, meaning a smaller Higgs mass. The extra dimensions are invisible since they are curled up so tightly that they have escaped experimental detection so far.

Both supersymmetry and the extra dimensions idea predicted the discovery of new physics at the LHC, in the form of either new supersymmetric particles or excitations in quantum fields that would run around the curled-up dimensions. So far, however, the LHC has found the Higgs boson and nothing else. The possible solutions to the fine-tuning problem have become increasingly fine-tuned themselves, because the LHC keeps ruling out hiding places.

In short, particle physics is in crisis. This is why a small group of theorists, including me, has recently started to explore another, radical approach – one that proposes an alternative to reductionism as we know it. Instead of treating the different energy scales of the universe separately, it treats them as if they all have some bearing on each other.

To understand how this works, consider an analogy used by physicists that invokes the boundaries where the colours of a rainbow become invisible. At the highest energies, and therefore lowest sizes, beyond the violet colour in a rainbow is what we call the ultraviolet (UV). At the lowest energies and largest sizes, you have what we call the infrared (IR). In between the two, in the visible part of the rainbow, is the realm in which the standard model works.

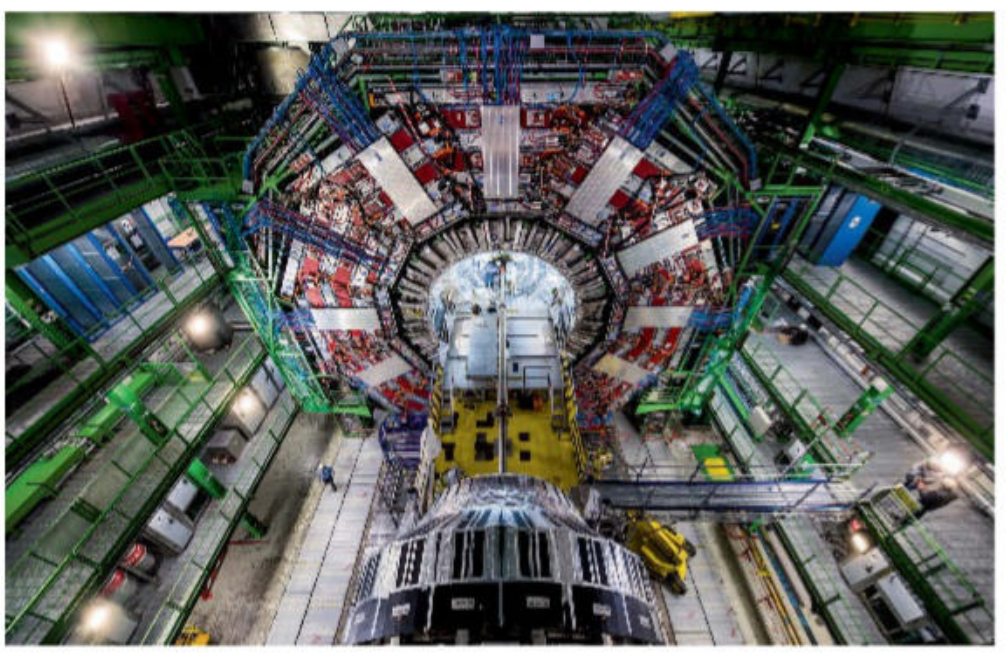
It has been generally accepted for a while that the model stops working at the infinitesimal sizes and high energies of the Planck scale. This is what we call the UV region, where the effects of quantum gravity would kick in. But in the late 1990s, Andrew Cohen at Boston University in Massachusetts, along with David Kaplan and Ann Nelson, then at the University of Washington in Seattle, wondered if there was also a limit at the very large distances, or low energies, that we call the infrared.

"We could quite literally see the entire universe in its tiniest pieces and particles"

While studying black holes, Cohen and his colleagues calculated that there is a maximum length, or minimum energy, at which the standard model stops being valid. Beyond it, gravity takes over. It might seem intuitive that if there is a lower limit, there must also be an upper one. But crucially the researchers found that these seemingly unrelated cutoffs aren't independent of each other. In other words, the physics at these vastly different energy scales seems to be related – a phenomenon dubbed UV/IR mixing.

The calculations didn't suggest any concrete values for the low-energy cutoff. So Cohen and his collaborators tried out the largest scale they could think of: the radius of the observable universe. In a further fascinating twist, the corresponding UV cutoff to this IR cutoff turned out to be exactly the tiny energy value of the universe's dark energy – not the Planck scale, after all. If the virtual particles contributing to dark energy abide by this limit, that could explain why these effects don't drive dark energy to ridiculously large values.

For a long time, no one took much notice of this result. Most people had their sights set on supersymmetry and its ability to resolve the problem of the Higgs particle. But recently the crisis in physics has become more apparent, as many potential solutions to the fine-tuning problem have fallen away. As a result, the



BRICE, MAXIMILIEN/CERN

The dearth of discoveries at the LHC has caused a crisis

BABAK TAFRESHI/SCIENCE PHOTO LIBRARY

To make sense of the universe, physicists divide reality up much like a Russian doll

SEFA KARACAN/ANADOLU AGENCY/GETTY IMAGES

insights of Cohen and his colleagues have been receiving a huge amount of interest from theorists like myself. I started to wonder: if UV/IR mixing might help to solve the dark energy problem, could it also assist with the second major problem in fundamental physics, namely the unbearable lightness of the Higgs?

To answer this question, Tom Kephart at Vanderbilt University in Tennessee and I first attempted to work out what the IR cutoff might be for the Higgs boson based on the limited lifetime of the particle. We determined a UV cutoff that is 11 orders of magnitude below the Planck scale. It is better than what we had, and yet still a million times too large for the Higgs mass we see. Adding extra dimensions could resolve the problem entirely.

Over recent years, theorists like me have tried several other ways to solve the Higgs problem using variations of UV/IR mixing – each coming from various angles. Some, like ours, take their inspiration from Cohen and his colleagues' work on black holes. Others were born in string theory, which suggests everything is made of unbelievably tiny strings. None of the attempts so far is supported by experimental evidence, but they may get us a step in the right direction. A few of them even point to one fundamental property of underlying reality that could be causing this mixing to happen, with big implications for how we see the universe.

Quantum entanglement is usually described as a startling correlation between quantum objects. Prepare two particles in a particular way and a measurement of one immediately fixes the other, regardless of the distance between them. But these correlations can be thought of as proof of the fact that entangled quantum systems can't be understood as being made out of parts: they are one and the same. Just as this indivisibility links faraway particles, it also can link quantum effects at different energies. In other words, quantum entanglement could be responsible for the UV and the IR scales of the universe seemingly talking to each other.

An entangled universe

As we proceed up the size scale and down in energy, the effects of lower energies could be broken by a process called decoherence. This well-understood quantum phenomenon hides entanglement from the eye of a local observer. It is the reason why we experience no quantum weirdness in our daily lives.

Some work has found a relationship between entanglement and UV/IR mixing, but the bounds in Cohen and his colleagues' study were caused by gravity rather than entanglement. Excitingly, recent work by leading researchers in string theory offers a solution: by suggesting gravity itself may be entanglement in disguise.

It is a bold idea, but I suspect entanglement causes UV/IR mixing. If so, there are huge implications for understanding reality at its most fundamental. If entanglement can be applied to the entire cosmos, then instead of everything being made of smaller and smaller pieces, it would turn the universe into "a single, indivisible unit", in the words of quantum pioneer David Bohm. All objects in existence would be encoded in a universal wave function, a mathematical entity that describes a single, entangled state.

Soon, we may know if this matches up with reality. Cohen and his collaborators suggested UV/IR mixing would affect the interaction of electrons or subatomic particles called muons with electromagnetic fields, showing up as a mismatch between the standard model's predictions and measurements. And the phenomenon may crop up in other processes, too. One example my colleagues and I are currently exploring relates to neutrino masses. Unlike any other particles, the almost non-existent masses of the elusive neutrinos can be entirely generated by virtual particles, according to some models. This means they should be more sensitive than other particles to any UV/IR mixing effects.

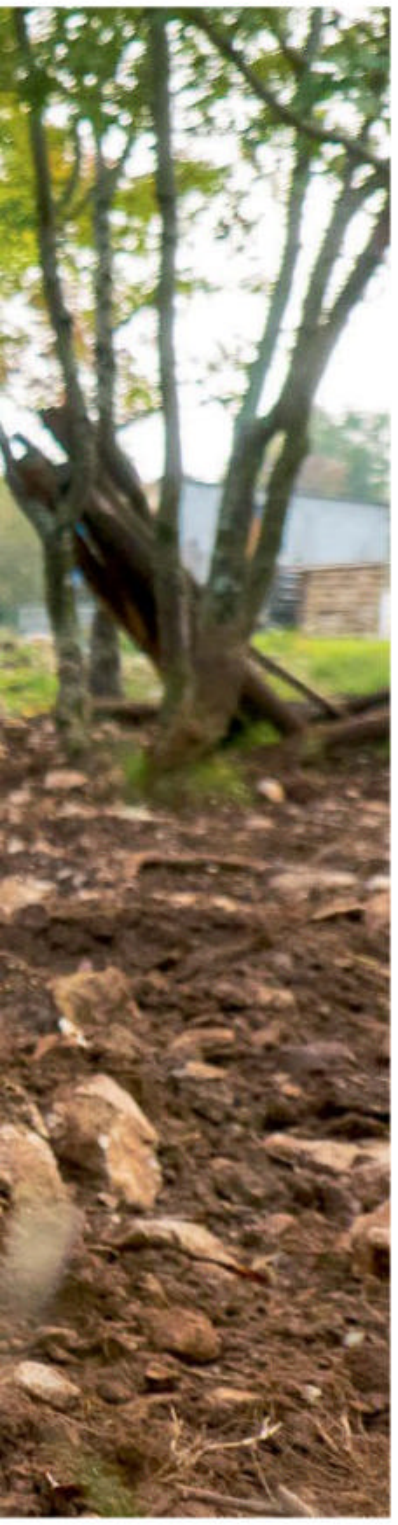
If we do find evidence to support this idea, it would dramatically alter the way we conceive of the cosmos. It would mean we could not only see a world in a grain of sand, as the poet William Blake once said, but we could also quite literally see the entire universe in its tiniest pieces and particles. While this might sound like just a different way of going about physics, it is much more than that. I believe that we are on the way to a completely new understanding of how the universe is put together. ▮

Heinrich Päs is a theoretical physicist at the Technical University of Dortmund in Germany and the author of *All is One*

The emotional lives of animals

We are finally figuring out how to discern the emotions of farm and zoo animals – and how we can make them happier, says **Sam Wong**

JASMINA81/GETTY IMAGES



Pigs emit particular grunts and barks when they are happy

AS HAPPY as a pig in – well, you know the phrase. But when we see a hog rolling in muck, a dog racing after a stick or an elephant reunited with a long-lost relative, how do we know what these animals are feeling?

One thing we can say is that many non-human animals do experience emotions. Today, biologists are increasingly accepting of the idea, once dismissed as mere anthropomorphism, that certain other species have a range of emotional states. Which doesn't change the fact that a pig's true feelings at any given moment are nigh-on incomprehensible to us, not least because it doesn't share our capacity for language.

In the past few years, however, researchers have been figuring out creative ways to discern when animals are pessimistic, bored or gleeful. "We're not just looking for signs of pain, fear or anxiety," says Fay Clark at the University of Bristol in the UK. "We're looking for signs of joy, the potential for happiness and fulfilment."

What they are discovering isn't just that animals reveal their emotions in subtle ways, but also that they seem to be surprisingly delighted by mental challenges – and might even enter a "flow state" when deeply immersed in an activity they enjoy.

All of this adds fresh impetus to the ongoing campaign to move from merely reducing suffering in animals we keep in farms and zoos to doing everything we can to ensure they lead happy lives. "People will soon start to realise that emotions are the main part of welfare, even more important than health," says Elodie Briefer at the University of Copenhagen, Denmark.

For much of the past century, scientists were sceptical about the idea that non-human animals have emotions. In recent years, just as we have come to realise that animals are more intelligent than we thought, we have arrived at a new awareness of their emotional capacities. As Frans de Waal outlined in his 2019 book *Mama's Last Hug*, it is a bigger leap of faith to believe that humans are exceptional in this regard. Observations of other mammals' behaviour, and the shared roots of our neurological systems, have convinced de Waal, a primatologist at Emory University in Atlanta, Georgia, and others that many species experience the full spectrum of emotion, from fear and pride to hope, joy and happiness.

That isn't to say these animals feel emotions in the same way we do. De Waal was careful to distinguish between feelings, which are internal, subjective states and therefore unknowable to others, and emotions – bodily and mental states we can recognise through their effects on behaviour and physiology. "Anyone who claims to know what animals feel doesn't have science on their side," writes de Waal.

The trouble is that it is also tricky to reliably detect animal emotions – especially positive ones. "We can observe them and infer how they might be feeling, or we can look at physiology, see if they might be stressed by how their hormone levels go up and down, but the connection to how it feels is a bit tenuous," says Clark. "We're very, very far away from being able to detect if an animal is happy or not – we can only make big assumptions."

In striving to do better, the obvious place to start is facial expressions. For species such as horses, cows and rabbits, researchers have identified facial expressions that are typically made when the animal is in pain. Positive emotions are more difficult, says Sara Hintze at the University of Natural Resources and Life Sciences in Vienna, Austria. "There is a lot of work looking at positive emotions in facial expressions, but this research is in its infancy."

"Emotions are the main part of welfare, even more important than health"

Researchers have had more success with vocalisations. For a study published in 2022, Briefer and her colleagues developed an algorithm to categorise pigs' utterances as positive or negative. They trained it on more than 7000 recordings from a variety of contexts. In situations thought to be positive, such as when they were running free, nursing or expecting a reward, the pigs tended to make sounds like grunts and barks. In negative scenarios, such as when they were fighting or being handled by humans, their grunts and barks were longer in duration and lower-pitched – or they unleashed high-pitched squeals and screams. ›

Briefer and her colleagues found that their algorithm could correctly classify 92 per cent of calls as positive or negative. They are speaking to several interested companies about developing a tool that farmers could use to monitor pig welfare. She reckons that, in future, systems that combine analysis of vocalisations with that of facial expressions and body movement might give us more precise ways to measure animals' emotions – to gauge if they are distressed, but also to identify signs of something akin to happiness.

For the moment, one of the best ways to gauge an animal's emotional state is to set them tasks designed to reveal, in human parlance, whether they see the glass as half full or half empty. Researchers call these cognitive bias tests, and their use stems from studies showing that, if humans are depressed or anxious, they have a more pessimistic outlook. This seems to be the case for animals, too. "If they're in a situation where you might expect they would be anxious, they tend to interpret things more negatively," says Rebecca Meagher at Dalhousie University in Canada.

Optimistic cows

The animals must first be trained to understand that a certain signal indicates a reward, while another indicates no reward. For example, the animal presses a button to start the test, then a door on the left opens, enabling them to access a tasty morsel of food. Alternatively, the door on the right opens and there is nothing. Once they have learned this association, they are given an ambiguous stimulus they haven't seen before – a door in the middle opens, for example. If they approach the door, this suggests they are optimistic. If they press the button to start the test again, this suggests they are pessimistic.

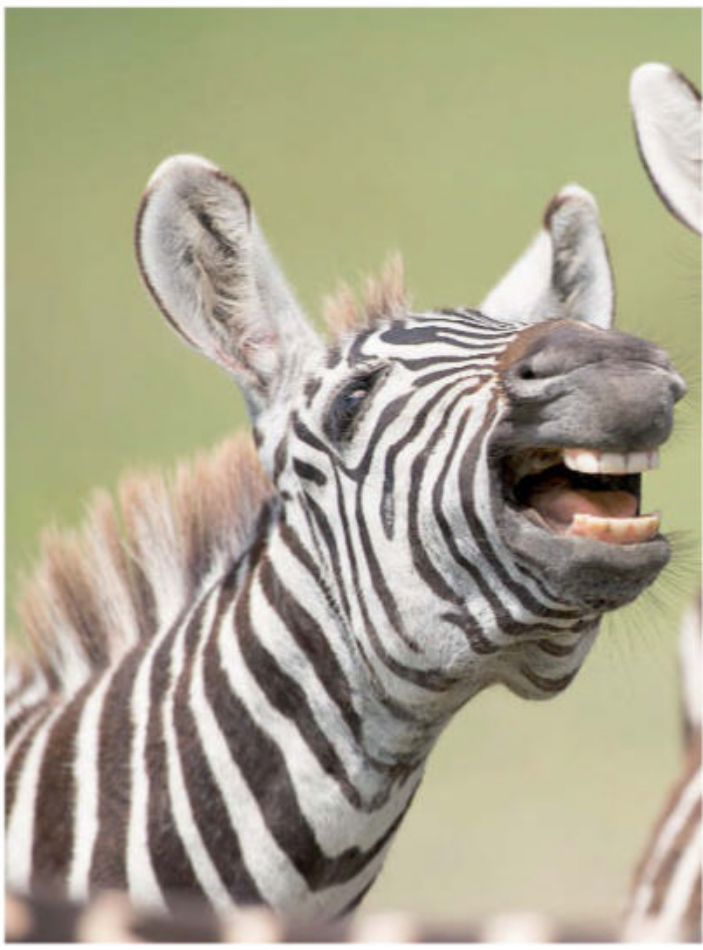
When Hintze did this for dairy calves, she found that they were more optimistic when housed in pairs. Optimism isn't the same as happiness, of course, but humans' long-term emotional states, or moods, have an impact on how we process information and make judgements. These sorts of experiments do at least suggest that we can detect positive emotions in captive animals through their effects on decision-making – and therefore we can begin to get a grip on what they like.

Coming at this from a different angle, one big question about the emotional welfare of captive animals is whether they can experience boredom. Meagher and Georgia Mason at the University of Guelph, also in Canada, have studied this in farmed mink by assessing their interest in novelty. They found that when the mink were housed in conditions where they had less to do, they were more likely to seek out things that would be scary or unpleasant. "Our conclusion was that the mink probably can experience boredom if they are in boring conditions," says Meagher.

"You get these lovely little expressions that may indicate a flash of positive emotion"

Animal welfare scientists have long recognised the importance of making living environments more stimulating, or enriching. But the evidence that animals get bored suggests that the key to making sure that captive animals are happy as well as healthy is to provide them with mental challenges.

Clark's research suggests that some animals enjoy a puzzle as much as we do. In 2018, she and her colleagues designed a maze for gorillas in which they could push a peanut through a series of wooden boxes with their fingers or a stick and retrieve the reward when it reached the exit. During six 1-hour trials at Bristol Zoo Gardens in the UK, five out of six gorillas played with the game and it was in use for almost all of the time available. Some of the gorillas played for up to 45 minutes,



PETER HAYGARTH

JEFF JARRETT/ALAMY

Gorillas seem to enjoy playing games, even when there is no reward on offer

Interpreting captive animals' emotional lives should improve their welfare

even though they seemed uninterested in the food reward. "When the nuts came out, they would just leave them to the side," says Clark. "So that's a really good indication that there's a positive impact of doing this challenge and it's not just to get the food."

Thanks to a built-in camera, Clark even spotted facial movements that corresponded with how well the gorillas were performing. "You get these lovely little expressions, as you would in a human face, that might indicate a little flash of positive emotion," she says.

Some animals will even work for a reward when the same prize is available for free. Back on the farm, pigs have been shown to prefer to search for food in straw rather than get the same rewards in a trough. And goats will choose to push open a sliding door to access food over taking it from an open door. Scientists call this "contrafreeloading" as it contradicts the assumption that animals should optimise their foraging efficiency by minimising their energy expenditure.

But it makes sense because challenges are a ubiquitous part of life for wild animals, and positive emotions have presumably evolved to reward animals for solving them, says Clark. "The better you are at solving your challenges, the more likely you are to thrive, to go on and breed and find the best food," she says. "So there's this really interesting link between challenges and emotions."

There is also evidence that farm animals find learning intrinsically rewarding. For a study published in 2020, Meagher and her colleagues trained 10 cows to associate different lids on containers with different types of food, so they could choose the food they wanted by recognising the lid. Another 10 cows were given the same food, but without learning to predict or control what they would get. The cows in the learning group subsequently approached the testing area more quickly, suggesting they were more motivated to take part in the experiment.

In the zone

Perhaps the most surprising claim, however, is the idea that animals, like humans, might enter a "flow" state – in which they are completely absorbed in a stimulating activity.

Flow has been studied in human psychology for decades, and it is strongly linked with positive emotions. To be clear, it has never been observed in animals. But Hintze argues that there is no reason to think it is unique to humans on the basis that animals are likely to have similar motivations to us to acquire skills and work towards a goal. In a conceptual paper published in 2022, Hintze and Jason Yee at the University of Veterinary Medicine, Vienna, proposed that for predatory animals, for example, we might be able to induce flow by simulating hunting behaviours, while a flow-inducing task for pigs might involve challenging their acute sense of smell.

Hintze and Yee suggest that one way to assess whether animals really do experience flow-like states is to measure their perception of time. The idea stems from the fact that when we experience flow, we perceive time to pass more quickly. So, for example, you might train an animal to press a red button when they hear a long tone and press a blue button when they hear a shorter tone. If you then play them an intermediate tone, their response might tell us how quickly they are experiencing time. "If we can induce flow, assess flow and find out what it means for animal welfare, it might be a new dimension for how to study positivity and improve ways of life," says Hintze.

That would be a boon for the campaign for positive welfare, which seeks to promote better lives for captive animals. In recent years, the movement has begun to spill over from the research community into the wider world. Welfare assurance schemes in the European Union, for instance, are now looking to integrate positive emotion indicators into the way that farms are assessed, says Hintze. "There is a change. Society doesn't accept just preventing suffering anymore," she says.

At which point, the question becomes: how can we incorporate what we are learning about positive animal emotions and what elicits them into how we treat the animals we keep by the thousands in farms and zoos?

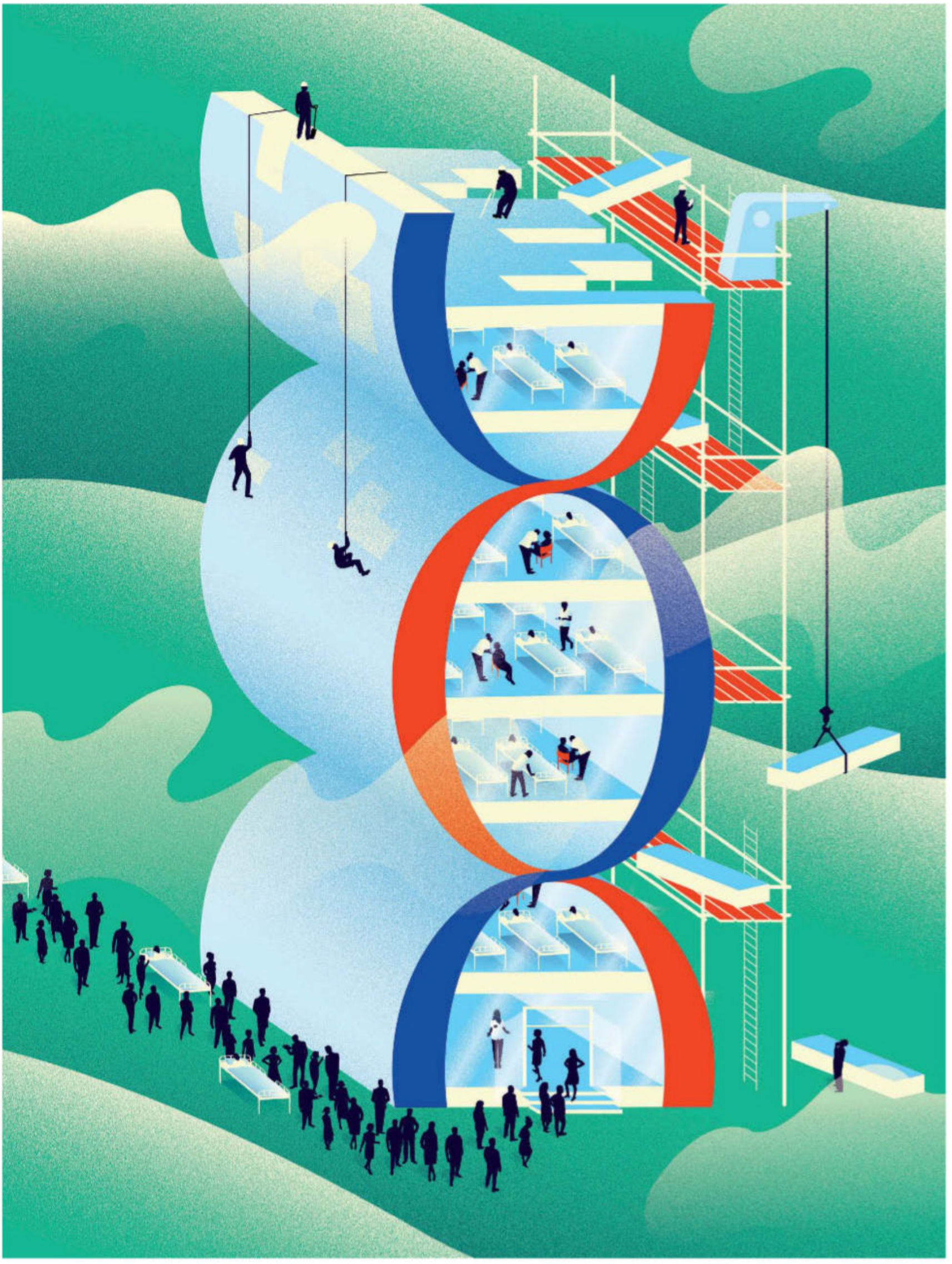
For Linda Keeling at the Swedish University of Agricultural Sciences, a key area to focus on is animals' early life experiences. She draws a parallel with child psychology: children who are insecure at a young age avoid taking risks, whereas children who feel secure enough to take risks learn that doing so can be rewarding. "If you rear an animal in an environment where there's more choice, then it helps improve their cognitive abilities –they are better at problem solving, they're better at handling situations, they cope with stress better," she says.

The other thing to keep in mind when it comes to providing a pleasingly challenging environment is that it isn't always easy to find the sweet spot between too easy and maddeningly difficult, says Clark. "This might be why cognitive enrichment is not being taken up as much as I would like. Sometimes, it takes a bit of training."

And yet there is a huge and potentially very grumpy elephant in the room. To put it bluntly, it is hard to imagine that these insights will lead to meaningful improvements in animal welfare unless there is a radical shift away from industrial-scale farming. "I really hope farms will move to a much smaller scale, where the animals have more space, more resources and more natural behaviours, which would mean less production," says Briefer.

That might sound unrealistic at first blush, but the researchers working in this field are hopeful that what they are revealing about captive animals' cognitive and emotional lives might force a shift in how we think about our relationship with them. "If people started giving animals a little more credit for what they actually can do, then maybe we will be more motivated to change how we keep them," says Meagher. ▮

Sam Wong is assistant news editor at *New Scientist*



NEIL WEBB

Cut, paste, cure

The world's first gene-editing CRISPR treatment is about to be approved. It could transform the lives of millions, and one day tackle everything from rare genetic conditions to high cholesterol, says **Michael Le Page**

THE bouts of terrible pain began further back than Victoria Gray can remember. Her grandmother would try to ease the discomfort with hot towels and medication, but it was fruitless. "I was born having to endure pain," she says. "It was a life that I felt wasn't worth living."

Gray has an inherited condition known as sickle cell disease, which causes red blood cells to form an abnormal "sickle" shape that can block capillaries, causing pain and sometimes organ damage. As Gray aged, her pain got worse. On one occasion, she temporarily lost the use of her arms and legs. By her 30s, Gray required in-home care. So, when she was offered the chance to become the first person to receive an experimental CRISPR gene-editing treatment, she took it.

Today, four years after this took place, she no longer has episodes of pain and works full time. "Now my life is full of optimism," she says.

The treatment involved will probably be given the green light by regulators in the US, UK and Europe soon, which will make it the first CRISPR therapy to be approved. It won't be the last.

There is now no doubt that this technology – used to edit genes – can treat and potentially even cure a huge range of conditions. The only question is, just how far can it go? Will it be an expensive therapy used only occasionally? Or will it become so widely used that many of us will be getting a CRISPR jab to, say, lower our cholesterol levels and enable us to live longer, healthier lives?

CRISPR gene editing exploded onto the scene in 2012. It came about thanks to the discovery that many bacteria produce so-called CRISPR-Cas proteins that can cut DNA at specific sites. The DNA-cutting part wasn't new – biologists had already found proteins that can do this, but each protein could only bind to and cut DNA at one specific sequence. To target a different sequence, biologists had to alter the shape of the DNA-binding part of the protein, a difficult and expensive process taking many months.

The revolutionary thing about CRISPR-Cas proteins is that the target sequence is determined by a piece of "guide RNA" that links up with the Cas protein and binds to any matching DNA sequence – and RNAs are cheap and easy to make.

Within months, hundreds of labs worldwide were trying CRISPR gene editing in all kinds of organisms. Many studies involve using CRISPR for research: detecting viruses, say, or recording cells' activities. But it is no longer restricted to labs. In some countries, people are already eating CRISPR-edited plants and animals – and in 2018, it was announced that three genetically modified children had been born in China. Their genes were edited using CRISPR technology at the embryonic stage by scientist He Jiankui in an effort to prevent them contracting HIV from their fathers (see "Editing eggs and sperm", page 40). Jiankui was jailed for his actions.

"Gene-editing therapies are going to change people's lives in important ways"

Most remarkably, more than 75 clinical trials involving CRISPR are under way or have already been completed. This is a phenomenal achievement as new medical technologies typically take several decades to develop to the point where they are ready to try on people.

"These gene-editing therapies are really exciting in the near term and I think are going to change people's lives for the better in a lot of important ways," says bioethicist Kelly Ormond at Stanford University in California.

Around half of these trials involve treating cancer. The idea here is generally to take immune cells from a person with cancer, edit them to be better at attacking the cancer and replace them in the body.

Most of the other CRISPR trials involve treating inherited conditions, such as sickle cell disease. This is caused by mutations in both copies – one inherited from each parent – of the gene for adult haemoglobin, the protein that carries oxygen in the blood. But a few ›

Editing eggs and sperm

With one CRISPR therapy set for approval and more to follow (see main story), a new question arises: should we edit the genomes of embryos, eggs or sperm so that the DNA in all of the cells of our children is changed, and those changes are passed down the generations?

For now, there is no compelling reason to do so. Almost every inherited genetic condition can already be prevented by existing forms of screening, including by testing IVF embryos before implantation. By contrast, using CRISPR is risky because it isn't guaranteed to fix the disease-causing mutation in all cells in children's bodies, and could introduce unwanted or dangerous mutations.

As a result, there is near-unanimous agreement among experts that no one should be attempting heritable genome editing at present. And as far as we know, no one has attempted it since biophysicist He Jiankui was jailed in China for creating three CRISPR-edited children – though one scientist in Russia has said he wants to perform the technique to prevent an inherited hearing condition.

But it could become possible to use CRISPR to fix mutations in sperm stem cells that make people infertile. "This could become a compelling reason for heritable genome editing," says Ephrat Levy-Lahad at the Shaare Zedek Medical Center in Jerusalem.

She also points out that the IVF process can sometimes result in so few embryos that screening out disease-causing mutations can greatly reduce the treatment's success. If heritable genome editing can be made safe, it might be better to gene-edit embryos in these situations rather than discard them, she says.

people with mutations in both gene copies don't get ill because they keep producing fetal haemoglobin as children and into adulthood, instead of stopping after birth as usual. This gave researchers the idea for a therapy: use CRISPR to reactivate fetal haemoglobin production.

This is how doctors treated Victoria Gray. First they extracted blood stem cells that produce red blood cells from her body. They then used CRISPR technology with a Cas enzyme called Cas9 to destroy the genetic "off switch" for fetal haemoglobin. Next, chemotherapy was used to kill the unmodified blood stem cells in Gray's bone marrow, to make room for the edited ones. Finally, the gene-edited cells were put back in her body.

Another 35 people have since received the same treatment. Of the 17 people treated long enough ago to assess the results, 16 have been free from episodes of pain for at least a year.

The procedure, developed by Vertex Pharmaceuticals in Boston, Massachusetts, can also be used to treat people with beta thalassaemia, a blood disorder that is also caused by haemoglobin mutations. So far, 48 people have been treated and out of the 27 with long follow-ups, 24 have gone at least a year without needing blood transfusions and the other three need fewer transfusions.

"After having the CRISPR therapy, no cancer cells could be found in Alyssa's body"

GREAT ORMOND STREET HOSPITAL

Alyssa is in remission from T-cell leukaemia thanks to a new CRISPR therapy

If, as expected, this CRISPR therapy becomes the first to be approved sometime this year, it will be a momentous milestone. But there is a major issue with the standard CRISPR-Cas9 method that could limit its future use: it is more accurately described as targeted gene destruction than gene editing.

That is because the Cas9 protein cuts DNA at the site determined by the guide RNA. The cell's repair systems then kick into action to stick the two severed ends back together. They may repair it perfectly, says Richard Liu at Harvard University, but then the Cas9 cuts the DNA again and again until a faulty repair is made, introducing mutations that disable a gene.

It is the equivalent of correcting a mistake in a text by scratching out an entire word. In a few instances, that can work well – say, if there is a stray "not" in a sentence that shouldn't be there. But, for most misspellings, it isn't enough. Similarly, treating most genetic diseases requires correcting genes rather than destroying them. "The vast majority require precise genome correction," says Liu. There are also safety issues with completely severing DNA. If several cuts are made, the wrong ends can get joined up, limiting the number of changes that can be made at the same time.

The good news is that several solutions have already been developed. One of the most promising, called CRISPR base editing, is a way

ERNIE MASTROIANNI/ALAMY

Geneticist Robin Lovell-Badge briefs the media on CRISPR-edited children

to turn one of the four DNA letters – A, G, T and C – directly into another without any cuts.

Liu created the first base editor by swapping the cutting part of the CRISPR-Cas9 protein for an enzyme that chemically alters an individual letter instead. While more base editors are still being developed and improved, the first few have produced many therapies that are already in the pipeline – and that may have already saved at least one life.

Last year, a teenage girl called Alyssa had run out of options after all the usual treatments for her leukaemia had failed. So her doctors instead tried an experimental approach that involves engineering immune cells to attack the cancer.

These modified immune cells, called CAR T-cells, are created by using a virus to add a gene to T-cells that makes them target a specific cell type. They are highly effective at treating many forms of leukaemia.

Life-saving solution

The trouble was that Alyssa had T-cell leukaemia, and if you make CAR T-cells target T-cells, the therapeutic cells kill each other. So, in addition to adding the targeting gene, Waseem Qasim at the Great Ormond Street Institute of Child Health in London also used base editing to stop the CAR T-cells recognising each other as T-cells.

In fact, Qasim made four additional changes altogether via base editing to improve the cells. Soon after receiving the base-edited CAR T-cells, no cancerous cells could be detected in Alyssa's body, though it is too soon to know if this is a complete cure.

While base editing is looking like an even more powerful and safer gene-editing tool than standard CRISPR, it is limited to altering single DNA letters. Enter prime editing, created by Liu's colleague Andrew Anzalone, now scientific co-founder of biotech company Prime Medicine.

Prime editors are Cas9 proteins modified in several ways. Instead of cutting right through DNA, they just "nick" one of the two strands that make the classic double helix shape. The Cas9 protein's guide RNA is given an extra bit of RNA, which is what the cell uses as a template when repairing the damage. This allows short stretches of around 40 DNA letters to be added or deleted.

Liu says that is enough to treat 95 per cent of genetic diseases. But biologists haven't stopped there. Last year, researchers reported that they had managed to add stretches of DNA up to 36,000 letters long to specific sites using a modified form of prime editing.

All this means we now have a rapidly growing set of CRISPR tools for true gene editing, not just targeted gene destruction.

But there remains another major issue: cost.

Vertex won't announce the pricing for its sickle cell treatment until after approval. Other gene therapies cost millions to make and buy, but they are usually for very rare diseases. Sickle cell affects millions worldwide, so Vertex may be able to charge much less and still make a profit, but it will still be very expensive due to its complex nature. "There are a couple of people in my family that are still suffering from this disease," says Gray. "That's our biggest worry, that once it becomes mainstream, they won't be able to afford it."

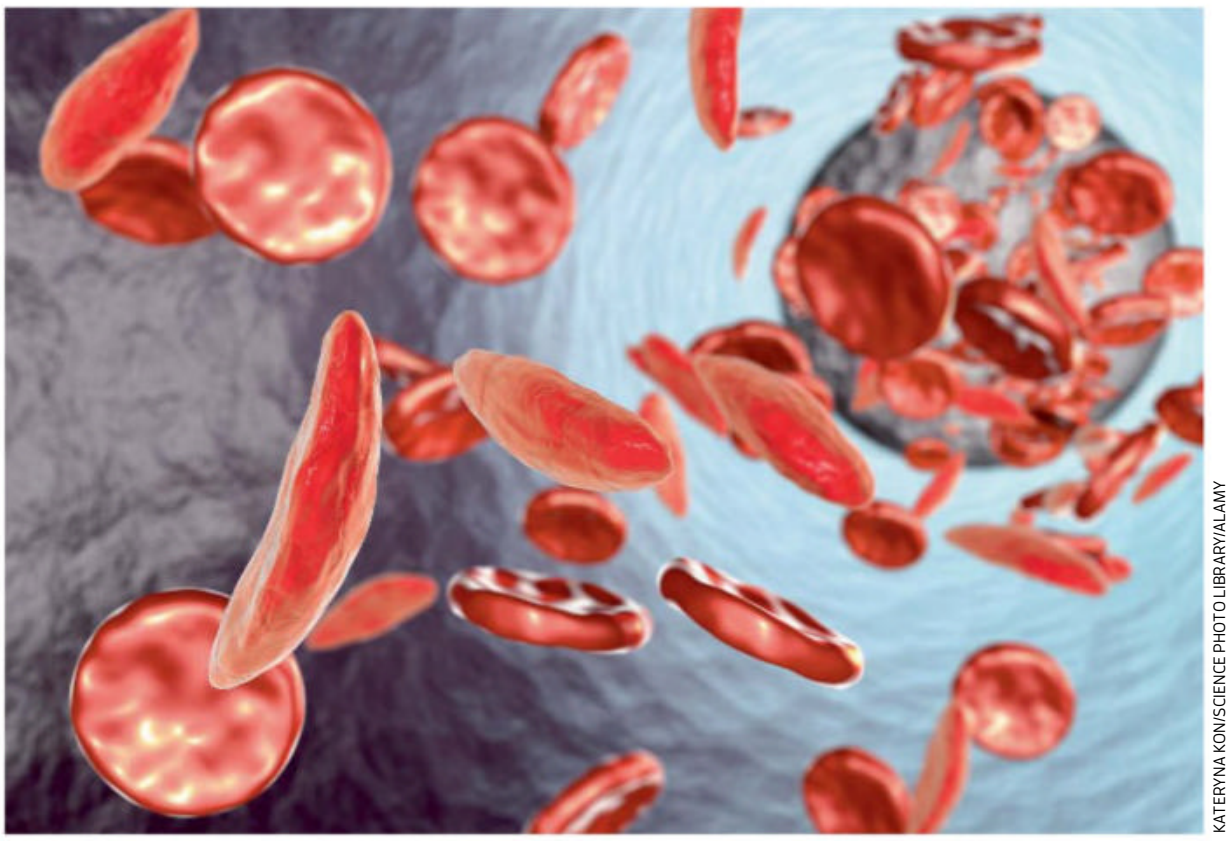
One way to reduce costs is to take cells from a single donor and gene edit them so they can be used to treat many different patients. Such off-the-shelf cells are already being used for cancer treatments, including the one Alyssa received.

The immune systems of people getting treatments for leukaemia are so weakened that rejection of the donor cells as foreign isn't an issue, but the donor CAR T-cells can see the body they are transplanted into as foreign. Gene editing can prevent this by disabling the key receptor protein T-cells use to spot foreign cells.

If the treatment is successful and people's immune systems are restored, the donor CAR T-cells get killed off. By this time, they have done their work, so this isn't an issue. But at least one company is editing out proteins on the donor cells that mark them out as foreign to the recipient, meaning they could persist indefinitely in the body without rejection. The aim is to use this approach to treat diseases such as type 1 diabetes in addition to cancer.

While all off-the-shelf cells could greatly reduce costs compared with extracting and modifying each individual's cells, any cell-based therapy is still going to be expensive because of the issues involved in growing and maintaining cells outside the body while ensuring their purity and safety.

To get treatments to all the people who need them around the world, what is really needed is a single shot that can be given to people without complex treatments and long hospital stays, says Emily Turner at the Bill & Melinda Gates Foundation in Seattle. ›



KATERYNA KON/SCIENCE PHOTO LIBRARY/ALAMY

Sickle-shaped blood cells, which cause severe pain, can be treated with CRISPR

"This is a big challenge."

But it could be done by editing cells inside people's bodies instead of outside them. What's more, this approach would solve a major drawback with treatments like the one Gray got: the chemotherapy that makes room for the edited blood stem cells usually renders people infertile.

To edit cells in the body, the CRISPR machinery has to be delivered to those cells. This is usually done by packaging a type of RNA called mRNA, which codes for Cas proteins, alongside guide RNAs in tiny fatty nanoparticles or in viruses, then injecting them into the blood.

When the mRNAs get into a cell, the cell will make the Cas protein, which then hooks up with the guide RNAs and edits the genome of the cell. After a few days, the added mRNAs and the Cas proteins will break down, so the gene-editing machinery doesn't persist in the body, which reduces the risk of unwanted changes to the wrong bits of DNA.

The first trial of in-body CRISPR-Cas9 gene editing, for treating a hereditary form of heart disease called ATTR amyloidosis, began in 2021 and results from the first few patients suggest it is safe and effective.

Cutting cholesterol

Even so, because numerous studies show that standard CRISPR can cause unwanted mutations – and thus potentially cancer – it is questionable whether the balance of benefits versus risk justifies its use for less serious conditions for now. Regulators will want to see much more evidence of safety.

Base editing, on the other hand, is safer than standard CRISPR because it doesn't cut DNA. In July last year, the first trial of within-body base editing got under way in New Zealand, with the aim of permanently reducing cholesterol levels – no more need for popping pills, with their attendant side effects. In animal tests, a single injection permanently reduced cholesterol levels by around 60 per cent.

The people in the trial have dangerously high cholesterol levels due to an inherited condition called familial hypercholesterolemia. But if the treatment is a success, Verve Therapeutics, the company behind this, aims to expand it to people with heart disease due to clogged arteries, and eventually to anyone merely at risk of getting this kind of heart disease.

In other words, Verve is hoping that, in the not-too-distant future, its one-time shot will start to replace the cholesterol-lowering drugs currently taken daily by more than 200 million people around the world.

Even if Verve's bold strategy succeeds, there is yet another challenge to overcome: delivery. To lower cholesterol, Verve is gene editing liver cells, which are the easiest cells in the body to target. That is because when lipid nanoparticles are injected into the blood, most of them get taken up by the liver.

The issue is that only a few conditions can be treated by targeting livers. For most purposes, we will need to target other tissues, such as brain or muscle cells, which is much harder. Researchers are exploring lots of different ways to achieve this, and while the matter certainly hasn't been solved, many teams around the world are reporting promising results. For instance, in April, researchers reported that they had managed to treat sickle cell in mice by injecting them with a virus that delivered prime-editing machinery to blood stem cells inside their bodies.

"One day, a single gene-editing shot may replace our cholesterol-lowering drugs"

Such a one-shot treatment would be a lot less costly and complex than the one Gray received, and would also avoid its big downside – the need for fertility-destroying chemotherapy.

"There's tremendous and exciting progress, but we still have a way to go," says Matthew Porteus at Stanford University. It isn't just about solving the biological problems, he says – rolling out CRISPR cures en masse would also require everything from training people to building infrastructure to industrialising the manufacture of the required components to having regulations that ensure safety without being too onerous.

The true finish line is delivering one-time cures to all the people in the world who need them, says Porteus. That process is now getting started for sickle cell disease, and could begin soon for many other conditions. "I'm part of something that could be amazing for all mankind," says Gray. ▮

Michael Le Page is a senior reporter at *New Scientist*

The back pages

Stargazing at home

Circling Jupiter

The icy Galilean moons of Jupiter are promising places to look for life. Now is a great time to spot them, says **Abigail Beall**

Abigail Beall is a features editor at *New Scientist* and author of *The Art of Urban Astronomy*. @abbybeall

What you need

A small telescope or large binoculars

Stargazing at home appears every four weeks. Share your stargazing successes with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistStargazing

Next week

Mathematics of life

ON 14 April this year, the European Space Agency sent a new spacecraft off on its eight-year journey to Jupiter. The Jupiter Icy Moons Explorer (JUICE, illustrated right) will fly by three of Jupiter's four biggest moons, Europa, Ganymede and Callisto, before going into orbit around Ganymede, the biggest moon in the solar system. This is an exciting mission because these icy moons, with their subsurface oceans, are some of the most promising places to look for life. And now that Jupiter is once again appearing in our night skies, we can see those icy moons ourselves.

The four biggest moons of Jupiter – Io, Europa, Ganymede and Callisto – are collectively known as the Galilean moons, because Galileo Galilei observed them in 1610, making them the first moons discovered beyond Earth. This was hundreds of years before Neptune, Uranus and Pluto were found. The fact they were discovered so long ago hopefully gives you some idea how easy it is to spot them, as long as you have access to a small telescope or large binoculars.

If you are using binoculars, they need to have at least seven times magnification to see these satellites. Your binoculars will be described by two numbers, usually written in the format "12x36", for example. The first number is the magnification, so if this is a seven or above, you should be in luck. The second number is the diameter of the lenses, in millimetres, so a bigger number means a bigger field of view – but this isn't so relevant here.

ESA/NASA

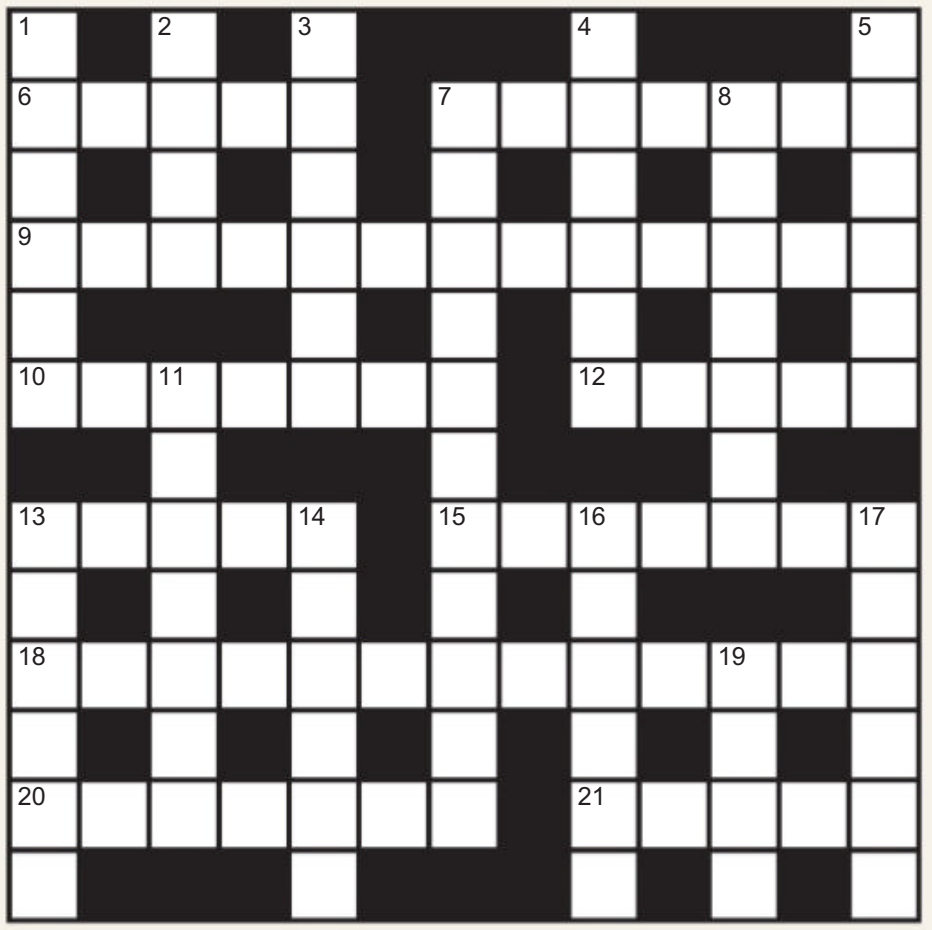
To look for Jupiter's moons, we must first find Jupiter. It is usually easy to spot because, when visible, it becomes one of the brightest objects in the night sky. Throughout July, Jupiter will be rising in the early hours of the morning. But as the months go on, it starts to rise earlier and earlier until, in September, it will be rising about an hour after sunset. From October, and for the rest of the year, Jupiter will be visible as soon as the sun has set for a few hours. This is the same all over the world.

Once you have found Jupiter, look through your binoculars or telescope and you will see a few small spots of light very close to the planet. There will be up to four of these, and they will appear in a line. They might all be on one side of the planet or they might be on both sides. There might be fewer than four – in which case, some of the moons will either be in front of or behind Jupiter. The exact formation the moons appear in changes each day, depending on their paths of orbit around Jupiter. To work out what you have seen, you can use the Stellarium web software, plug in your location and time and zoom right into Jupiter.

I love looking at these moons because it reminds me the search for alien worlds doesn't need to involve distant exoplanets: we have very exciting environments in our cosmic back garden. ▮

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

Cryptic crossword #113 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

6 Juvenile monkey finally asleep at hospital (5)
7 Power company replaced by couple from Wales in quaint home (7)
9 Joy circles certain rock over valuable cache (8,5)
10 Chewed marker tip oozed (7)
12 Close badly lit well the wrong way (5)
13 STEM lecture follows start of symposium (5)
15 Gripping device put behind argon light (3,4)
18 Horned beasts destroyed a poster in moments (13)
20 Enhance new mutagen (7)
21 Feel bad around beginning and end of poor month (5)

DOWN

1 Engineer-suffragette not returning after a year (6)
2 Poolroom item boasting black 8, say (4)
3 Tool lying in ditch is electronic (6)
4 Runner's complaint: second time with skin irritation (6)
5 Map's list of symbols is hip? (6)
7 Line in news recalled ambush as "very different" (6,5)
8 An operator's lost symptom of covid-19 (7)
11 Loud lad almost feeds bear (7)
13 Vast shifts involving North American geopositioning system (6)
14 Zoo employee Kelvin upset about animal waste (6)
16 Pink captures hearts for a vocal group (6)
17 Gadfly on the French grinder (6)
19 Dry spot across river (4)

Quick quiz #209
set by Bethan Ackerley

1 Who first proposed the gunslinger effect, the idea that an intentional movement will always be slower than an automatic reaction?

2 Breathing powered by the expansion and contraction of the mouth, as seen in animals like frogs, is known as what?

3 Which of these is the least massive known exoplanet: Draugr, Hypatia or Rocinante?

4 Viruses that infect and replicate within bacteria are known as what?

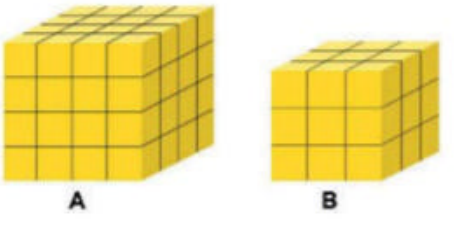
5 Who shared the 2020 Nobel prize for chemistry with Emmanuelle Charpentier for work on CRISPR-Cas9 gene editing?

Answers on page 47

Headscratcher
set by Brian Hobbs
#229 The greater gouda

Madeline has many large cheese cubes to cut into smaller cubes for tonight's charity event. She wants to turn some of the large cubes into 4x4x4 smaller ones, creating 64 in total (see image A). She could do that with nine straight cuts, three along each axis, but her knife is as dull as the task, and she realises that if she rearranges the pieces between cuts, she can double their number with every cut she makes, and thus get the same result with fewer slices. After the first cut, there are two pieces; after the second, four; after the third, eight, and so on, giving 64 cubes with only six cuts.

Likewise, a 3x3x3 stack of cubes (image B), or 27 total cubes, could be achieved in six cuts without moving any pieces around, but she thinks she should be able to, well, cut that number down if she similarly rearranges the pieces between each slice. What is the minimum number of cuts she will need to end up with 27 cheese cubes?



Solution next week

On the run

I have just seen two people exercising together. She was running while he cycled beside her. She was only moving herself, but he was moving the bike too. Who expended more effort?

Tony Green
Ipswich, Suffolk, UK
A bicycle is a supremely efficient tool for converting muscle power into motion. So much so that while I can happily ride 130 or more kilometres, even a 1-kilometre run is utterly beyond me.

So, the runner is undoubtedly expending more effort than the cyclist in my view.

Peter Slessenger
Reading, Berkshire, UK
If level or downhill, the runner is definitely using more energy because lifting the body off the ground is hard work.

I recently used an "anti-gravity" treadmill, which uses air pressure to reduce your weight on the track. Running at 70 per cent bodyweight (about 25 kilograms lighter) was easy, at a speed I could never manage for more than a minute normally.

When running uphill, though, I have several times overtaken struggling cyclists.

Ron Dippold
San Diego, California, US
The cyclist is expending less effort, even if he weighs twice as much.

Every rotation of the cyclist's feet is going directly into forward motion, minus only the friction of the wheel and chain.

The runner, on the other hand, wastes much of her energy on producing vertical forces every time her foot hits the ground.

"Studies show that cycling on flat, firm ground is about one-third the effort of walking or running at the same speed"

Studies show that cycling on flat, firm ground uses about one-third the effort of walking or running at the same speed. I need to bike 32 kilometres for the same workout as fast-walking for 8 km.

The best resource for such comparisons is the Compendium of Physical Activities website, which regularly incorporates the latest studies into its list of Metabolic Equivalents (METs). A MET of 1.0 corresponds to resting level. An activity with a MET of 2.0 burns twice as many calories as that.

The formula for these values is MET × weight (kg) × time (hours) = calories burned (kilocalories).

For instance, leisurely biking at 8 kilometres per hour has a MET of 3.5, while running at 8.4 kilometres per hour has a MET of 9.0. Those values are directly comparable. This shows that cycling is burning about 2.5 times fewer calories (3.5/9.0).

Note that a cyclist going at a moderate cycling speed (MET 7.5) will burn around twice as many calories as someone walking at a moderate walking speed (MET 3.5), but, of course, the cyclist is going much faster and further. In the example given, the cyclist is held back to a snail's pace, so that doesn't apply here.

Of course, the cyclist puts in zero effort on a downward slope, but they put in more effort on a steep, upward slope. On a sufficiently bad trail, the cyclist will be walking – or flat on the ground! Terrain matters.

But in the example given, it is the cyclist who is slacking.

MANOJ SHAH/GETTY IMAGES

This week's new questions

Small fry **Why are the largest modern land animals so small compared with prehistoric ones? Some dinosaurs weighed up to 80 tonnes.** ***Richard Swifte****, Darmstadt, Germany*

Sticking point **Why does runny honey stop dripping when there is still plenty left on the spoon?** ***Jane Pearn****, Selkirk, Scottish Borders, UK*

Why were some dinosaurs so much larger than modern elephants?

Dave Jackson
Telford, Shropshire, UK
Like a lot of *New Scientist* readers' questions, this is less straightforward than it would appear.

I am an ex-runner who now cycles at my previous running pace. Speed, weight and fitness will factor in, but bikes are a very efficient way of turning human energy into speed, so I suspect in most cases the runner is expending more energy. However, we are asked about effort rather than energy expenditure.

When I was running fit, it was more comfortable to maintain a 1000 kcals per hour energy expenditure while running than while cycling or using gym equipment. So, burning energy isn't directly related to effort. I suspect, for the people in this situation, a smartwatch would answer the energy question, but not the more complex and less objective question of "effort".

Eric Kvaalen
Les Essarts-le-Roi, France
Definitely the person who was running. There was an article in *Scientific American* in 1973 examining the efficiency of various modes of transportation, including walking, running and cycling, and it showed that cycling was by far the most efficient. Riding at a moderate speed takes no more energy than walking.

Word memory

When I read a word that I don't know how to pronounce, I can't remember it. Why do I need to be able to pronounce a word for my brain to recall it?

Guy Cox
Sydney, Australia
Humans had been using language for a very long time before writing was invented, so this isn't really surprising. We have evolved to

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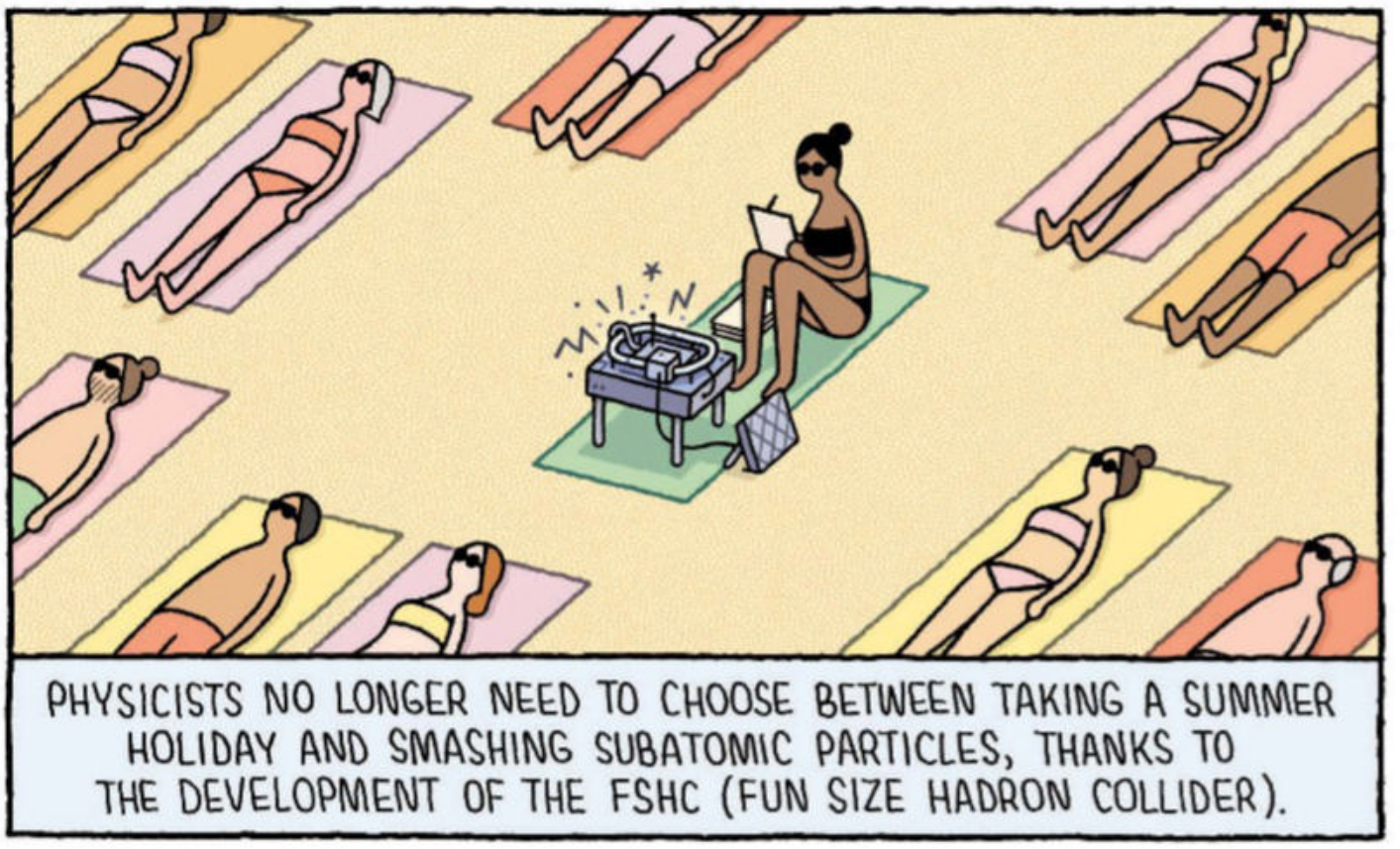


remember sounds, not letters.

But the funny thing is that we only have such poor memory for written words when we can't guess how to pronounce them. We can perfectly remember words for which we have conceived an incorrect pronunciation.

For example, up to age 9, I thought that "gesture" had a hard "g" – I had read the word often enough, but had never heard it spoken. This can have hilarious consequences. The story of the radio announcer who referred to Pyotr Tchaikovsky's opera as "you gene one gin" may be apocryphal, but I have heard many broadcasters announce Wolfgang Amadeus Mozart's "Don Geo Varney".

The funniest one (and I swear this is genuine) was a volunteer announcer on a community station, who referred to the Kyrie movement from a Mass setting – but as you would pronounce Kylie!

David Bortin
Whittier, California, US

The pronunciation of a word is a single, easily memorable fact – or, at most, one fact per syllable. Its spelling, however, is a sequence of independent facts that must be separately recalled and correctly ordered, with exponentially greater opportunities for error.

"The pronunciation of a word is a single, easily memorable fact. Its spelling, however, is a sequence of independent facts"

Stacking up

Is there a correct way to fill a dishwasher to maximise capacity and cleanliness? (continued)

Marian Smales
York, UK

I have been interested in the correspondence regarding the stacking of dishwashing machines. I would like to mention a different perspective on this.

If we ever move house again, I will be tempted to put into practice an idea I had a few years ago. Why not have two dishwashers side by side?

Dirty items would be put in until the washer is full. The clean items would be taken straight from that machine, used, and put into washer two. That is run when full, and the process repeats.

This effectively provides two storage units for cutlery, crockery and pans, which means that less cupboard space is required. The footprint of each is no more than a standard kitchen unit.

No more electricity is used because they are never run at the same time. Plus, no unnecessary time or energy is expended in emptying one and transferring all the contents to somewhere else in the kitchen.

One final advantage is that, in the case of the breakdown of one machine, there is always a spare.

Chris Robinson
London, UK

There are as many correct ways of loading a dishwasher as there are people who load dishwashers. ▮

Answers

Quick quiz #209 *Answers*

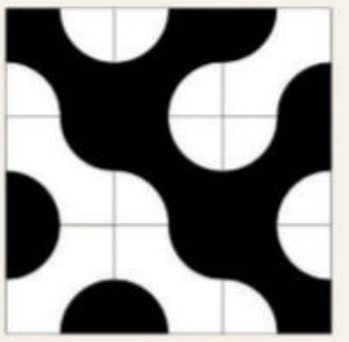
1 Niels Bohr
2 Buccal pumping
3 Draugr, which is about twice as massive as Earth's moon
4 Bacteriophages, or phages
5 Jennifer Doudna

Quick crossword #136 *Answers*

ACROSS 5 Chitin, **7** Mayflies, **9** Adhesion, **10** Humvee, **11** Kidney stones, **13** Elytra, **15** EarPod, **18** Antiparticle, **21** Heroin, **22** Cubiform, **23** Appendix, **24** Solids

DOWN 1 Ethernet, **2** Entity, **3** By chance, **4** Flames, **6** Hadfield, **7** Minute, **8** Ewes, **12** Collared, **14** Actinide, **16** Rainfall, **17** SpaceX, **18** Avocet, **19** Ribose, **20** Beep

#228 A knight on the tiles *Solution*



The three dots specify the locations of nine diagonals, but only touch eight squares. Therefore, two of them – the two black dots – must share a diagonal. The other three squares neighbouring the white dot must have white diagonals, and then the pairs of tiles remaining next to the black dots must have black diagonals. The top-right tile must be placed to prevent an island forming.

Flowery language

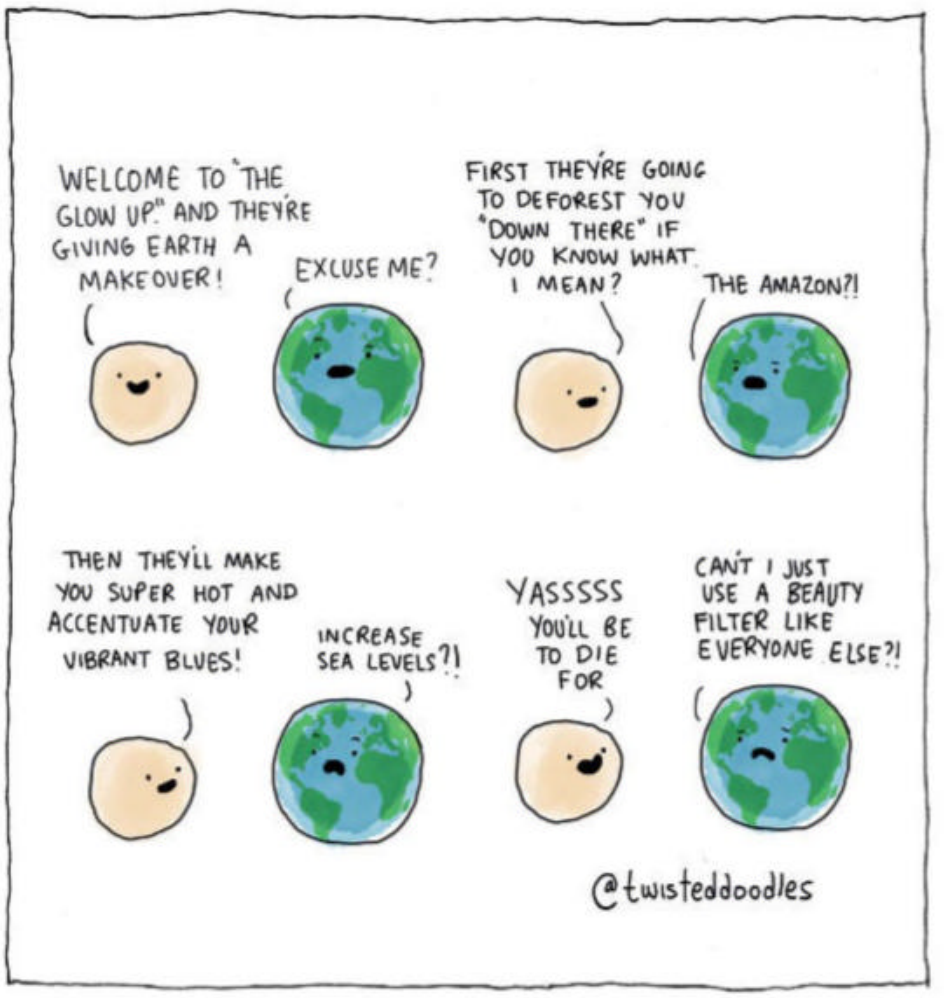
Polymorphic perversion has fallen by the wayside in academia. As a subject of study, that is. Research publications in recent years make few overt mentions of it.

The phrase and long-running quarrels as to its meaning are associated with psychoanalyst Sigmund Freud, whose death in 1939 prevented him putting paid to those quarrels. Grażyna Gajewska at Adam Mickiewicz University in Poland is one of the few academics who is now overtly studying polymorphic perversion on a broad, societal level. Her recent treatise "Polymorphic perversion of human and other-than-human bodies" appears in the journal *Porównania*.

Gajewska gives a peek into aspects of life that will be new to many readers. She focuses mainly on our relationships to plants, rather than to bacteria, archaea or non-human animals. Her paper, she says, "presents some of my impressions regarding the 'vegetal facet of the human' ".

She then specifies that "one could cite the captivating images of flowers resembling female lips (*Psychotria Elata*), figures of dancing men (*Orchis Italica*), [and] swaddled infants (*Anguloa Uniflora*)". The orchid, says Gajewska, "can be treated as a figure of this polymorphic perversion". The remainder of her paper demonstrates the truth of that statement.

Twisteddoodles *for New Scientist*



Got a story for Feedback?

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Screwing up

Six per cent of 53,400 screwings got screwed up in a massive test done on a vehicle assembly line in Portugal. The test was meant to try out new machine vision equipment and to see how well those new vision gizmos would cooperate with the existing robotic screw-tightening machinery.

The tale is told, with some expected twists, in "Comparison of 3D sensors for automating bolt-tightening operations in the automotive industry" by Joana Dias and her colleagues. They choose a matter-of-fact style to report their joyous news: "the automated bolt-tightening system was able to achieve 94% of success in 53,400 screwing operations."

Bolt tightening is step two of an especially riveting portion of the complex process of building an automobile. Step one is to get the bolt into its proper place. That isn't as simple as it sounds. You can see step one lovingly and lengthily described (from a human perspective) in "A review on significant technologies related to the robot-guided intelligent bolt assembly under complex or uncertain working conditions" by Jingjing Xu and her colleagues at Beijing University of Technology.

After step one comes step two: bolt tightening. More often than laypeople might expect, step two is followed by unplanned bolt loosening, which necessitates step three, a slick bit of robotic detective work known to insiders as "loosened-bolt detection". A classic work about loosened bolt detection is Lovedeep Ramana and colleagues' "Automated vision-based loosened bolt detection using the cascade detector".

Successful detection of a loose bolt leads, of course, to another go at step two, bolt tightening. And so it goes, with much repetition, robotic life on the assembly line being a long succession of mechanical screwings, screw-ups, recoveries and let's-get-on-with-its. That is the quotidian, nuts-and-bolts reality of auto-auto-making machinery.

Midnight musings

Feedback has been having late night fun flipping through the digital pages of the *Journal of Controversial Ideas*, which describes itself as a "peer-reviewed, interdisciplinary journal specifically created to promote free inquiry on controversial topics".

The journal is filled with papers filled with cleverness. Its aim appears to be stimulation. Stimulation of the fun kind that grows increasingly antic from the hours of midnight to dawn. It reads much like the starts of conversations people have late at night in the first year of university – fun explorations of what-ifs as if maybe there are no ifs – but done here by people who have the high-honed thinking and writing skills of professional philosophers.

Behold an example that gives the flavour. A person named Michael Plant, a research fellow at the University of Oxford, wrote a paper called "The meat eater problem".

"I argue," Plant says, "that, if meat eating is wrong on animal suffering grounds then, once we consider how much suffering might occur, it starts to seem plausible that saving strangers would be the greater evil than not rescuing them and is, therefore, not required after all." Plant is planting the idea that we should let people die because that prevents them from later maybe doing bad things.

The *Journal of Controversial Ideas* is similar in spirit to *Medical Hypotheses*, a journal that, in its heyday, published a stream of brilliantly super-reasoned ideas. Among them: E. Tuncay Ustuner's "Baldness may be caused by the weight of the scalp: Gravity as a proposed mechanism for hair loss" and Jarl Flensmark's "Is there an association between the use of heeled footwear and schizophrenia?"

If you are old enough to look back fondly on your late-teenage post-midnight what-if chats, you might welcome a fresh journey into that happy frame of mind. If you aren't yet old enough to have had late-teenage post-midnight what-if chats, you might enjoy a peek ahead at how the older kids get to rev up their wits in the wee hours. ▮

Marc Abrahams

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