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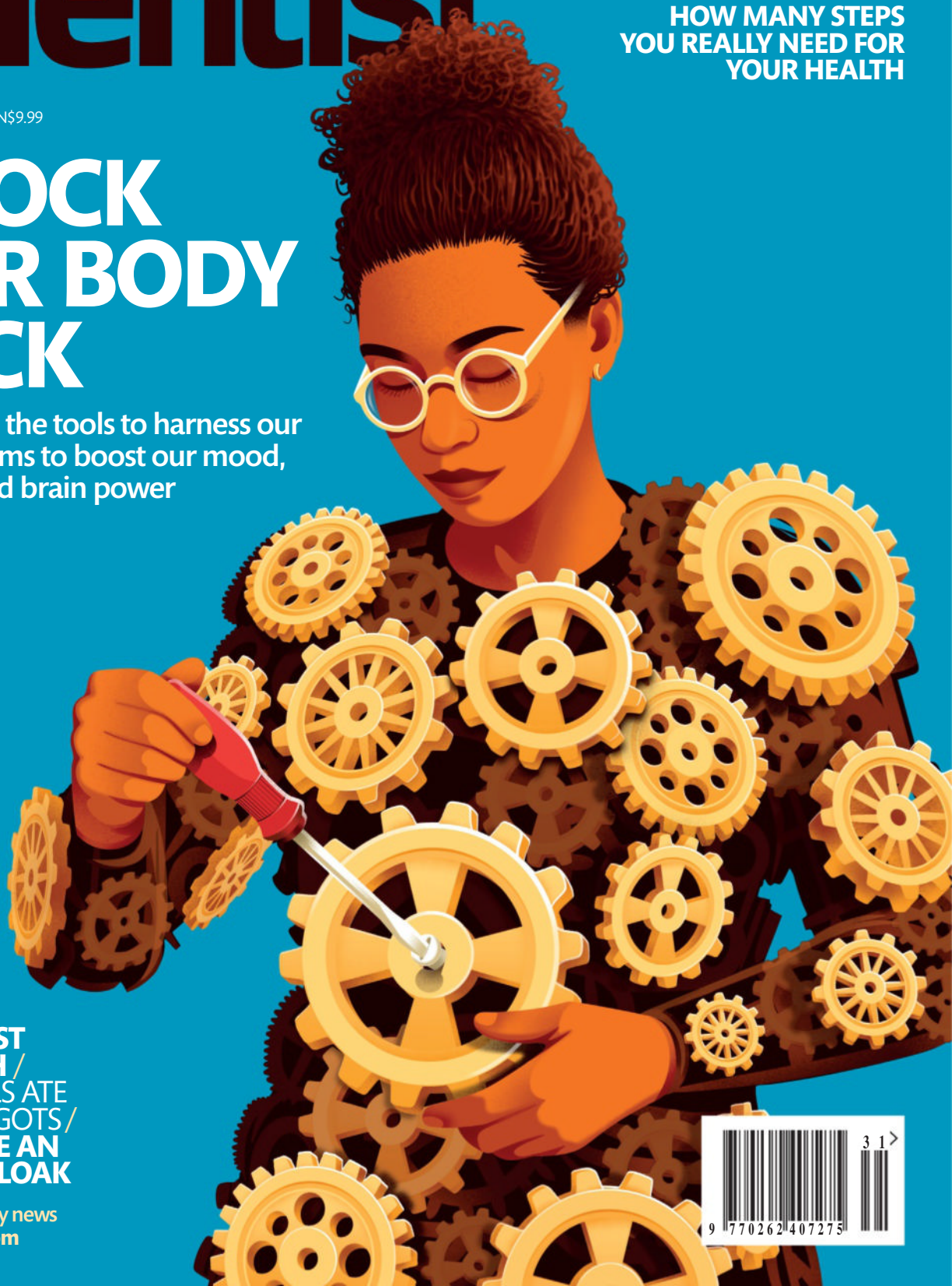
DOES GRAVITY EMERGE FROM CHAOS?

THE TRUE STORY OF PREHISTORY'S POWERFUL WOMEN

HOW MANY STEPS YOU REALLY NEED FOR YOUR HEALTH

UNLOCK YOUR BODY CLOCK

We finally have the tools to harness our circadian rhythms to boost our mood, metabolism and brain power



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We finally have the tools to harness our circadian rhythms to boost our mood, metabolism and brain power

Vol 267 No 3554
Cover image: Nash Weerasekera

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"We have long been missing a vital ingredient in health – the body clock"

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17 Fool me once Octopuses fall for the rubber-hand illusion, too

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Luminessence.

WATCH AWARDS 2024

Despite a height of only 10.95mm, the **C60 Trident Lumière** is impossible to ignore from your wrist. Day or night. This is due to its proudly protruding indices and logo they encircle. Featuring facets finely machined to tolerances of 0.03mm, these mini-monoliths are super-legible during daylight hours. But it is Globolight®, the unique luminous ceramic from which they're hewn, that produces their super-brilliance at night. And inspired this timepiece's name. The light show doesn't end there. Sculpted from titanium, the 41mm case incorporates a second sapphire crystal displaying its super-accurate movement. But it's not the back of this stunning tool watch you're thinking about. Is it?

Do your research

Christopher Ward

christopherward.com

Time for change

New body clock tests should be used to alleviate the health burden of shiftwork

THE graveyard shift is aptly named. People who work at night have an elevated risk of health problems including heart attacks, type 2 diabetes and depression. So greatly increased is their chance of getting cancer that the World Health Organization has declared shift work a probable carcinogen.

Toiling while the rest of us slumber, these workers often go unseen, though their labour underpins medical and emergency services on which we all depend. We may rely on them as a matter of life and death, yet the impact of their hours on their own health is an ironic and unfortunate inevitability.

That could be set to change with the development of tests that can finally discern the timings of someone's internal body clock as it relates to the ticking of external time (see page 30). This promises to unlock a powerful new force in medicine in a way that helps many more people.

We already know that a lot of the most commonly taken drugs affect body systems that work on a 24-hour rhythm and are more effective if taken in sync with it. Surgery and vaccines, too, work better at certain times of the day. Early efforts to accommodate this are based on a standard biological clock. But for those whose body time is out of whack, this can not only be ineffective, but also harmful. Which is where the new tests come in.

"Night workers often go unseen, but they underpin services on which we all depend"

The good news is they are set to become cheaper and more widely available. The bad news is they could end up just being used by the worried well seeking to optimise their health, using them alongside other metrics such as step count (see page 16).

But the real potential will be using them to give a window into the inner workings of those whose body clocks are seriously disrupted, offering them better treatment for the effects of working at night, more intelligent tools to manage their shift patterns and, one day, to ensure they get medical treatment at times that work with the clock their body is ticking to.

This offers a real chance to alleviate the health burden of night work and give such staff a new lease of life. Employers must wake up to this opportunity. ▮

PUBLISHING & COMMERCIAL

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Email displayads@newscientist.com
Sales director Claudia Nicoletti
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CONTACT US

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General & media enquiries
US 600 Fifth Avenue, 7th Floor, NY 10020
UK 9 Derry Street, London, W8 5HY
Australia 58 Gipps Street, Collingwood, Victoria 3066

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great taste PRODUCER

News

VCG/VCG VIA GETTY IMAGES

Environment

Catching a glimpse of the Silver Dragon

Crowds gathered along the Qiantang river in Hangzhou, China, on 27 July to watch the "Silver Dragon" pass. This is no fire-breathing monster, though, but a tidal bore, a phenomenon where a tidal wave from the sea enters a river and reverses its current. This is the world's largest bore, with waves that can reach 4 metres tall – and larger if it hits an obstacle – and travel at up to 10 metres per second.

Climate change

Is the land carbon sink collapsing?

Ecosystems on land are taking less CO_2 out of the atmosphere, raising fears that a crucial carbon sink could be weakening decades earlier than expected, finds **James Dinneen**

HOT and wet weather in 2024 – the hottest, wettest year on record – caused ecosystems on land to emit nearly as much carbon dioxide as they took out of the atmosphere. This is the second year in a row in which the land carbon sink has nearly vanished due to climate-related stressors, and would explain why 2024 saw a record jump in the concentration of CO_2 in the atmosphere.

The findings could also mean that the land carbon sink – which normally removes billions of tonnes of CO_2 from the atmosphere each year and is essential for meeting climate targets – is weakening decades earlier than expected. It remains unclear, however, if the past two years represent a long-term trend.

"Everybody I've talked with who is working on this subject is very surprised," says Guido van der Werf at Wageningen University in the Netherlands.

Forests, grasslands and other ecosystems on land take up CO_2 from the atmosphere as they grow. When they decompose or burn, this carbon is returned to the atmosphere. The uptake and release should generally be in balance. But over the past half century or so, these ecosystems have tended to take up more CO_2 than they have released, creating a carbon sink that varies in strength from year to year.

This tilted balance is thought to be due mainly to increased concentrations of CO_2 in the atmosphere fertilising plants, plus other factors like reforestation. But it isn't expected to last forever because the climate consequences of rising CO_2 are catching up with the fertilisation effect.

In 2023, researchers were concerned when the land carbon sink nearly disappeared due to extreme wildfires, heat and drought making ecosystems less productive. These conditions were driven mostly by rising concentrations of greenhouse gases, as well as the emergence of the El Niño pattern in the Pacific Ocean, which is generally associated with a weaker sink.

STEFAN ESPENHAHN/IMAGEBROKER.COM/ALAMY

Shrublands, like Damaraland in Namibia, are becoming less capable as carbon sinks

2.6 billion

The reduction in the amount of CO_2 (in tonnes) that was removed from the atmosphere by the land carbon sink in 2024 compared with usual

Greenness of the land's surface can be used as a measure of carbon uptake

NASA EARTH OBSERVATORY

In 2024, the sink was expected to strengthen as El Niño faded and there were fewer wildfires. But an international research team that includes Van der Werf found that the sink was extremely weak again.

To estimate carbon cycling, the researchers used satellite data on the greenness of the land's surface – which generally corresponds to plant growth – to calculate the productivity of the planet's terrestrial ecosystems, and therefore the amount of CO_2 they took up. They subtracted from this the amount of CO_2 released in wildfires and by decomposition, using measurements of CO_2 in the atmosphere from all over the world to estimate how much was released.

They found the land carbon sink in 2024 nearly disappeared, removing around 2.6 billion tonnes less CO_2 than usual (Research Square, doi.org/px24). This was even less than the sink removed during the 2015-2016 El Niño, making it the weakest land carbon sink in over a decade.

A disappearance or a blip?

Unlike in 2023, however, the researchers found this weakening wasn't mainly driven by fires and dry weather. Instead, their analysis found hot and wet conditions sped up the rate at which organic matter was decomposing. Ecosystems also saw an increase in productivity – greenness reached record highs – but this was outpaced by the total amount of CO_2 released, a measure called total ecosystem respiration.

Most regions saw a weaker sink, says Guanyu Dong at Nanjing University in China, who led the analysis, but the effect was especially notable in grasslands and shrublands in the tropics.

Van der Werf says other teams teasing apart what happened with the carbon sink could get different results. But this would explain most of the record jump in the concentration of CO_2 in 2024, which was too large to be due to fossil fuel emissions alone.

The disappearance of the sink for the second year running could also be a sign it is diminishing earlier than expected. The early loss of the sink would mean concentrations of CO_2 in the air would rise faster than anticipated, and contribute to temperatures continuing to rise even after reaching net-zero emissions.

However, Scott Denning at Colorado State University says it could be that the past two years were a blip. "You need to be cautious interpreting even two years of growth as a persistent collapse," he says. ▮

Palaeontology

Remarkable set of footprints suggests different dinosaurs herded together

Michael Le Page

DID different species of plant-eating dinosaurs herd together for protection, like many modern animals do? A set of 76-million-year-old tracks discovered in Canada might be the first evidence of this – but the case is far from closed.

Last year, Brian Pickles at the University of Reading, UK, and his colleagues discovered parallel tracks in Dinosaur Provincial Park in Alberta that were made by at least five individual animals (*PLoS One*, doi.org/g9t23c).

Initially, the researchers thought all the tracks were made by ceratopsians, horned dinosaurs such as the famous *Triceratops*. They can't be sure exactly which ceratopsian made the tracks, but fossil bones show that species such as *Styracosaurus albertensis* were present in the area at the time.

"As we were excavating, we realised that one of these sets of tracks wasn't like the others," says Pickles. "It's about the same size, but it's got three toes, and the only large animals that make footprints like that in the park at that time are ankylosaurs. So what we have is an ankylosaur in amongst a bunch of ceratopsians." Ankylosaurs were heavily armoured dinosaurs with club-like tails.

The tracks are thought to have been made near a river, so the ankylosaur may have been walking among the ceraptopsians simply because the animals were all heading to the river to drink at the same time, he says. But it is also possible that different species of herbivorous dinosaurs herded together for longer periods for defence. In fact, the tracks of two predatory tyrannosaurids were also found nearby.

Ceratopsians may have walked alongside ankylosaurs

JULIUS CSOTONYI

"In modern African ecosystems, giraffes, zebras and wildebeest form these multi-species herds, and part of that is to do with different species having different abilities to detect predators," says Pickles.

However, with just a single possible ankylosaur footprint found so far, the case for multi-species herding in dinosaurs isn't yet conclusive.

"Sure, the ceratopsians and ankylosaur could have moved through that place at different times, but the closeness and spacing of their footprints make for a good argument that they were at least influenced by one another," says Anthony Martin at Emory University in Atlanta, Georgia.

But Anthony Romilio at the University of Queensland, Australia, isn't convinced two different species made the tracks. "The proposed ceratopsian and ankylosaur tracks look strikingly similar in shape," he says.

Based on the width of the tracks and the fact that only hind footprints have been found, Romilio suggests they were in fact made by duck-billed dinosaurs. "To my mind, these are more likely to be poorly preserved footprints of large-bodied hadrosaurs," he says.

Pickles dismisses Romilio's suggestion about the tracks. "They definitely aren't hadrosaur tracks," he says. ▮

Health

Feelings of intense grief could shorten a mourner's life

PEOPLE who experience high levels of grief after a loved one's death seem to have a greater risk of dying within the next decade than those who come to terms with their loss more easily.

Most studies linking grief to poor health only track the bereaved for a few years after their loss, says Andreas Maercker at the University of Zurich in Switzerland, who wasn't involved with the research.

Now, Mette Kjærgaard Nielsen at Aarhus University in Denmark and her colleagues have examined how grief is linked to mortality up to a decade later.

The researchers used a national registry to obtain information on people who were being treated for a terminal condition. They then recruited more than 1700 of these people's loved ones, such as a parent or partner, to complete a series of surveys – taken before their death and six months and three years after. These asked the loved ones – who were aged 62, on average – questions, like whether they were trying to avoid reminders that the person was ill or dead.

They found that 670 of the loved ones were persistently experiencing low levels of grief, while 107 of them were experiencing high levels of grief. The remaining participants experienced either grief that declined or delayed grief that kicked in some time after their loss.

Next, they analysed the loved ones' medical records 10 years after their loss. The death rate in the high-grief group was 88 per cent greater than in the low-grief one (*Frontiers in Public Health*, doi.org/pxnh).

"Offering extra support to people experiencing severe, prolonged grief could save lives"

"There's a saying that bereavement breaks hearts," says Maercker. The findings support the idea that intense grief puts a strain on the body, leading to earlier death, he says. It may also bring about lifestyle changes, as bereaved people might be more likely to be inactive.

Offering extra support to people experiencing severe , prolonged grief could save lives, he says. ▮

Carissa Wong

Space

Dying star defies explanation

A red supergiant is surrounded by a puzzlingly large bubble of dust and gas

Alex Wilkins

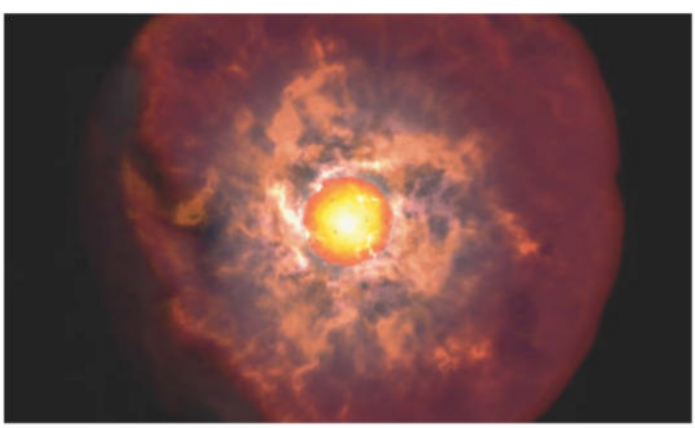
ASTRONOMERS are baffled by a vast sphere of dust and gas around a dying star. This cloud is about half as wide as our solar system and there is no known mechanism that could produce such a large amount of material from one star.

Red supergiants are the largest stars in the universe. They are the latter stage of fairly massive stars that have exhausted most of their fuel, just before exploding in a supernova. During this relatively short phase, the star rapidly expands in volume and expels large amounts of gas and dust that create a bubble around it, called the circumstellar medium, which can influence how the star explodes.

Mark Siebert at Chalmers University of Technology in Sweden and his colleagues have found that a red supergiant star called DFK 52 has the largest known circumstellar medium for this type of object, forming a bubble 50,000 times wider than the distance between Earth and the sun. Mysteriously, the star is also relatively dim, implying it has less energy than is thought to be required to make such a large debris field. "We have no idea how you can throw off this much material in that amount of time," says Siebert.

DFK 52 had previously been observed with several different telescopes, and astronomers found a relatively normal amount of gas being expelled from the star. But when Siebert and his team looked at the star with the Atacama Large Millimeter Array (ALMA) in Chile, which can observe wavelengths of light from much colder, older material, they found a far more extensive structure (arXiv, doi.org/pxnk).

Red supergiants expel gas and dust before exploding in a supernova



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"We see this just enormous circumstellar medium around DFK 52, and it has this extremely, extremely complex geometry to it that we really can't fully explain right now," says Siebert.

As well as an intricate stream of bubbles moving throughout the structure, Siebert and his team identified a ring-like bar around halfway through the overall sphere that is expanding at nearly 30 kilometres per second. They calculated that this must have come from a dramatic event around 4000 years ago, which may be key to explaining how the star produced so much material.

One possible explanation for the large circumstellar medium is that the star was once much brighter and has dramatically dimmed – but red supergiants aren't known to fluctuate in this way, says Siebert.

It is also possible that another star may have been circling close around, or even within, the larger star and slinging off DFK 52's material, but that would have produced a more symmetrical bubble, says Siebert.

"The outburst likely won't change the star's overall evolution, but it could have a significant impact on the appearance of its future supernova," says Emma Beasor at Liverpool John Moores University, UK.

"This is an exciting result and could help us understand some unusual supernovae." ▮

Health

Your frenemies could be ageing you as much as smoking

MANY of us have people in our lives who bring more angst than joy. But rather than just dragging us down, these individuals could be speeding up the rate at which we age.

In 2012, researchers at the University of Utah found that "frenemies" – relationships that blow hot and cold – seem to accelerate the shortening of our telomeres, the protective caps at the end of chromosomes. Shortening happens naturally with age and has been linked to heart disease.

Now, Byungkyu Lee at New York University and his colleagues have analysed the effects that negative social ties have on tiny chemical changes to DNA called methylation marks. This is an example of epigenetics, the way your behaviours and environment can cause changes that affect how your genes work. "As we age, the pattern of these marks shifts in predictable ways," says Lee.

The team got 2232 people to provide saliva samples for epigenetic testing and to describe their relationships with key members of their social network, answering questions such as: "How often has X hassled you, caused problems or made life difficult?"

Anyone who caused such issues either occasionally or often was labelled a "hassler". These individuals seemed to have a significant impact, with each hassler being linked to accelerated biological ageing in people by about 0.5 per cent, making their biological age 2.5 months older, on average, than expected (medRxiv, doi.org/px25).

"People with 'hasslers' in their lives were 2.5 months older biologically than their actual age"

Negative social ties may trigger a chronic inflammatory stress response, with Lee's team observing higher levels of these markers in people with such relationships, which may impair the immune system.

"The biological impact of having a high proportion of hasslers in one's social network is comparable in magnitude to the difference between never-smokers and ever-smokers," says Lee. ▮

David Robson

Ancient humans

Neanderthals probably feasted on maggots

Michael Le Page

OUR ancient relatives may not have been the hyper-carnivores we thought they were. It has been claimed, based on the nitrogen isotope ratios in their bones, that Neanderthals ate little besides meat. But these ratios can also be explained by a more balanced omnivorous diet that included a lot of maggots.

"Masses of maggots are these easily scoopable, collectible, nutrient-rich resource," says Melanie Beasley at Purdue University, Indiana.

Nitrogen has two stable isotopes, nitrogen-14 and nitrogen-15. The lighter isotope is more likely to be lost from living organisms than the heavy one, so, as matter moves up food chains, the ratio of nitrogen-15 to nitrogen-14 increases.

Looking at the isotope ratios in collagen within fossil bones can therefore tell us about the diet of those animals, with carnivores having higher ratios than herbivores. But when researchers started looking at the ratios in the bones of Neanderthals, they found something surprising: even higher ratios than those seen in lions and hyenas. "So there became this narrative that Neanderthals were these hyper-carnivores very focused on big game hunting," says Beasley.

But many researchers don't buy this idea. For one thing, the bones of *Homo sapiens* living in prehistoric times have similar ratios – and these humans couldn't have survived on lean meat alone. The issue is that if a person's diet is too rich in protein, their body can't mop up all the toxic breakdown products, such as ammonia.

There is also now plenty of evidence that Neanderthals also ate plants, for instance from studies of their dental calculus. So why were their nitrogen-15 ratios so high?

Back in 2017, John Speth at the University of Michigan suggested it could be because Neanderthals stored meat and ate it later in a rotten state. As meat rots, gases like ammonia are given off, which would result in nitrogen-15 enrichment.

> "Masses of maggots are these easily scoopable, collectible, nutrient-rich resource"

At the time, Beasley was applying to do research at the "body farm" at the University of Tennessee where human cadavers are studied as they decay to help with crime scene analysis. She realised she could test Speth's idea alongside the forensic research – and while she was at it, she also looked at the maggots in the bodies.

Together with Speth and Julie Lesnik at Wayne State University in Michigan, Beasley found that nitrogen isotope ratios do increase as muscle tissue rots, but by only a modest amount. There is, however, a much bigger jump seen in the maggots of various kinds feeding on the corpses (*Science Advances*, doi.org/px27).

These are just initial results, but they show that eating a diet very high in meat isn't the only possible explanation for the isotope ratios in Neanderthals, says Beasley. She thinks those ratios are probably due to a combination of factors – the storage, processing and cooking of meat, as well as the consumption of maggots. ▮

Environment

Hotter oceans may be the 'new normal'

Madeleine Cuff

EXTREME marine heat recorded since 2023 might herald the start of a regime shift in the oceans that poses a grave threat to life on Earth.

Record-breaking marine heatwaves emerged in the North Atlantic and Pacific oceans in 2023 and were unprecedented in their severity, endurance and scale, with many lasting well over a year. Some researchers fear that the world's oceans have transitioned to a new, hotter state.

To find out more about what is going on, Zhenzhong Zeng at the Southern University of Science and Technology in China set out with colleagues to identify the drivers of the 2023 marine heatwaves around the world, analysing the movement of heat, wind and currents in the oceans. Reduced cloud cover, which increases the amount of solar radiation hitting the water, was found to be a key influence, alongside weaker winds and the appearance of a warming El Niño pattern in the Pacific Ocean (*Science*, doi.org/pxng).

Given the duration of the heat, which began in earnest in 2023 and continues today in some regions, Zeng argues that this is the start of a "new normal" for the world's oceans. He says emerging data indicates the heat in the oceans is accumulating exponentially, a trend that would defy climate model predictions.

Persistently high water temperatures will have a devastating effect on marine life, escalating the threat of coral reef collapse and triggering a mass die-off and migration of marine life. It would also accelerate heating on land, leading to more severe droughts, heatwaves and wildfires.

But Neil Holbrook at the University of Tasmania in Australia says there is no "clear evidence" yet to support warnings that we have reached a tipping point, particularly given there are only a few years of data to assess. "We don't know what's going to happen next year, and it [ocean temperatures] might just come back to something that's much more, let's say, normal," he says.

However, Holbrook stresses that unless greenhouse gas emissions are rapidly curtailed, "marine heatwaves around the globe will continue to increase in intensity and duration, and potentially at rates faster than various marine species can adapt". ▮

High temperatures in the oceans put coral reefs at risk of collapse

DAVID GRAY/AFP VIA GETTY IMAGES

Artificial intelligence

AIs score top marks in mathematics

A gold-medal performance by two AI systems at a prestigious maths competition has been hailed as an important milestone – but some mathematicians are more cautious, finds **Alex Wilkins**

EXPERIMENTAL AI models from Google DeepMind and OpenAI have achieved a gold-level performance in the International Mathematical Olympiad (IMO) for the first time.

The companies are hailing the moment as an important milestone for AIs that might one day solve hard scientific or mathematical problems, but mathematicians are more cautious because details of the models' results and how they work haven't been made public.

The IMO, one of the world's most prestigious competitions for young mathematicians, has long been seen by AI researchers as a litmus test for mathematical reasoning that AI systems tend to struggle with.

After last year's competition held in Bath, UK, Google DeepMind announced that AI systems it had developed, called AlphaProof and AlphaGeometry, had together achieved a silver medal-level performance, but its entries weren't graded by official markers.

"There are going to be many, many unsolved scientific problems within reach"

Before this year's contest, which was held in Queensland, Australia, companies including Google, Huawei and TikTok-owner ByteDance, as well as academic researchers, approached the organisers to ask whether they could have their AI models' performance officially graded, says Gregor Dolinar, the IMO's president. The IMO agreed, with the proviso that the companies waited to announce their results until 28 July, when the IMO's closing ceremonies had been completed.

OpenAI also asked if it could participate in the competition, but after it was informed about the official scheme, it didn't respond or register an entry, says Dolinar.

GOOGLE DEEPMIND

The Google DeepMind team at the International Mathematical Olympiad

On 19 July, OpenAI announced that a new AI it had developed had achieved a gold medal score marked by three former IMO medallists separate from the official competition. The AI answered five out of six questions correctly in the same 4.5-hour time limit as the contestants, OpenAI said.

Two days later, Google DeepMind also announced that its AI system, called Gemini Deep Think, had achieved gold with the same score and time limits. Dolinar confirmed that this result was given by the IMO's official markers.

Unlike Google's AlphaProof and AlphaGeometry systems, which were crafted especially for the competition and worked with questions and answers written in a computer programming language called Lean, both Google and OpenAI's models this year worked entirely in natural language.

Working in Lean meant the AI's output could be instantly checked for correctness, but it is harder for non-experts to read. Thang Luong at Google, who worked on Gemini Deep Think, says the natural language approach could produce more understandable answers, as well as being applicable to generally useful AI systems.

Luong says the ability to verify solutions in a large language model has been made possible thanks to progress with reinforcement learning, a training method in which an AI is taught what success looks like and is left to figure out the rules and how to succeed solely through trial and error. This method was key to Google's previous success with its game-playing AIs, such as AlphaZero.

Show your working

Google's model also considers multiple solutions at once, in a mode called parallel thinking, as well as being trained on a dataset of maths problems specifically useful for the IMO, says Luong.

OpenAI has released few details on its system, apart from that it also uses reinforcement learning and "experimental research methods".

"The progress is promising, but not performed in a controlled scientific fashion, and so I will not be able to assess it at this stage," says Terence Tao at the University of California, Los Angeles. "Perhaps once the companies involved release some papers with more data, and hopefully enough access to the model for others to replicate the results, one can say something more definitive, but, for now, we largely have to trust the companies themselves for the claimed results."

Geordie Williamson at the University of Sydney in Australia echoes this sentiment. "I think it is remarkable that this is where we're at. It is frustrating how little detail outsiders are provided with regarding internals," he says.

While systems working in natural language could be useful for non-mathematicians, it could also present a problem if models produce long proofs that are hard to check, says Joseph Myers, one of the organisers of this year's IMO. "If AIs are ever to produce solutions to significant unsolved problems that might plausibly be correct but might also have a few subtle but fatal errors hidden accidentally, or potentially deliberately from a misaligned AI, having those AIs also generate a formal proof is key to having confidence in the correctness of a long AI output before attempting to read it."

Both companies say that they will offer these systems to mathematicians for testing in the coming months, before releasing them to the wider public. The models could soon help with harder scientific research problems, says Junehyuk Jung at Google, who worked on Gemini Deep Think. "There are going to be many, many unsolved problems within reach," he says. ▮

Health

Our brain's mitochondria may play a crucial role in the onset of sleep

Christa Lesté-Lasserre

A STUDY in fruit flies suggests that mitochondria in the brain help trigger sleep when they sense that the insects have been awake for too long – and the same mechanism may exist in people.

Researchers have some understanding of how the brain reacts to sleep deprivation. These include changes to neuronal firing, the structural shapes inside cells and how genes are expressed. They have also identified specific neurons in the brain that switch on when sleep begins, but they are less sure what tells them to fire.

To find out more, Gero Miesenböck at the University of Oxford and his colleagues used sequencing and fluorescent markers to study the genes expressed by sleep-centre neurons in about 1000 female fruit flies (*Drosophila melanogaster*). They sleep for 13 to 16 hours over the course of a day, usually at night.

The team let roughly half the flies get a full night's sleep, while others were kept awake, either by gently shaking the tubes they were in or by genetically engineering them so that their wake-promoting neurons were switched on by a rise in temperature.

Among the sleep-deprived flies, the researchers found that sleep-inducing neurons ramped up the activity of genes involved in running and maintaining their mitochondria. These mitochondria also showed signs of being under stress, such as breaking into smaller pieces and forming contact points with nearby structures that help with repairs.

This stress may stem from the fact that the mitochondria keep producing energy even when the neurons are inactive. The researchers observed that this led to a build-up of electrons that leak out, generate free radicals – unstable molecules that can damage DNA – and ultimately trigger pressure to sleep, says Miesenböck. When these flies were finally allowed to sleep, the mitochondrial damage was repaired (*Nature*, doi.org/g9tdzb).

"This provides opportunities to come up with new ways to treat people with sleep problems"

They also found that flies with fragmented mitochondria in their sleep neurons slept less than normal and didn't catch up on it after being kept awake. By contrast, flies whose mitochondria were engineered to fuse more readily, suggesting better repair mechanisms, slept more than usual and showed a stronger rebound after sleep deprivation. This supports the idea that mitochondria are involved in sleep pressure.

In another part of the experiment, flies were engineered to have raised mitochondrial activity in response to light. The team found that 1 hour of artificial lighting caused sleep duration to rise by as much as 20 to 25 per cent, compared with control flies.

While the study investigated flies, mitochondria are relatively similar across animals. The work supports the idea that aerobic metabolism – the production of energy from nutrients and oxygen, which takes place within the mitochondria of most animals – can drive sleep pressure in humans, says Ryan Mailloux at McGill University in Canada.

"This provides us with novel opportunities to target these pathways [and] come up with new, efficacious ways to treat people who have sleep problems," says Mailloux. ▮

Zoology

Tiny gecko in the Galapagos has been rediscovered

A GECKO has reappeared on Rábida Island in the Galapagos, where it was believed to have been wiped out by invasive rats.

The leaf-toed gecko (*Phyllodactylus maresi*), whose adults are just 8 centimetres long, was previously only known to have existed on Rábida from 5000-year-old fossil records. But teams collected live specimens during expeditions in 2019 and 2021, which have now been officially confirmed as this species (*PLoS One*, doi.org/pxg4).

The gecko's resurgence was down to a successful restoration and rewilding project that began in 2011, led by the US-based non-profit Island Conservation in partnership with Galapagos National Park, Charles Darwin Foundation and The Raptor Center. The project, which also included 10 other islands in the Galápagos, used helicopters to distribute poisoned bait to wipe out invasive rats over large areas.

By 2012, these rats were confirmed as successfully removed on Rábida, with nature bouncing back immediately, including the geckos. "We conducted extensive monitoring prior to the removal of invasive rats and they weren't detected at all," says Paula Castaño of Island Conservation. "We believe a small population held on all those years and then, without invasive predators, it finally had the opportunity to recover and grow its population. You can call it one of the most historic comebacks ever or just a long-overdue reappearance."

RORY STANSBURY/ISLAND CONSERVATION

The leaf-toed gecko was thought to be locally extinct on Rábida Island

Through the use of DNA analysis, Castaño and her colleagues have determined the Rábida population is closely related to *P. maresi* from nearby islands, but classified it as a distinct lineage – technically known as an evolutionarily significant unit – underscoring its importance for conservation.

The case of Rábida demonstrates the benefits of island restoration and removing invasive species, says Castaño. "We found the 'extinct' gecko, rediscovered a snail last seen in 1906, as well as two other snail species being recorded on the island for the first time ever that are still being identified, and Galapagos hawks have returned and are thriving," she says. "Nature is remarkable – allow it an opportunity to thrive and it comes roaring back." ▮

Graeme Green

Space

First glimpse of primordial stars?

We may have found a galaxy that is home to some of the universe's elusive earliest stars

Alex Wilkins

A GALAXY marooned in an empty region of the universe appears to be unexpectedly full of primordial stars. This could give astronomers their first glimpse of a kind of stellar object thought to have formed shortly after the universe's first moments and which has never been directly observed.

Despite being able to peer back to nearly the beginning of the universe with the James Webb Space Telescope (JWST), astronomers have struggled to definitively find evidence of the first stars. Known as population III stars, these are giant balls of mostly hydrogen that would have formed in the early universe. Being the first stars, they would have almost none of the heavier elements that are produced when stars die and explode.

It has been difficult to find conclusive evidence of them in the early universe, as galaxies appear to be contaminated with heavier elements relatively soon after the big bang, in just a few hundred million years.

Now, Takahiro Morishita at the California Institute of Technology and his colleagues have found a galaxy made up almost entirely of hydrogen, a sign of population III stars. But the galaxy exists much later than expected for one containing such stars, around a billion years after the beginning of the universe.

"We don't expect to find such pristine galaxy environments so late in the universe's development"

Called AMORE6, it was originally spotted in a galaxy cluster known as Abell 2744. Morishita and his team then measured the light coming from AMORE6 with JWST and found that a common oxygen ion was entirely absent. This means that the galaxy can have no more than 0.2 per cent of the oxygen found in our own sun, implying it is particularly uncontaminated by heavier elements (arXiv, doi.org/pxmv).

As the universe grows older, it becomes increasingly unlikely to contain pristine galaxies of this sort. In the JWST images, AMORE6 appears to be relatively isolated, which may be the reason why it is so pristine, suggests Morishita. "That isolation means that this galaxy might be in an area that didn't have enough gas to trigger star formation earlier. That means that this galaxy might be a late bloomer in one sense," he says.

"If the results are confirmed, it's really remarkable, because typically we don't expect to find such pristine galaxy environments so late in the development of the universe," says Fabio Pacucci at the Harvard-Smithsonian Center for Astrophysics in Massachusetts.

It also has implications for our ability to observe "direct collapse" black holes, which form from huge clouds of pristine gas rather than the typical route of an imploding star. Although these have been predicted by astronomers, they have never been conclusively seen forming, in part because pristine gas was only thought to be available for this perhaps up to 100 million years after the big bang, which is too early for us to detect them.

But if pristine gas can survive much longer, then this might dramatically increase our chances of seeing one, says Pacucci. ▮

Health

Skincare routine could stop babies getting eczema

APPLYING moisturiser to a baby's skin every day could reduce their risk of developing eczema, but it may depend on whether they are genetically at risk of the condition.

Eczema, or atopic dermatitis, is an inflammatory condition characterised by itchy and dry skin that may blister or bleed. It usually begins in infancy, with symptoms generally subsiding with age.

To explore whether moisturisers can help, Hywel Williams at the University of Nottingham, UK, and his colleagues recruited more than 1200 parents in the US whose babies didn't have eczema. Half of the babies, who were aged between 0 and 8 weeks, had an immediate family member with the condition.

MEAGHANBROWNING/GETTY IMAGES

Moisturising a baby's skin could have many health benefits

The researchers randomly assigned about half of the parents to apply any of five moisturisers, which were available without a prescription, all over their babies' bodies every day. The parents could choose any moisturiser and swap between them.

The remaining parents were told not to use moisturisers unless they deemed it necessary. More than half of the parents in this group reported doing this up to once a week.

Two years later, the researchers found that overall, 43 per cent of those in the non-moisturiser group had been diagnosed with eczema, compared with 36 per cent in the moisturiser group (*JAMA Dermatology*, doi.org/pxmq). "That's a substantial reduction," says Michael Cork at the University of Sheffield, UK.

However, they also found that moisturisers were protective only among those who didn't have an immediate family member with eczema.

Moisturisers are thought to fill gaps between skin cells, helping to prevent irritants from entering the body and triggering inflammation that manifests as eczema.

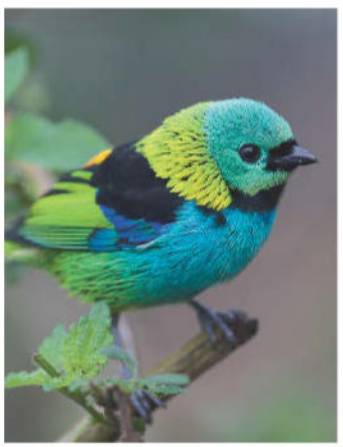
Elevated levels of inflammation may already exist in the bodies of people who have a high genetic risk of eczema, which moisturisers cannot protect against, says Cork. ▮

Carissa Wong

Ornithology

Why songbirds have such dazzling colours

Chris Simms



DANIEL FIELD

This green-headed tanager has a hidden layer of plumage

BRIGHTLY coloured songbirds called tanagers are so eye-catching because they have a hidden layer of black or white beneath their dazzling plumage.

Painters often prime a canvas with a layer of white to enhance the colours they will eventually layer on. But it seems this is a mechanism that birds were using long before humans picked up paintbrushes.

Rosalyn Price-Waldman at Princeton University and her colleagues have found that when songbirds in the tanager genus *Tangara* have bright red or yellow plumage, they usually have white layers hidden underneath. When they have blue plumage, they have black layers beneath.

To investigate why, they removed 72 feathers from taxidermied tanager specimens in a collection at the Natural History Museum of Los Angeles County.

By taking pictures of the feathers on different backgrounds, the team measured how their reflectance or absorption of light changed, finding that the underlayers make the top layers look more colourful (*Science Advances*, doi.org/g9t4xg).

The red and yellow colouration is created by pigments, which are molecules that selectively absorb light to make colour. This means the extra light from the white below makes them brighter, says Price-Waldman.

But blue colouration is created by nanostructures within the feathers that selectively scatter light, rather than absorbing light to create the colour we see. Because of this, the light-absorbing black below makes the blue look brighter. "If you have white underneath them, they look a white-grey colour," says Price-Waldman.

The overall effect of the plumage is created because feathers are layered like tiles on a roof, she says. When you take a single feather, it may have a colourful tip, an intermediate region of either black or white and then the fluffy, downy base. When these feathers are layered on the body, the tips create a contiguous layer of colour, above a contiguous layer of white or black.

"The overall effect of the plumage is created because feathers are layered like tiles on a roof"

Price-Waldman and her colleagues found that, in some cases, these layers of feathers generate the differences in colour between the sexes.

They also found that this colour-boosting strategy is seen in many other songbirds, including manakins and cotingas.

"While a lot of research has already been done to understand how birds produce such striking colours, there is clearly a lot left to discover," says Chris Cooney at the University of Sheffield, UK. ▮

Artificial intelligence

AI helps fill in history's blanks

A system called Aeneas can reconstruct damaged Latin texts from the Roman Empire

Jeremy Hsu

LATIN inscriptions from the ancient world can tell us about Roman emperors' decrees and enslaved people's thoughts – if we can read them. Now an artificial intelligence tool is helping historians reconstruct the often fragmentary texts. It can even accurately predict when and where in the Roman Empire a given inscription came from.

"Studying history through inscriptions is like solving a gigantic jigsaw puzzle, only this is tens of thousands of pieces more than normal," said Thea Sommerschield at the University of Nottingham, UK, during a press event. "And 90 per cent of them are missing because that's all that survived for us over the centuries."

The AI tool developed by Sommerschield and her colleagues can predict a Latin inscription's missing characters while also highlighting the existence of inscriptions that are written in a similar linguistic style or refer to the same people and places.

They named it Aeneas in honour of the mythical hero, who, according to legend, escaped the fall of Troy and became a forebear of the Romans.

> "We enable Aeneas to actually restore gaps in text where the missing length is unknown"

"We enable Aeneas to actually restore gaps in text where the missing length is unknown," said Yannis Assael at Google DeepMind, a co-leader in developing the AI tool, during the press event.

The team trained Aeneas on the largest ever combined database of ancient Latin texts that machines can interact with, including more than 176,000 inscriptions and nearly 9000 accompanying images.

What's more, by testing it on a subset of texts of known provenance, the researchers found that Aeneas could estimate when these texts were written to within 13 years – and it even achieved 72 per cent accuracy in identifying which Roman province an inscription came from (*Nature*, doi.org/pxct).

During testing with inscriptions that were deliberately corrupted to simulate damage, Aeneas achieved 73 per cent accuracy in restoring gaps of up to 10 Latin characters. That fell to 58 per cent accuracy when the total missing length was unknown – but the tool shows the logic behind the suggestions so researchers can assess the validity of the results.

When nearly two dozen historians tested the tool's ability to restore and attribute deliberately corrupted inscriptions, historians working with the AI outperformed either AI or historians alone.

"I think it will speed up the work of anyone who works with inscriptions, and especially if you're trying to do the equivalent of constructing wider conclusions about local or even empire-wide patterns and epigraphic habits," says Elizabeth Meyer at the University of Virginia. "At the same time, a human brain has to look at the results to make sure that they are plausible for that time and place."

"Asking a general-purpose AI model to assist with tasks in ancient history often leads to unsatisfactory results," says Chiara Cenati at the University of Vienna in Austria. "Therefore, the development of a tool specifically designed to support research in Latin epigraphy is very welcome."

Palaeontology

Velociraptor's cousin had strong hands for tackling bigger prey

A SPECIES of *Velociraptor*-like dinosaur from the Gobi desert in Mongolia had giant claws and exceptionally thickset hands, which may have enabled it to take down larger prey.

Its name, *Shri rapax*, was inspired by "the rapacious features we see in the hand", says Andrea Cau, an unaffiliated palaeontologist in Italy.

Shri rapax measures around 2 metres long and its fossil comes from the Djadochta formation, the remnants of a land of sprawling sand dunes and intermittent lakes from 75 and 71 million years ago.

It was unearthed in 2010 and smuggled into private collections in Japan and the UK before recently being brought back to Mongolia. Cau and his colleagues have now formally described it as a species new to science after their work on the remains, which found bones previously buried in layers of rock, including the extraordinary hand (*Historical Biology*, doi.org/pxg5).

"The extremely robust [heavily built] hand structure and notably elongated claw of *Shri rapax* indicate an adaptation for powerful gripping," says team member Tsogtbaatar Chinzorig at North Carolina State University. "Such a configuration likely enabled it to grasp and restrain relatively large prey."

The middle claw measures 79.5 millimetres, which is nearly twice as long as the same claw in closely-related species such as *Velociraptor mongoliensis*.

ROYAL BELGIAN INSTITUTE OF NATURAL SCIENCES, BRUSSELS

Shri rapax was a species of dinosaur that measured around 2 metres in length

"Compared to *Velociraptor*, which is about the same body size, the hand is 150 per cent more robust and the claw is longer," says Cau. "This suggests [it] was adapted to hunt animals stronger and more robust than those usually preferred by its relatives."

While the skull and several vertebrae were lost prior to repatriation, Cau and his colleagues digitally reconstructed the missing pieces using CT scans of the fossil made in 2016. The results show the skull was probably short and stout, which indicates it also had a stronger bite than many of its peers.

James Napoli at Stony Brook University in New York would like to see the missing pieces recovered.

"The skull, in particular, is very important for our understanding of this animal, its possible lifestyle and its position in the story of theropod dinosaur evolution," he says.

Taylor Mitchell Brown

Physics

A solid with no melting point?

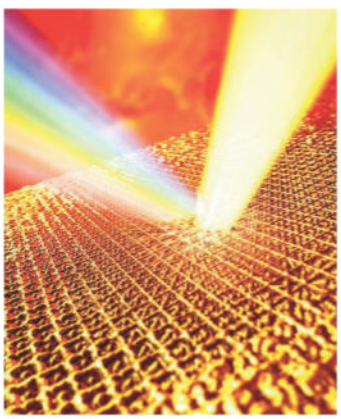
Gold surpasses the theoretical maximum temperature a solid can have before it melts

Alex Wilkins

WAFER-THIN sheets of gold shot briefly with lasers can be heated to up to 14 times their melting point while remaining solid, far beyond the theoretical limit. This raises the possibility that some solids may have no upper melting point at all.

Superheating is a common phenomenon where a solid can heat up beyond its melting point, or a liquid can heat up past its boiling point, without changing state. For example, a cup of water heated in a microwave can reach temperatures above 100°C (212°F), as long as the cup is sufficiently still. However, as soon as the cup is jostled, the water will violently boil.

For solids, many physicists have proposed an upper limit for superheating, at a temperature around three times the standard melting point in kelvin. This point is called the entropy catastrophe, which is where the entropy – often defined as the amount of disorder in a system – for the solid state would become larger than if the substance were liquid. If the substance remained solid above this temperature, then it would violate the second law of thermodynamics, which says that entropy cannot decrease over time for most systems.



GREG STEWART/SLAC NATIONAL ACCELERATOR LABORATORY

Gold sheets were fired with lasers to heat them up 14 times past their melting point

Now, Thomas White at the University of Nevada, Reno, and his colleagues have found that gold can heat up to 14 times its melting point while remaining solid, far above its entropy catastrophe point.

White and his team fired a powerful laser at a 50-nanometre thick sheet of gold for 45 quadrillionths of a second, then used a relatively new method to measure its temperature using reflected X-rays. By measuring how the frequency of the reflected X-rays had changed and calculating how much extra energy they had gained from bouncing off the gold, the team could work out how much the sheet had heated up.

"We measured these temperatures, and we were like, wow, that's really hot. Like, can it really be that hot before it melts?" says White.

After confirming their measurements, White and his team revisited the theory and realised that heating the gold so fast meant the entropy of the solid form could remain smaller than the potential liquid form, allowing it to surpass the predicted temperature limit (*Nature*, doi.org/g9t2tx). "It's important to say that we have not broken the second law of thermodynamics," says White.

The true limit of superheating remains an open question, he says. "Maybe we thought we solved it in the 1980s with this superheating limit, but now I think it's an open question again."

Measuring how solids heat up using this technique could help simulate how extreme heat and pressure from planetary cores affects materials on extremely short timescales, says Sam Vinko at the University of Oxford.

It would also be interesting to see whether this applies to other solids apart from gold, he says, and whether there is any upper limit to heating before melting. "The thing that's intriguing here is to ask the question of whether or not it's possible to beat virtually all of thermodynamics, just by being quick enough so that thermodynamics doesn't really apply in the sense that you might think about it." ▮

Health

Walking 7000 steps a day may be enough to keep us healthy

WE ARE often told to aim for 10,000 steps a day to maintain good health, but it turns out that taking just 7000 can significantly reduce the risk of conditions such as heart disease and dementia.

The 10,000 steps target is thought to have originated from a marketing campaign promoting pedometers in Japan. However, research suggests it does have some merit.

To better understand what number of steps is needed to maintain good health, Melody Ding at the University of Sydney in Australia and her colleagues reviewed 57 studies, published between 2014 and 2025. These covered hundreds of thousands of adults, most of whom hadn't been diagnosed with a serious health condition at the start of those studies.

Perhaps unsurprisingly, the more active people were, the better their health outcomes, with 10,000 steps being superior to 7000. But the latter still had serious benefits. The researchers found that people who walked around 7000 steps a day had a 47 per cent lower risk of dying from any cause over the studies' follow-up periods, on average, compared with taking just 2000 steps a day. They also had a 25 per cent lower risk of developing cardiovascular disease and a 47 per cent lower risk of dying from it (*The Lancet Public Health*, doi.org/g9t27c).

CULTURA/ALAMY

Going outside for even a short walk can have many health benefits

Taking 7000 steps is also linked to a reduction in the risk of death from cancer by 37 per cent and the risk of developing dementia by 38 per cent.

Ding says it is important not to discourage people from taking 10,000 steps. But 7000 steps is "a lot more accessible" for a lot of people, she says. ▮

Chris Stokel-Walker

Health

Gluten may not actually trigger many IBS cases

Carissa Wong

SOME people who think gluten worsens their irritable bowel syndrome (IBS) symptoms actually experience no more discomfort when they eat the protein, which is found in wheat, barley and rye.

IBS commonly causes abdominal pain, bloating, diarrhoea and constipation. While the mechanism is unknown, many people with the condition believe eating gluten or wheat, which contains gluten, worsens their symptoms.

To understand whether these really are common triggers, Premysl Bercik at McMaster University in Canada and his

> "The expectation that symptoms will worsen can cause this to actually occur"

colleagues recruited 28 people with IBS who said they had experienced improvements on a gluten-free diet.

The researchers asked the participants to eat a gluten-free diet for three weeks, before ranking the severity of their symptoms on a scale of 0 to 500, with an average score of 183.

They then randomly assigned the participants to eat one of three types of cereal bars, which looked and tasted the same, every day. One of the bars contained wheat, the second contained gluten but no other components of wheat and the third had neither. The first two bars contained doses of gluten equivalent to four slices of bread, says Bercik.

The participants were told the bars could worsen their symptoms, but weren't told which ones contained what ingredients.

One week later, participants ranked the severity of their symptoms, then switched back to a gluten-free diet for two weeks, to reverse any of the bars' effects. They repeated the experiment twice, so that each participant ate all three bars.

After the sham bars, eight of the participants reported a 50-point worsening in their symptoms – a level of change doctors consider to be significant, says Bercik. Meanwhile, this occurred in 10 of the participants when eating the gluten-only bars and in 11 of them after consuming the wheat ones (*The Lancet Gastroenterology & Hepatology*, doi.org/pxgf).

While gluten and wheat are probably genuine triggers for some people with IBS, the results suggest others are affected by the nocebo effect – where the expectation that symptoms will worsen causes this to actually occur, says Bercik.

In a comment piece accompanying the paper, Sigrid Elsenbruch at the University of Duisburg-Essen in Germany noted the participants were told any of the bars could worsen their symptoms, which may have enhanced the nocebo effect compared with real-world settings.

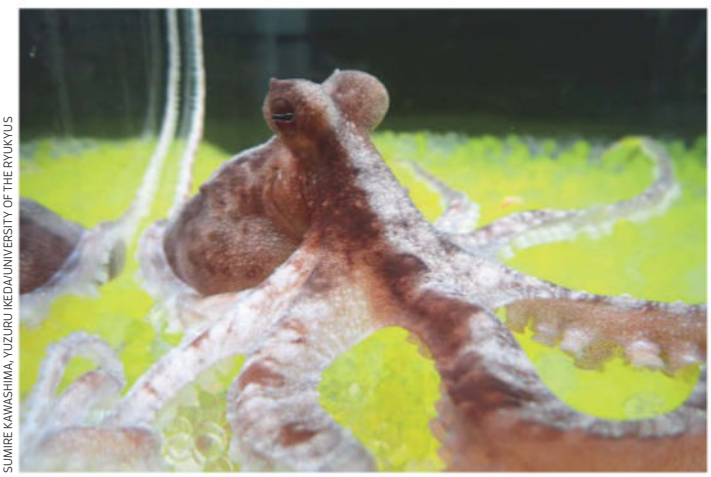
Stool samples from the participants also revealed a handful of them didn't eat the bars as instructed. This could mean they weren't consuming enough gluten or wheat for these ingredients to particularly affect their IBS.

Bercik says the researchers are exploring pathways through which gluten and wheat may cause IBS symptoms in some people, for instance by altering the gut microbiome. ▮

Zoology

Octopuses also fall for the rubber hand illusion

James Woodford



SUMIRE KAWASHIMA, YUZURU IKEDA/UNIVERSITY OF THE RYUKYUS

This plain-body octopus had a fake arm placed over one of its real ones

JUST like humans, octopuses can be fooled into thinking a fake arm is actually theirs.

First demonstrated in the late 1990s, the rubber hand illusion involves hiding a person's real hand and placing a fake one on a table in front of them, then stroking both simultaneously. Later, it was found that other mammals, such as mice, can also be fooled by the same trick.

Now, Sumire Kawashima and Yuzuru Ikeda at the University of the Ryukyus in Okinawa, Japan, have discovered that octopuses are also vulnerable to the illusion.

For the study, captive plain-body octopuses (*Callistoctopus aspilosomatis*) were placed in an experimental tank. A fake octopus arm made of soft gel attached to an opaque partition was placed over one of the octopus's arms, blocking its view of the real arm. Then one of the researchers used plastic callipers to stroke both the fake arm and the real arm at the same time.

After about 8 seconds, the researcher pinched the fake arm with tweezers. All six of the octopuses that participated in 24 trials of this test exhibited defence responses, such as changing colour, retracting their arm or fleeing.

When the test was carried out with no stroking or with non-simultaneous stroking, or when the posture of the fake arm didn't match that of the real arm, the effect of the illusion disappeared (*Current Biology*, doi.org/g9twp7).

The experiment demonstrates both a benefit and a flaw in the wiring of human and octopus brains, says Ikeda. "The illusion would suggest the ability for octopuses to anticipate and predict, which is advantageous for survival," he says. "On the other hand, this ability arises as a side effect of a mistake or conflict of processing in the brain and is also a flaw."

Peter Godfrey-Smith at the University of Sydney, Australia, says the results were unexpected for him. "It suggests that octopuses have quite a rich body image," he says. "I am struck by the fact that the 'posture incongruence' condition worked as it did: the octopuses did not see the rubber arm as their own in that case, despite the stroking." ▮

Environment

Cleaner air has increased the number of city heatwaves

James Dinneen

KEVIN CARTER/GETTY IMAGES

Populated areas may become hotter as the air gets cleaner

HEATWAVES have become more frequent as the world cleans up harmful aerosol pollution, unmasking more of the warming effects from greenhouse gases in the atmosphere. This warming influence is even greater in populated places, where there tends to be more air pollution.

"Reducing aerosol pollution is a public health imperative," says Geeta Persad at the University of Texas at Austin. "But we need to recognise that this is going to reveal these unique risks that are going to be amplified where people live."

While gases like carbon dioxide trap heat in the atmosphere, aerosols lower temperatures because they reflect sunlight away from the planet, either directly or by changing clouds. By some estimates, aerosol pollution has masked as much as half of the warming effect of greenhouse gases to date.

This means efforts to clean up air pollution to benefit human health come with a warming effect on the climate. Until now, however, it wasn't clear how the change in aerosols affected heat in populated areas in particular.

To get a spatially specific view across the world, Persad and her colleagues used a climate model to test how aerosols affect the frequency of heatwaves on land, both historically and in future projections. They defined a heatwave as three consecutive days that would have been among the hottest 10 per cent of days for that part of the year in a pre-industrial climate.

"Reducing aerosol pollution is a public health imperative – but reveals unique risks"

For most of the 20th century, they found aerosols were slowing down the increase in heatwave frequency caused by rising greenhouse gases. But after 2005, this dynamic flipped, and declines in aerosols began to accelerate the increase in heatwaves across the planet by about two days per decade.

Moreover, the researchers found aerosols have a greater influence on the frequency of heatwaves in populated places than on land in general – with the reduction in aerosol concentration mattering more than twice as much as the increase in greenhouse gas concentrations in some areas (*Environmental Research Letters*, doi.org/g9tdkh).

Under a scenario where greenhouse gas emissions continue to increase to very high levels and aerosols decline at a moderate pace, the team projected a dramatic rise in the number of heatwaves, with the average number of days with heatwaves in populated areas rising from about 40 per year to over 110 days per year by 2080.

"The uniqueness of this study is that it shows the daily timescale statistics. You can actually feel these aerosol reductions in different parts of the globe," says Shiv Priyam Raghuraman at the University of Illinois Urbana-Champaign. He points out, however, that the results come from just a single model under a worst-case emissions scenario.

"It will be interesting to see how these results vary across other models and if we can detect them in historical observations," says Daniel Westervelt at Columbia University in New York.

Another major uncertainty is how aerosol concentrations will change in the coming years, says Persad. "In the current generation of future emissions scenarios, there is a huge range of what is going to happen with aerosols over the next 30 years." ▮

Health

Covid-19 may have aged our brains even before we caught it

Luke Taylor

RELATIVELY early on in the covid-19 outbreak, brains aged by 5.5 months, possibly due to stress or lifestyle changes.

We know that many people with long covid experience brain fog, but the pandemic's broader neurological impact is far from fully understood.

To get a grasp on this, Ali-Reza Mohammadi-Nejad at Nottingham University, UK, and his colleagues trained a machine-learning model on 15,000 scans of the brain to see how its structure changes with age.

They then fed the model pairs of brain scans from 996 volunteers from the UK Biobank study. Of these, 564 had both scans taken before March 2020, which is when lockdown was introduced in the UK, and acted as the control group. The remaining 432 volunteers had one scan before March 2020 and one later. Each scan was three years apart, on average.

When the researchers compared individuals from the two groups, who were matched for age, sex and overall health, they found the pandemic may have accelerated the ageing of our brains by 5.5 months, based on structural changes to white and grey matter (*Nature Communications*, doi.org/g9twvw). This was true even among those without a known covid-19 infection.

The effect was particularly pronounced among men and those who were more socioeconomically deprived. But Biobank participants are generally healthier, wealthier and collectively less ethnically diverse than the rest of the UK, so the findings may not apply more broadly. The fact that participants were all from the UK also means the results may not reflect the potential effects of lockdowns elsewhere.

The researchers speculate these changes, which they write could be "at least partially reversible", may be due to stress, or lifestyle shifts that occurred around that time. ▮

Palaeontology

Giant caiman bit ancient 'terror bird'

About 13 million years ago, in a vast South American wetland, two colossal predators clashed

Jake Buehler

A FOSSILISED bone from an enormous flightless bird found in Colombia shows tooth marks made by a giant caiman.

Andrés Link at the University of the Andes in Colombia and his colleagues were studying crocodile fossils in a museum collection when they realised one of the bones didn't fit. It turned out to belong to a phorusrhacid bird – a group also known as the "terror birds". These top predators had hatchet-shaped beaks and powerful legs with sharp claws on their toes. The fossilised bone came from the lower leg of a 2.5-metre-tall species, possibly one of the largest types of terror bird yet discovered.

But this predator may have met a grisly end. The bone, discovered in Colombia's Tatacoa desert region by local palaeontologist César Perdomo, was scarred with four deep divots: teeth marks.

Link and his team wanted to know what beast dared wrap its jaws around such an intimidating predator. So they scanned the surface of the fossil to generate a digital model of the tooth marks and compared them with the teeth of other predators from the region.

"There's no evidence of gnawing and the marks are rounded and in [a] line, more similar to those inflicted by crocodiles and caimans," says Link.

The terror bird lived at a time when northern South America was dominated by the Pebas system, a massive network of wetlands interspersed with tropical forests and grasslands. The flooded ecosystem hosted a great diversity of crocodilians, and the team found a match for the teeth marks in one of them: a giant caiman called *Purussaurus neivensis* (*Biology Letters*, doi.org/pxch). Link estimates the reptile was about 4.5 metres long.

The team can't rule out the possibility the bird was already dead when the caiman found it, and the tooth marks are evidence of scavenging. There are no signs of bone healing around the tooth marks. So either way, the bird didn't survive the encounter.

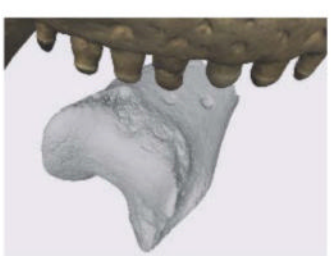
"These kinds of [tooth] traces are more common than people think," says Carolina Acosta Hospitaleche at the National University of La Plata in Argentina.

In a study published last year, she and a colleague described tooth marks on a much smaller and older terror bird fossil – roughly 43 million years old – from Argentina. The markings suggest an ancient carnivorous marsupial fed on that bird. Since those traces were also on the lower leg, Hospitaleche wonders if that part of the terror bird body was especially vulnerable.

When studying ancient environments, there can be a tendency to precisely categorise extinct organisms within particular ecological roles, says Stephanie Drumheller at the University of Tennessee.

"This is an animal that was living in the water and doing things in the water, this is an animal that was living up on land and doing things upon land, and never the two shall meet," says Drumheller. "But of course, nature is always messier than our nice, little, neat boxes." ▮

JULIAN BAYONA BECERRA



A giant caiman chomped on a terror bird's lower leg, as depicted in this artistic impression (left) and digital model of the bone (below)

Psychology

Timing of oral exams may affect how well you do

UNIVERSITY students are more likely to pass oral exams if they are taken at around midday.

Carmelo Vicario at the University of Messina, Italy, was inspired to investigate this after coming across a study that suggests judges' decisions are affected by how close it is to a mealtime. "I was trying to see if this could be true in education," he says.

With his colleagues, Vicario combed through a public database to gather information on the outcomes and timings of more than 104,500 oral assessments taken by around 19,000 university students in Italy. The tests happened between October 2018 and February 2020 and were from 1243 courses.

They found that, on average, pass rates were 54 per cent at 8am, rising to 72 per cent by midday and then dropping to 51 per cent by 4pm (*Frontiers in Psychology*, doi.org/pxgx).

This was consistent across all types of oral assessments, such as language exams and research presentations. But Vicario acknowledges that we don't know if it also applies to written tests.

"There are a lot of external factors that affect student performance," says Thomas Lancaster at Imperial College London. "Scheduling is one – whether it's time of day or even the gaps between exams."

Why such variation exists is tricky to unpick. It may come down to the students' chronotypes – the natural inclination of our body to sleep at a certain time, which determines whether we are an early bird or a night owl.

"Younger people are more likely to be night owls, and favour a lie-in, than their older examiners"

Research suggests younger people are more likely to be night owls and may favour a lie-in. This may be mismatched with the chronotypes of their older examiners, and so the point at which they align would be around midday.

Vicario hopes the research will help universities plan the timings of their oral exams. ▮

Chris Stokel-Walker

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Views

Comment

Mixing it up

Volatility isn't always a bad thing. When the world is at a turning point, your brain can (finally) think something new, says **Daniel Yon**

PANDEMICS. Conflicts. Crashing markets. Collapsing governments. A cursory glance at the headlines over recent years is enough to give the sense that the world is an unstable and uncertain place. But "volatility" isn't just something hedge fund managers care about. It is deeply important to your brain too.

In my new book, *A Trick of the Mind*, I argue that the latest science tells us the brain is like a scientist, building its own hypotheses and paradigms to understand the world, other people and itself. However, if your mind is in the business of building paradigms, it also needs to know when those paradigms should shift. It turns out a set of frontal and subcortical brain regions, trading in chemicals like noradrenaline, plays a key role in tracking how unstable the world around us seems.

ADRIÀ VOLTÀ

This "volatility tracking" system is how your brain listens out for turning points in the outside world, using unexpected changes to shake up its hypotheses and expectations. Thanks to these systems in our heads, our minds' paradigms become more flexible when our everyday reality seems to be shifting. In many ways, this is a perfectly adaptive and rational process. After all, if things are changing, we want our minds to change with them.

But in a transforming world, an open mind can be a dangerous thing. For instance, research during the covid-19 pandemic found that the unexpected virus and unprecedented lockdowns made it possible for perfectly ordinary minds to think the unthinkable. One study in the US found that, as lockdowns kicked in state by state, there was a spike in erratic, volatile thinking. Those who began to experience their surroundings as unstable were more likely to begin endorsing bizarre conspiracies – about the pandemic and much more. These thinkers would start to believe that vaccines contained mind-control microchips, but would also begin believing in political conspiracies like QAnon.

Though these conspiracies might seem ludicrous, from a brain's-eye-view this behaviour makes perfect sense. Our minds need to be malleable and impressionable in order for our paradigms to shift in response to a world that seems to be changing. We need to entertain thoughts we haven't entertained before.

I actually think that living in uncertain times isn't always bad for us and our brains. After all, unpredictable doesn't mean that something bad is destined to happen. It just means we don't know what's going to come next. If we look with a historical lens, we can see that many points of positive progress came around at similar points where our familiar reality was shaken up and the future seemed hard to predict. In the UK, support for women's suffrage reached a tipping point after the first world war, and transformative changes to the welfare state like the creation of the National Health Service emerged after the second.

Though I can't travel back in time to scan those historical brains, we can imagine that these new moments of possibility depended on precisely the same processes unfolding in our heads. When the familiar touchstones of our surroundings seem unstable, old ideas become dislodged and new ones can take hold.

Once we think about how our brains work, we see uncertainty and volatility rather differently. Though volatility can make us feel anxious, living in a world full of flux and change means our brains are opened up to new possibilities. While we need to be vigilant against bad actors who might be trying to mould our malleable minds in extreme or conspiracist directions, having our brains tipped towards a turning point makes it possible for us to embrace a better and brighter future too. ▮

BRIAN RANKIN

Daniel Yon is director of The Uncertainty Lab at Birkbeck, University of London, and author of *A Trick of the Mind*

Future Chronicles

Now you see me, now you...

Rowan Hooper spies a future where materials allow us to disappear completely – at least with regards to artificial intelligence

Rowan Hooper is *New Scientist*'s podcast editor and the author of *How to Spend a Trillion Dollars: The 10 global problems we can actually fix*. Follow him on Bluesky @rowhoop.bsky.social

In Future Chronicles, he explores an imagined history of inventions and developments yet to come.

THE desire to disappear has been strong throughout history. It didn't go well for the protagonist in H. G. Wells's *The Invisible Man*, but that is because his invisibility was permanent. What was needed – and what was longed for – was a means of disappearing temporarily, as popularised by Harry Potter's invisibility cloak.

Metamaterials developed in the early 21st century gave hope that a garment offering universal invisibility was feasible. But while some forms of cloaking device did become possible, the sheer level of engineering required to produce them meant they remained rare, ultra-expensive and out of reach to the vast majority. (Nor was the fabric anything like that of the gossamer cloaks of wizardry.) Instead, invisibility went down a different path. Clothes were designed that concealed their wearers not from other people, but from a more insidious enemy: artificial intelligence. They didn't visibly disappear, but their identity – even their humanity – was concealed from ubiquitous visual-recognition systems.

Metamaterials are engineered fabrics containing nanostructures or microstructures that control and manipulate electromagnetic waves' paths. Like water flowing around a stone, when light hits a metamaterial, it isn't absorbed or reflected but redirected.

The main issue with metamaterials was that they were specific to wavelength. Some of the first invisibility devices, such as those conceived by John Pendry at Imperial College London in 2006, could conceal objects, but only from microwave radiation. Hiding from shorter wavelengths, including visible light, required an even more highly engineered nanostructure material.

One promising approach came from an engineered optical device called a metalens, which is similar to a traditional lens in that it can manipulate light, but is flatter and thinner. By pairing metamaterials with metalenses, scientists could construct fabrics that manipulated light such as to render an object or person behind it invisible. Still, fabrication was too hard for it to go mainstream.

Key here were materials first made in 2024 using self-adaptive photochromism (SAP) (SAP) – essentially the same method used by octopuses and chameleons to change the colour of their skin to match their background. They contained molecules that change structure when exposed to light, taking on the colour of the background. "Chameleon clothing" became common among field biologists, who were able to observe animals without detection, and of course among the military. But fabrics with changing colours became immensely popular among fashion designers too.

> **"Mainstream fashion in the 2030s acquired a more radical political aspect than had been seen for many years"**

It was in the early 2030s when SAP clothing was combined with electronics that could dynamically manipulate and program patterns, that a new kind of invisibility was discovered. It wasn't long before mainstream fashion acquired a more radical political aspect than had been seen for many years.

In 2024, students at Wuhan University in China had developed InvisDefense, a fabric that rendered wearers invisible to cameras run by AI. The key lay in the pattern, designed to disrupt and evade image-recognition systems. When caught on CCTV, a person wearing InvisDefense clothing wasn't classified as human by the AI.

But the patterns in InvisDefense clothing were static. Dynamic SAP materials then came along that could be programmed to display a morphing, transient, endless swirl of colours. AI systems couldn't recognise so-called polymorph clothing or even classify the wearers as people – the systems simply categorised them as noise.

It was perhaps not surprising that InvisDefense was developed in China. By the 2020s, the citizens of China were among the most surveilled in the world. (China had some 200 million camera systems in the 2020s, while the UK had around 7.5 million cameras and the US some 50 million.) It was hard to argue that CCTV didn't play a protective role, but it also played a stifling, authoritarian one.

The next SAP development was ultra-thin full-face polymorph masks, known as polymasks, designed to be worn with regular clothing. The masks created a look that appeared to be completely authentic, moving naturally with the muscles beneath. However, the outward appearance was completely unlike the real face beneath.

Governments initially tried to regulate access to polymasks, but the technology required to produce the material was relatively simple and restricted access became impossible. There was, inevitably, a criminal element among the users of polymasks, but most people used the mask to escape relentless targeted advertising, racial profiling and the endless surveillance of the modern world. ▮

This column appears monthly. Up next week: Chanda Prescod-Weinstein

23 January 2026 | 13 days

Alfred Russel Wallace expedition cruise, Indonesia

Explore the Maluku Islands (Spice Islands) and Raja Ampat Islands as Alfred Russel Wallace did, visiting several sites that were important to his discoveries. You will be accompanied by George Beccaloni, an entomologist, evolutionary biologist and Wallace expert.

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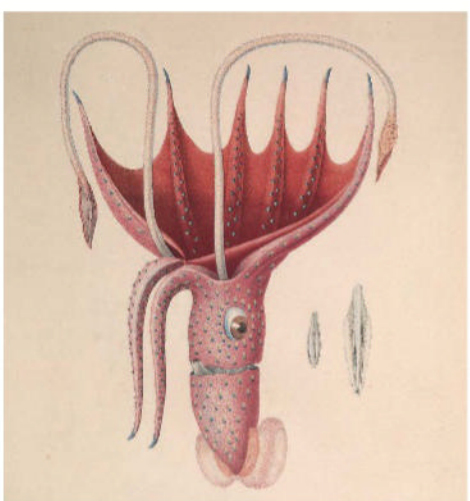

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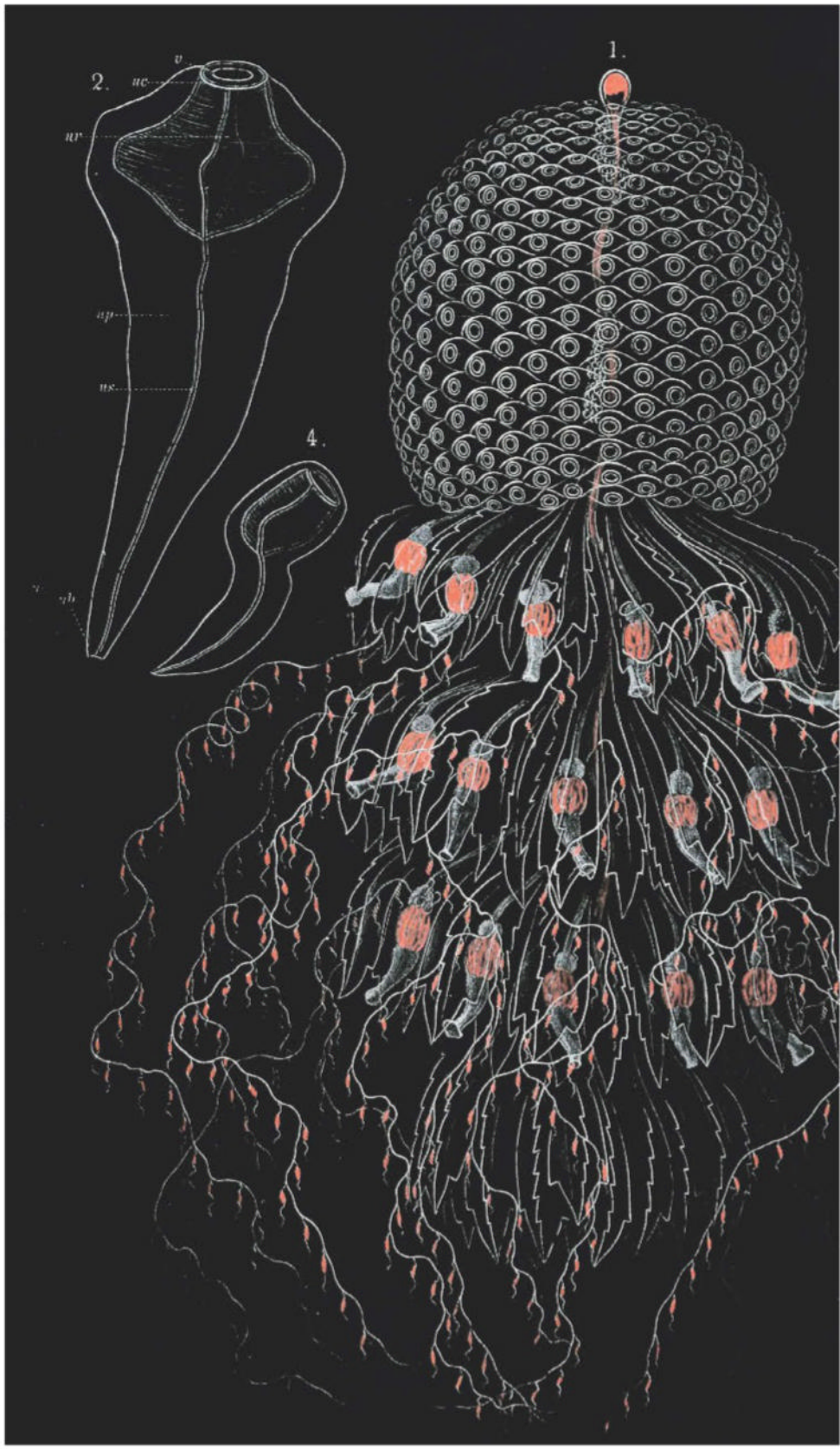

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Sea spell

Reaktion Books

SALT WATER covers seven-tenths of Earth's surface and is where life began. So it is no surprise that our oceans are home to a wide diversity of creatures of all shapes, colours and evolutionary strategies.

Marine biologist and writer Helen Scales's latest book, *Ocean Art: From the shore to the deep*, takes us on a journey through these vast underwater landscapes and their inhabitants via 140 photographs and illustrations – ranging from fine ceramic art to scientific drawings.

The art is as diverse as the ocean life it represents. And Scales tells us as much about the artists as the sea life in a fusion of marine biology and art history.

"I find it fascinating to see the sea through the eyes of artists and craftspeople," says Scales. "They capture a vivid sense of what life is like beneath the waves."

Cultures throughout history have been fascinated with ocean life. The artworks here are (clockwise from bottom far left): a lithograph of a strawberry squid (*Histioteuthis heteropsis*) from 1851; a hand-coloured engraving of a pilchard (*Argentina carolina*), 1743; an 1830 woodblock print from Japan featuring crabs; an 1888 illustration of a siphonophore (*Forskalia tholoides*); a Mycenaean jar depicting an octopus, from around 1200-1100 BC; a ceramic vessel from Peru in the form of a lobster, 4th to 6th century AD; and a Nazca bowl, also from Peru, showing a crab, made between the 2nd and 4th centuries AD.

Ocean Art is published in the UK on 1 August and in the US on 26 September.

Matthew Sparkes

Into the deep biosphere

A marvellously alien adventure can be had right here on Earth by studying the microbes that inhabit our planet's strangest habitat, finds **James Dinneen**

Book

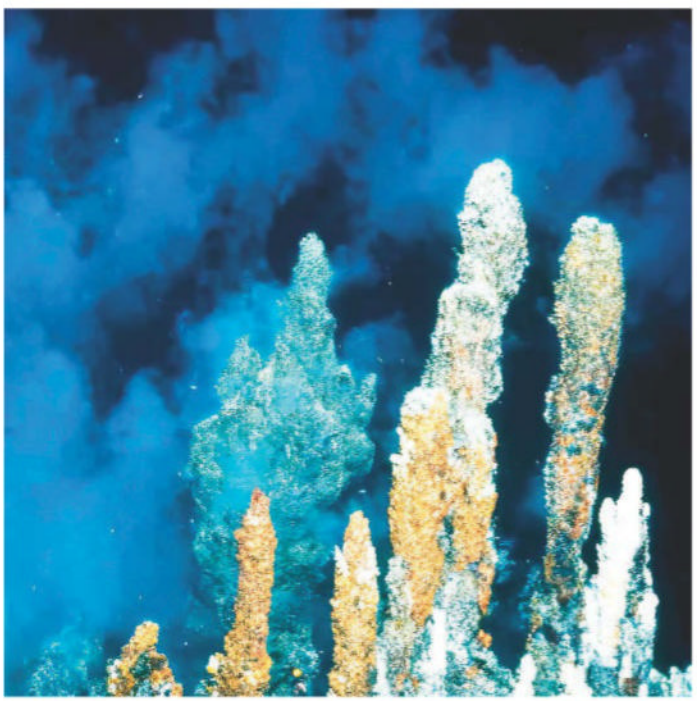
Intraterrestrials
Karen G. Lloyd
Princeton University Press

I CAN think of a shelf-full of books about forests, and nearly as many about the ocean or deserts. And consider how much ink has been spilled over expeditions to far-flung ecosystems, from the Amazon to Antarctica. Yet with a few notable exceptions, such writing has neglected one of Earth's largest, most fascinating habitats. This is the microbial life within the planet's crust: the deep biosphere.

No longer. *Intraterrestrials: Discovering the strangest life on Earth* by Karen G. Lloyd is a much-needed field guide to Earth's subterranean life – at least the parts of it we have been able to probe so far. "In fact, we have not yet encountered a depth at which life ceases to exist," she writes.

That the very existence of the deep biosphere isn't common knowledge reflects our understandable preoccupation with the surface. We live up here, after all. But Lloyd, a microbial biogeochemist at the University of Tennessee, Knoxville, makes a strong case that learning more about this life can change how we think about life in general.

As she sees it, the deep biosphere includes any place below ground or below the seafloor, where life exists without exposure to sunlight, the primary energy source for most life on the surface. Such a definition stretches across a huge range of metabolic contexts, from methanogens living off rotting plants beneath a few centimetres of swamp muck to chemolithotrophs respiring atop rock 3 kilometres down.



GALIH/ALAMY

Microbial life lurks in places like this thermal vent in the Pacific Ocean

For these microbes, she writes, "it's as if there are millions of little low-powered suns distributed throughout Earth's crust, each one with its own tiny orbit of a subsurface ecosystem".

How much life is down there? We don't really know. But all our estimates are too low, argues Lloyd. She cites one claiming marine sediments alone could contain 2.9×10^{29} cells, with twice as many again making do in the fractures and pores of continents. These are astonishing numbers.

"It's like a movie: careful not to slip on the shards of volcanic glass, lest you fall into the lake of acid!"

We are now coming to know more about these teeming ecosystems, thanks to a combination of genetic-sequencing tech and globetrotting fieldwork. The first, Lloyd explains, helps researchers distinguish between different species of microbes and make inferences about their metabolism based only on DNA. This is helpful given most of these deep-living bacteria and archaea proved impossible to cultivate in surface labs.

The fieldwork part is to do with how researchers get their hands on new DNA, whether it is spewing from hydrothermal vents on the seafloor, drilled out of continental rock or collected from water dripping in deep mines. "To study extremophiles, sometimes you have to have to become one yourself," writes Lloyd.

Through witty prose, she brings us along on some of her own adventures chasing microbes from the high desert of the Andes to the perilous summit of a Costa Rican volcano. These are scenes out of an action movie: careful not to slip on the shards of volcanic glass, lest you fall into the lake of acid!

But fortunately, the book is much more than an account of daring expeditions. It features extended, approachable explanations of the chemistry that makes the deep biosphere possible. This is complicated stuff. Equations are involved. You will see a lot of ΔG – the all-important measure of the energy a microbe might extract from a given chemical reaction. Yet somehow, impossibly, Lloyd helps us begin to see the chemical contours that enable these organisms to live at the "energetic edge".

To pull us up this steep learning curve, she relies on analogies with surface ecosystems, as well as our own dietary habits, to bring the subsurface world into focus. For example, sulphide-munching bacteria are "couch-potatoes". They compete with methanogenic "freeloaders" by withholding hydrogen, the universal food, in an ecological drama worthy of the Serengeti. Sulphate-reducers in the fjords of Svalbard "have access to a perpetually stocked fridge". All this makes for fun and evocative reading about biogeochemistry – no easy feat.

The climax of the book, however, is Lloyd's discussion of how some forms of deep life have extremely sluggish metabolisms that might let individuals live for millennia, or possibly millions of years. These "aeonophiles" (should they prove so long-lived) continue "smashing our preconceived notions on how life is supposed to work", she writes. Indeed, these are truly alien lifestyles. How fortunate we can learn more about them on Earth. ▮

A new economic order?

Saving Earth means factoring nature into our economics, argues a new book. Will people listen, asks **Jason Arunn Murugesu**

Book

On Natural Capital

Partha Dasgupta

Witness Books (UK, out now); Mariner Books (US, 20 January 2026)

HOW much would things cost if the environmental harm caused by producing them were taken into account? What impact would that have on a country's economy? Can we put a price on the importance of a pleasant living environment – or on the biodiversity around us?

In 2021, Partha Dasgupta, an emeritus professor of economics at the University of Cambridge, wrote a 610-page report delving into such questions for the UK government. His new book, *On Natural Capital: The value of the world around* us, is an attempt to broaden its appeal.

How successful you think Dasgupta is will depend on your enthusiasm for relatively dry descriptions of economic concepts, surrounded by larger chunks of livelier writing. His main argument is that the way we use GDP to determine the success of a country's economy is wholly inadequate. Human invention has been key to rising living standards throughout history, but, as Dasgupta writes: "Labour and capital saving devices, not Nature saving devices, were the entrepreneur's goal."

This is especially clear with the latest of humankind's "labour and capital savings" efforts: artificial intelligence. The tech billionaires behind AIs promise incalculable hikes in productivity as they become ever more ubiquitous. Yet the amount of water required to cool the data centres that will run them is barely mentioned.

In his original report, Dasgupta wrote that estimates show that between 1992 and 2014, human capital per person – our health, education and skills – increased by about 13 per cent globally, but natural capital per person declined by nearly 40 per cent. To address this, he argues for the widespread adoption of "global inclusive wealth per capita", to factor in nature.

This big picture can also be scaled down. Take shrimp farms in Vietnam and Bangladesh. Dasgupta reveals how they can negatively affect the "natural capital" of those countries in a way not reflected in the crustacean's retail price. Creating shrimp farms typically means destroying some mangroves and salt marshes, he writes, thereby reducing their capacity to store carbon.

About 30 per cent of these animals' diet comes from soya grown in plantations that displace tropical forests. Dasgupta cites case studies he has read to suggest that if their true environmental costs were taken into account, shrimp may have a 15 to 20 per cent higher export price. In other words, the richer countries buying the shrimp are getting a better deal than they should.

I won't profess any deep knowledge or understanding of economics, but I do possess a general unease with the pursuit of economic gain at the price of great harms to the environment. So, what can be done? In an all-too-short chapter, Dasgupta offers ways in which we could value nature more. This includes collecting rent from shipping firms that cross the oceans. That cash could fund work to ease pressure on ecosystems worldwide.

These ideas make intuitive sense to me, but where is the detail? Dasgupta touches on the difficulties in making collective agreements and the lack of enthusiasm for a global shipping rent collector. It is here I wished he had made a more passionate argument. His ideas are fascinating, but aren't presented with the urgency I believe the general reader wants.

On Natural Capital will make you reconsider the economy, but I would have liked more feeling. That may be too much to ask from such a book, but I worry people may not listen otherwise. ▮

Jason Arunn Murugesu is a writer based in Newcastle upon Tyne, UK

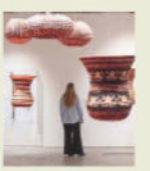
Shrimp harvesting at a farm in south-east Vietnam

QUANG NGOC NGUYEN/AL AMY

New Scientist *recommends*

Rollo Buckley
Work experience
London

The Design Museum in London's latest exhibition, **More Than Human**, is a fresh foray into the question of how we work with, and for, the natural world. It is an intriguing show (on until 5 October),



with thought-provoking, stunning installations.

Being Landscape kicks things off, with its emphasis that humans are part of the natural world, from the woven baskets (pictured) of the Indigenous Ye'kuana people of Venezuela and Brazil to the rumiti, ivy-covered "tree-men" of southern Italy.

Next is Making with the World, which features architect Andrés Jaque's *Transspecies Rosette*. A beautiful, practical cork-and-resin cladding that provides waterproof insulation for buildings and a home for microbes, fungi and more.

Shifting Perspective is a fitting finale, with a tapestry iteration of artist Alexandra Daisy Ginsberg's *Pollinator Pathmaker* project at its centre. This shows a garden from an insect's perspective, challenging us to see the world as animals and plants do.

LUKE HAYES/THE DESIGN MUSEUM

The TV column

All good things

What is it like to finally catch up with *Devs*, a smart, beautiful-looking, sometimes self-indulgent and cold, but never less than compelling TV show? After five strange years, **Bethan Ackerley** finds out

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

ALBUM/ALAMY

Forest (Nick Offerman) is the CEO of quantum computing firm Amaya

MARCH 2020 was an inauspicious time, I think we can agree. This may be why *Devs*, an eight-part sci-fi series by Alex Garland that debuted as the world went into lockdown, didn't attract as large an audience as it could have – we certainly had other things to worry about. I was, I confess, one of the many people who missed it.

There are lots of reasons why I have recently rectified that: Garland was on my mind after watching *28 Years Later*, for which he wrote the screenplay, and the cold, dark world of *Devs* was also the perfect antidote to the heatwave this column was written under. But the main reason is that five strange years have passed since the show aired, and I was intrigued to see how it looked, at half a decade's remove.

In *Devs*, Lily Chan (Sonoya Mizuno) is an engineer at Amaya, a quantum computing firm in San Francisco. Every day, she travels to work with her boyfriend and fellow employee Sergei (Karl Glusman), who works in Amaya's AI division, until he impresses CEO Forest (Nick Offerman) with his work predicting the behaviour of nematode worms. Sergei is invited to join Devs, a secretive enclave in the company. After a day in his new role, Sergei disappears, and Lily is convinced that Amaya and the mysterious Devs project are somehow involved.

Almost everything in *Devs* is cold and beautiful. The score and sound design are arresting, punctured by static and bursts of dialogue. The performances are frigid – some too much so, like Mizuno's stilted turn as Lily. Others, like Alison Pill, who plays Amaya scientist Katie, do compensate. The company campus is glass and polished concrete, surrounded by pine trees ringed in halos of light and watched over by the enormous statue of a young girl.

> **"The Devs compound is like stepping into a Byzantine mosaic, turned secular and three-dimensional"**

But all this pales in comparison to the Devs compound itself, which is like stepping into a Byzantine mosaic, turned secular and three-dimensional. Awash in dimpled gold, floating on electromagnetic fields within a vacuum within a Faraday cage, it is a perfectly calibrated home for Forest's secret research.

The nature of that research is paradigm-shifting, born from deeply human impulses even as it threatens to rewrite what it means to be human. It is a project in which only total success is of any value, according to Forest. It was bracing to consider how many great tech leaps might be achieved or avoided due to the personal world views of privileged men like him.

At its best, watching *Devs* feels like being in a sound bath, with long, slow reverberations washing over you. At its worst, it is full of self-regard. That isn't to say it isn't clever – and it is good to watch a series that doesn't just namecheck ideas like the many-worlds interpretation but really engages with them. Yet once the human stakes of Lily's quest to understand what happened to Sergei fall away in favour of the Amaya mystery, *Devs* starts to get drunk on itself.

In one of life's funny quirks (limited spoiler here), perhaps the show's most successfully realised theme concerns the impulse to look back at the past, and what we gain or lose in the process. Here, it has more interesting things to say than in its highfalutin visions of our tech future. I am pleased I saw *Devs* five years after it aired: there is so much to like, despite its occasional onanistic tendencies. Though Forest and his ilk may call a qualified success no success at all, *Devs* is more than good enough for me. ▮

TV

Devs
Alex Garland
FX
Hulu, Disney+

Bethan also recommends...

Films

Ex Machina
Alex Garland
In Garland's directorial debut, programmer Caleb (Domhnall Gleeson) is asked by his boss to assess whether Ava, a humanoid robot, is capable of true sentience. This one will really get under your skin.

Never Let Me Go
Mark Romanek
This Garland-penned adaptation of Kazuo Ishiguro's novel about students at an unusual boarding school isn't perfect, but it is well worth a watch.

Editor's pick

Beware strange orcas bearing gifts

12 July, p 19

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

It is interesting that altruism was used to explain why orcas were apparently offering people gifts. This is based on a human trait, but there is another possible explanation also based on human activity. We frequently offer small edible titbits, usually on the end of a line, with the purpose of securing much larger eatables. Can the researchers be sure that what they are being offered isn't bait? Before venturing into the sea to accept the "gifts", I feel we ought to be absolutely certain of the motives of these apparent benefactors.

Inequality is about more than invisible rivalry

12 July, p 38

From Alasdair Smith, London, UK

Your headline "The enemy within" echoes the phrase that UK prime minister Margaret Thatcher used to demonise striking miners in 1984/85. The ruling class planned to crush the National Union of Mineworkers to pave the way for deregulation and privatisation. There was no "invisible rivalry", just open and often brutal class war. Cooperation and solidarity kept mining communities going for over a year. But the ruling class, using the instruments of state and media, crushed the resistance.

The pattern of class struggles is a better basis for understanding gross inequality than the theories of invisible rivalry in your piece.

How to ensure home solar can't be hacked

12 July, p 11

From Roy Harrison, Verwood, Dorset, UK

You report on home solar being vulnerable to hacks that could derail power grids. My solar installation poses little or no threat as its design limits its output to the grid so that, in the event of there being no demand for its electricity, it will detect this and reduce output appropriately.

I insisted on it having no internet connection via which the parameters controlling these behaviours could be interfered with. I did this because of the primitive nature of the security arrangements. If you know the password for such systems, you can not only read performance data, you can also change the parameters, possibly leading to destruction of the inverter or instability in the grid. This is a formula for ransom demands.

Wallaby poop may have spread plants far and wide

5 July, p 19

From Matthew Stevens, Sydney, Australia

The discovery of wallaby and bandicoot bones on islands near New Guinea and in Indonesia is fascinating. The fact that ancient humans took them there alive implies that seeds of the animals' food plants could have survived in their guts and been deposited on arrival to colonise new land. The presence of disconnected populations of non-crop plant species beyond their endemic ranges could offer clues to the past movements of humans whose remains haven't yet been found.

Baby gene screening is wrong in so many ways

12 July, p 21

From Sam Edge, Ringwood, Hampshire, UK

I couldn't agree more with Suzanne O'Sullivan that the half-baked UK government plan to screen all newborns for hundreds of gene variants is dangerous, a waste of money and unscientific.

As well as being pointless from a clinical point of view, as with previous plans to put babies' fingerprints or other biometrics into a central database, it is an irreversible invasion of the privacy of people who have no possible way of giving informed consent.

Another explanation for doomed early human clan

5 July, p 30

From Spencer Weart, Hastings-on-Hudson, New York, US

Your description of traces of an isolated population of early humans, never more than a few hundred individuals, has them "scattered over a distance of 1500 km" from Britain to Poland. This is more likely to point to a single, cohesive clan that, over centuries, migrated either east or west over this distance. Such a small, inbred population would have accumulated many genetic defects over time, making their extinction in the harsh glacial climate almost inevitable.

We must make Mars a plastic-free zone

12 July, p 14

From Michael E. Weaver, Weston-super-Mare, Somerset, UK

The story on human habitations on Mars that could be built from bioplastics filled me with horror. We have already polluted our own planet with plastics to such an extent that they are found everywhere and in every species. We are now proposing to pollute another world. Not only that, but the algae we end up using to make the plastic would be bred to survive in Martian conditions. I foresee our descendants looking at Mars with telescopes and no longer observing a red planet, but a world of whatever colour the algae happens to be.

Who will take the blame if geoengineering goes awry?

28 June, p 35

From John Fewster, London, UK

Geoengineering projects are nothing new: mining, coal, oil, etc. have impacts beyond borders and create mounting environmental problems. In the main, these industries are for profit and answer to shareholders. Because of the environmental damage they cause, we may need to consider geoengineering solutions that could have wider impacts too – possibly good, possibly bad. But who will run these projects? Who will take the profits? Who will take responsibility for unintended consequences?

My chat with AI showed it has a humorous side

12 July, p 34

From Sue Tudor, Leeds, UK

Amid debate about the capabilities of artificial intelligence, I asked one about socks going missing in the washing machine. It gave me a reasonable and rational reply. I then asked if the issue could be related to an interaction of relativistic effects of the spinning and electromagnetic oddities of the washing machine. To my surprise, it not only knew I was making a joke, it also replied with humorous suggestions of its own. It then made a reference to the title of a non-existent orchestral piece by the composer Louis Spohr. The context clearly showed deliberate humour, not a hallucination, and the made-up title was actually rather clever.

That struck me as remarkable. If it had been a human, I would have willingly labelled that trivial chat as intelligent and witty. How then should I describe it when my conversation is with software?

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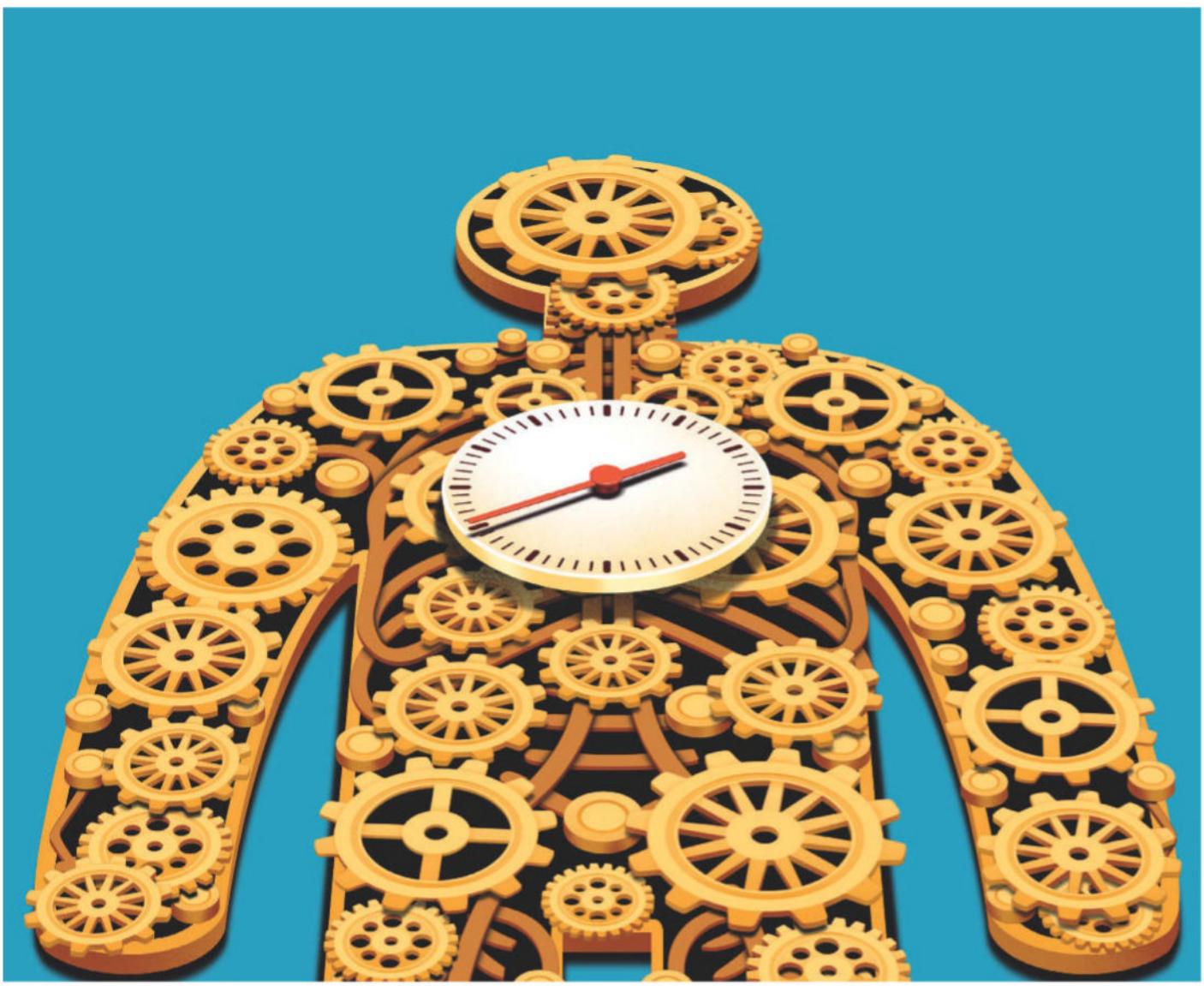


NASH WEERASEKERA

Great timing

Understanding your circadian rhythm can supercharge your health. **Linda Geddes** tries the new tools for decoding your body clock

SOME people check a wristwatch; others use a smartphone app, or the position of the sun. But although these methods will tell you what time it is, they won't reveal your internal time – that is, the timing of the clocks in your cells and tissues. This explains why I am standing in front of a mirror, plucking hairs from my head and plunging their bulbous roots into a small tube of buffer solution. Once the hairs have been analysed by a lab in Germany, I should discover what time it is inside my body.

For centuries, we have been missing a vital ingredient in health and medicine – the body clock. Over the past few decades, researchers have discovered that our mood, metabolism, athletic performance and cognitive capabilities vary over the 24-hour period, while a disrupted body clock is implicated in an ever-growing list of health conditions, from type 2 diabetes to cancer. It has also become clear that giving medications or interventions at different times of day can profoundly alter their efficacy and side effects, with more than half of drugs influenced by these time-of-day, or circadian, rhythms.

Yet, without a way to quickly and accurately read body clocks, our ability to capitalise on such insights is limited, which may even be harming us. A raft of tests now in development should change that, promising to help us understand our body clocks from a sample of saliva or blood, or even from hair cells like those I am sending to Germany. One of these tests is already on the market. Together, they could lead to a revolution in medicine.

Circadian rhythms are natural oscillations in the activity of our tissues that are driven by an internal clock – or rather trillions of clocks, ticking in every cell of our bodies.

"If you look at the expression of genes in different tissues, they're all doing different things at different times of day, and what those genes are doing depends on the timing of the clocks in that tissue," says Rosemary Braun at Northwestern University in Chicago.

"We have long been missing a vital ingredient in health – the body clock"

These clocks are controlled by a set of clock genes that produce daily fluctuations in a handful of clock proteins, and these influence the activity of numerous other genes in turn. Indeed, in 2014, researchers led by John Hogenesch at the University of Pennsylvania discovered that 43 per cent of mice genes are expressed rhythmically. Moreover, the study revealed that 56 of the 100 best-selling drugs in the US, and a similar proportion of the World Health Organization's essential medicines – the drugs that are supposed to be in every hospital in the world – target proteins whose rhythms fluctuate over 24 hours.

These results support the idea of chronotherapy – giving drugs at the time of day they are most likely to be effective and least likely to trigger side effects. Some clinical evidence backs the approach too, with cancer medicine leading the way.

Francis Lévi at Paris-Saclay University, France, became interested in the idea of biological rhythms through traditional Chinese medicine, which describes the vitality of different organs peaking at various times of day. He began to investigate this in the context of cancer, recognising that, whereas healthy cells usually only divide at certain times of day, cancer cells do so all the time. Because many chemotherapy drugs target rapidly dividing cells, he reasoned that giving these drugs when healthy cells are effectively asleep might allow larger doses to be delivered with fewer side effects. Initial experiments in mice confirmed this, followed by a small clinical trial in women with advanced ovarian cancer. Published in 1990, it suggested that side effects such as nausea and fatigue could be significantly reduced if the women received chemotherapy drugs at 6 am rather than at 6 pm.

Since then, Lévi and others have conducted further chronotherapy trials with other drugs, in various types of cancer. According to a 2022 review of 18 such trials, most showed evidence of reduced toxicity, while the efficacy of the drugs was maintained.

Similar results are now being reported in other fields of medicine. For example, the heart may be better able to withstand surgery in the afternoon compared with the morning, and the seasonal flu vaccine generates four times as many antibodies if given between 9 am and 11 am compared with 6 hours later.

"Not only is how the drugs hit their target influenced by the clock, but there's also evidence that how they enter the body and ›

how they are excreted differs by time of day," says Robert Dallmann, director of the Patho-Physiological Molecular Clocks Lab at the University of Warwick, UK.

Even so, "there have been some studies that did not show the expected benefit", says Lévi. One explanation could be that each participant's internal clock is set slightly differently. "Until now, chronotherapy has adapted treatment to an average circadian rhythm in a population of people," he says. "But the timing of these rhythms can differ by up to 12 hours between patients."

Perhaps then, chronotherapy isn't only about administering the right drug at the right time, but at the right time for each specific patient, says Angela Relógio at MSH Medical School Hamburg in Germany. "The problem is you need to be able to measure the [internal] time."

Until now, the gold standard for assessing internal time has been to record when individuals start to release a hormone called melatonin from their pituitary gland, which usually happens about 2 to 3 hours before they naturally fall asleep. This nightly event is controlled by a central body clock in the brain called the suprachiasmatic nucleus (SCN), whose job it is to keep the billions of clocks in our tissues synchronised with each other – and with the time of day outside (see "How to shift your internal clock", opposite).

Melatonin's release is thought to be one of these synchronising signals, helping the body transition into nighttime mode, so measuring the onset of this event is the metaphorical equivalent of listening for when a clock strikes midnight.

Useful as it is to measure this "dim-light melatonin onset", recording it is laborious. It requires blood or saliva samples to be taken every 30 minutes from late afternoon onwards, and because the release of melatonin is inhibited by bright light, the subject ideally needs to remain in a darkened room for the duration. The samples must then be sent to a laboratory for processing, so it can take days or weeks to find out someone's internal time.

This difficulty of telling internal time has hindered scientific progress in circadian medicine. However, researchers have been working on alternatives. Given that the products of clock genes – and the genes they regulate – fluctuate at different times of day, scientists have been searching for various proteins or other "biomarkers" in body fluids and tissues that could reliably

WIRESTOCK, INC./ALAMY

The intricate processes within your various body clocks dictate a preferred waking time

"The heart may be better able to withstand surgery in the afternoon"

infer somebody's internal time.

For instance, Relógio is CEO of TimeTeller, a company that has developed a saliva-based test, while Hogenesch's team is investigating skin-based circadian biomarkers. Other research teams – including one led by Braun and others led by Derk-Jan Dijk at the University of Surrey, UK, and by Christopher Depner at the University of Utah in Salt Lake City – are developing blood-based biomarker tests.

For now, however, the only analysis available to consumers like me is BodyClock's hair test. For €199, it examines the relative amounts of messenger RNA – the genetic template for protein production – being expressed by clock genes in the subject's hair follicles at the time they were plucked from their head. Through comparison with when the resulting proteins are known to peak and trough in people on average, BodyClock's algorithm calculates how far advanced or delayed someone's internal clock is relative to this.

My test results suggest that I am an intermediate type, or "dove", and that my body begins to ramp up melatonin release at around 9.30 pm. Roughly 2 hours later, its concentration hits a level where my body switches to sleep mode, meaning I should naturally become tired at around midnight. This is when BodyClock recommends that I try to start sleeping, and I should try to wake up at around 8 am.

The company also suggests that my optimal eating time is between 8.30 am and 8.30 pm – or 6.30 pm if I am trying to lose weight, as my body is best equipped earlier in the day to convert food to energy, and not store it as fat (see "Eating with your body clock could improve your health", p 34). Meanwhile, the best time for me to exercise if I wish to optimise strength or endurance is between 5.30 pm and 7.30 pm. This is because body temperature, blood flow and blood pressure gradually increase during the day, contributing to improved muscle performance in the early evening.

As the author of a book on circadian rhythms, I didn't find any of this particularly surprising. It also fits with when I would naturally choose to go to bed and wake up, if not for the fact that I am forced to set my alarm clock to 7 am, to get my kids out of bed and off to school on weekdays.

However, I am not really BodyClock's target customer. Bert Maier, a chronobiologist at Charité – Universitätsmedizin in Berlin, Germany, who sits on the company's scientific advisory board, says most people who buy the test have sleep problems. "Some types of insomnia are related to a disrupted circadian clock, and in this case, we might help customers to readjust their clock or inform them what they should do to enhance or strengthen it."

The biomarker tests could also be useful in the context of clinical trials. Later this year, Lévi hopes to begin a chronotherapy trial that will see 242 people with non-small cell lung cancer receive immuno-chemotherapy. Although most will be randomly allocated to receive morning or afternoon treatment, a subgroup will have their internal rhythms assessed using TimeTeller's saliva test to see if personalising the timing of these drugs could further boost their efficacy.

In a recent trial, Lévi and his colleagues discovered that administering the treatment to people before 11.30 am was associated with a nearly twofold increase in overall survival from the cancer. "If we can double the survival of patients by treating them in the morning compared to the afternoon or evening, I'd expect that we should be able to at least further double this by personalising the time of administration," says Lévi.

Out of sync

There is a third way in which biomarker tests could be helpful. Over the past decade, evidence has been building of the harm circadian disruption can have on people's health, with links to psychiatric and neurological conditions, cancer, type 2 diabetes, obesity and cardiovascular disease. Such disruption occurs when our internal clocks fall out of sync with one another, perhaps because of shiftwork, inappropriately timed light exposure or social jet lag caused by inconsistent bedtimes.

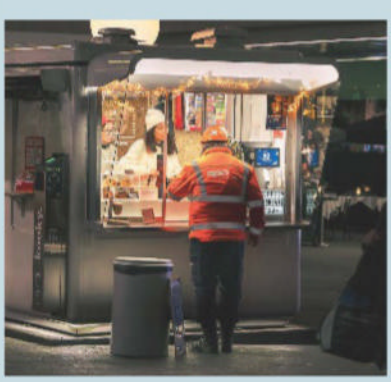
"Circadian misalignment is very strongly linked with many of the health issues of modern society," says Depner. "If we could measure biomarkers effectively, this would expand the populations that we can reach with our research. Most excitingly, we could use them on real-world shift workers to understand how their clocks are moving around with their different shift schedules. This could allow us to devise interventions ›

How to shift your internal clock

Our circadian rhythms are controlled by a small patch of brain tissue called the suprachiasmatic nucleus (SCN). Although its timing is regulated by a network of "clock genes", it is also influenced by our exposure to light, through conversations with a group of light-sensitive cells in the retina at the back of the eye.

When light hits these retinal cells, they send a signal to the SCN, altering the expression of its clock genes and tweaking its timing. The retinal cells are particularly responsive to light in the blue part of the spectrum, which includes daylight. Their effect on the circadian system is also strongly time-dependent. For instance, exposure to light in the early evening and at night delays our central body clock, meaning we feel sleepy later, while exposure to light shortly after dawn advances our clock and makes us more lark-like – early to bed, early to rise.

Melatonin supplements can also be used to tweak the timing of the SCN. To advance your clock (waking early and going to sleep earlier), you should take it roughly 4 to 6 hours before your normal bedtime. To delay your clock (go to bed and wake later), take it in the early morning, immediately after you wake up.



DIJANA ZULFIKARIC/ALAMY

Light exposure after dark can mess with your body clock

to help mitigate the health risks."

For instance, researchers are exploring whether restricting when people eat, or the type of light they are exposed to during night shifts, could help to mitigate some of the detrimental health effects of shiftwork.

However, the tests that are currently available, or are being developed, are somewhat limited in what information they can provide, because samples must be sent to a laboratory for processing, rather than providing the results in real time.

For instance, BodyClock's hair test currently takes five weeks to deliver results to customers, which is a potential problem because our "chronotype" isn't entirely fixed, with the type and timing of light exposure being a major factor that can push or pull our internal clocks forwards and backwards. I previously conducted an experiment with Dijk that saw me cut out artificial light after dusk and expose myself to more natural light during the daytime. Doing so caused my body clock (as measured by my dim-light melatonin onset) to shift 2 hours earlier.

So, while BodyClock's results suggest my melatonin release significantly ramps up at 9.30 pm, this reflects my biology as it existed several weeks ago, which may not reflect my situation today, or five weeks from now.

PLAINPICTURE/SASKIA SANDROCK

Eating at certain times of day – in a pattern unique to you – could help with weight loss

Slightly out-of-date results may not matter if a doctor is simply trying to ascertain whether someone's insomnia is related to a significantly advanced or delayed clock, or in the context of a clinical trial. However, the ability to deliver more instantaneous results could be useful for shift workers who would like to adapt to a new shift pattern, or frequent travellers who want to overcome jet lag more quickly.

Say you had just flown from London to New York. "In the morning, you could pull a hair and run a test to find out the timing of your internal clock," says Dijk. "You could then use this information to help you overcome your jet lag through timed light exposure or taking a melatonin pill."

Getting it together

Another useful add-on would be if biomarker tests could assess the timings of individual organs, and how closely aligned they are. Although our body clocks gradually adjust themselves to altered patterns of light exposure caused by changing shifts at work or time zones, they do so at different rates, which can result in our gut rhythms falling out of synchrony with those of our brain, and so on. This ongoing desynchrony is suspected to be behind some of the adverse health effects that have been associated with shiftwork.

"If there are molecular markers that reflect what's going on in the liver, pancreas, muscle and all these other specific tissues, the question is: could we then use that information to try and devise interventions to help to better align them?" says Depner.

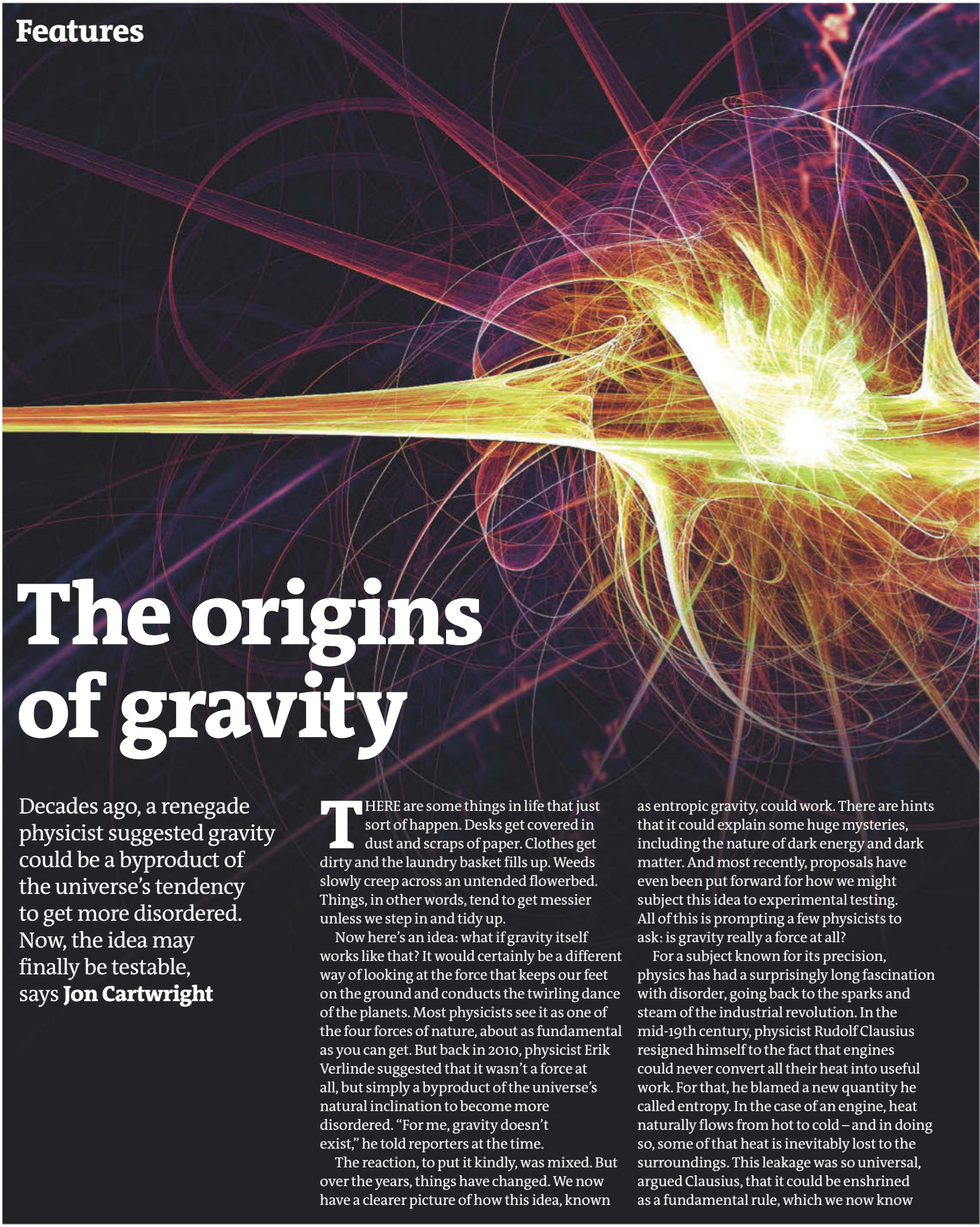
In other words, this first generation of body clock tests simply scratches the surface when it comes to reading the time inside us in a way that could usefully shape our lifestyles or improve healthcare. But researchers see the tests as a good start. If the past two decades have highlighted the importance of body clocks for human health, the hope is that the coming one will illuminate the cogs, levers and gears that we could pull to fine-tune their movements and keep all of us running on time. ▮

Linda Geddes is the author of *Chasing the Sun: The new science of sunlight and how it shapes our bodies and minds*

Eating with your body clock could improve your health

What if the timing of your meals mattered almost as much as what is on your plate? Mounting research suggests that our bodies may be primed to process food, especially carbohydrates, more efficiently in the morning compared with later in the day. Earlier on, our tissues are most sensitive to insulin, the hormone that helps to absorb sugar into cells.

Eating a large, carb-rich meal later in the day could lead to higher levels of glucose circulating in the blood, which, over time, could increase someone's risk of developing type 2 diabetes or metabolic syndrome, a group of health issues that puts you at risk of various conditions including this form of diabetes. Furthermore, we may burn slightly more calories digesting food in the morning. Several small studies indicate that evening snacks may reduce the amount of fat the body burns overnight, while eating earlier in the day boosts fat burning. While larger studies are needed to determine how such findings relate to fat storage and weight change in the wider population, it appears there is wisdom in the saying: "Eat breakfast like a king, lunch like a prince and dinner like a pauper."



The origins of gravity

Decades ago, a renegade physicist suggested gravity could be a byproduct of the universe's tendency to get more disordered. Now, the idea may finally be testable, says **Jon Cartwright**

THERE are some things in life that just sort of happen. Desks get covered in dust and scraps of paper. Clothes get dirty and the laundry basket fills up. Weeds slowly creep across an untended flowerbed. Things, in other words, tend to get messier unless we step in and tidy up.

Now here's an idea: what if gravity itself works like that? It would certainly be a different way of looking at the force that keeps our feet on the ground and conducts the twirling dance of the planets. Most physicists see it as one of the four forces of nature, about as fundamental as you can get. But back in 2010, physicist Erik Verlinde suggested that it wasn't a force at all, but simply a byproduct of the universe's natural inclination to become more disordered. "For me, gravity doesn't exist," he told reporters at the time.

The reaction, to put it kindly, was mixed. But over the years, things have changed. We now have a clearer picture of how this idea, known as entropic gravity, could work. There are hints that it could explain some huge mysteries, including the nature of dark energy and dark matter. And most recently, proposals have even been put forward for how we might subject this idea to experimental testing. All of this is prompting a few physicists to ask: is gravity really a force at all?

For a subject known for its precision, physics has had a surprisingly long fascination with disorder, going back to the sparks and steam of the industrial revolution. In the mid-19th century, physicist Rudolf Clausius resigned himself to the fact that engines could never convert all their heat into useful work. For that, he blamed a new quantity he called entropy. In the case of an engine, heat naturally flows from hot to cold – and in doing so, some of that heat is inevitably lost to the surroundings. This leakage was so universal, argued Clausius, that it could be enshrined as a fundamental rule, which we now know

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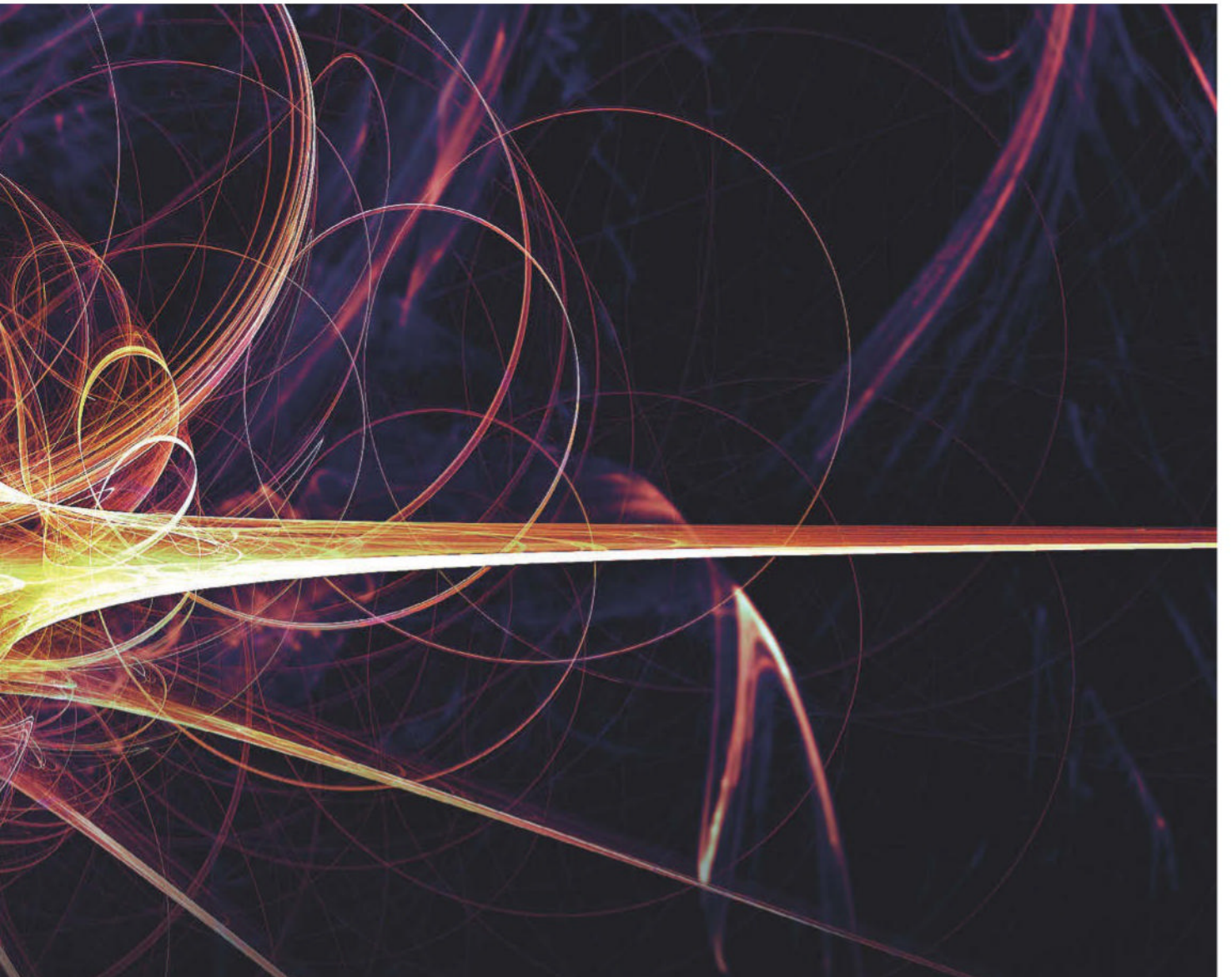


as the second law of thermodynamics.

A proper definition of entropy came a decade later from Ludwig Boltzmann, who considered the number of possible arrangements of atoms and molecules in a given space. His insight was that some arrangements are more orderly than others. For instance, a scenario with zillions of fast molecules on one side of a piston and zillions of slow ones on the other is tidier than one with fast and slow molecules mixed together. Entropy, said Boltzmann, is a measure of this disorder – and overall, it always rises.

About a century later, the physics of entropy took an astronomical leap. Theorist Jacob Bekenstein at Princeton University had been studying the disorder contained inside a black hole. He worked out that a black hole's entropy must be proportional to the surface area of its event horizon, the boundary beyond which nothing can escape its gravitational pull.

Physicist Ted Jacobson went on to show that, in certain circumstances, the gravity in space itself behaves like a thermodynamic system. This was a startling finding: gravity is believed to be a force that applies to all objects, even single elementary particles, whereas thermodynamics usually only emerges from things made up of a great many small parts. Still, Jacobson's insight was widely taken as a coincidence, rather than any deep statement about nature.

Then came a moment in the summer of 2009, when Verlinde was stranded on holiday, his passport having been stolen. He had read Jacobson's paper many times and couldn't shake off the idea that this equivalence between entropy and gravity was more than a coincidence. Now, stuck with little else to do, he turned it over in his mind again and arrived at an interpretation he would outline in a curiously simple paper the following year.

In essence, he argued that gravity is just an artefact of the deeper, truly fundamental law that entropy must always rise. "I emphasised more than others that if you take these laws of thermodynamics and black holes seriously, you should take the emergent perspective of gravity seriously," he says.

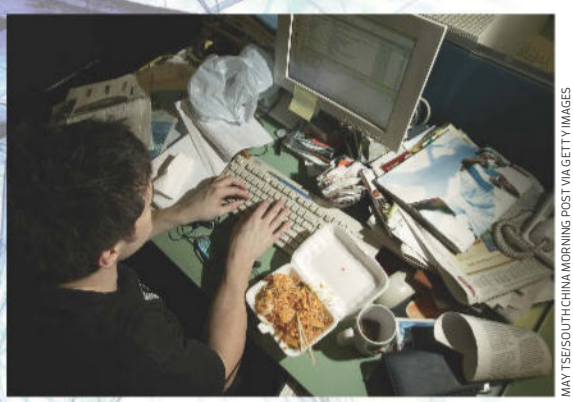
Emergent gravity

That word "emergent" is important. Physicists distinguish between fundamental ingredients of reality, which can't be broken down into simpler parts, and emergent phenomena, which are a result of many simpler things acting together. Take something like the air pressure in a tyre. Pressure is a useful concept, but it isn't fundamental to reality – we understand that it is the result of many air particles bouncing around inside the tyre.

Verlinde was arguing that gravity is emergent in a similar sense. His peers didn't know what to make of it. "Some people have ›

TREVOR RAY HART/MILLENNIUM IMAGES, UK

Clutter is inevitable, and that might be the rule that leads to gravity



MAY TSE/SOUTH CHINA MORNING POST VIA GETTY IMAGES

"If this idea is right, we ought to see tiny jitters in gravitational attraction"

said it can't be right, others that it's right and we already knew it," said Harvard University theorist Andrew Strominger at the time.

The trouble was, physicists already thought they knew they were on the right track with gravity. Our best understanding of this force comes from Albert Einstein's theory of general relativity. But for most of the past century, physicists had been trying to find ways to describe it in the language of quantum theory – not an easy task, as the two theories start from totally different assumptions.

The most promising way to mend the division has been string theory, which reconstructs particles and space-time from one-dimensional entities known as strings, which are coiled and spread over 10 dimensions. After decades of effort, string theorists haven't been able to describe a universe similar to ours, but their hopes are undiminished.

At first glance, entropic gravity might seem like a completely different approach, but in fact, Verlinde's original work leaned heavily on an idea in string theory known as holography. The gist is that, mathematically speaking, there are ways to perfectly translate what goes on in one reality into another reality that has fewer dimensions. It means that the three-dimensional world we move through could be no more real than a ghostly hologram, a mere projection from a deeper and altogether flatter two-dimensional reality.

Thinking along these lines, Verlinde imagined a mass placed just outside a two-dimensional screen in the shape of a sphere, enclosing another mass within. He worked out that the outer mass experiences a gentle push inwards – not due to any physical pull, but because the total entropy of the system increases if the two masses get closer. This was Verlinde's epiphany: to see gravity not as a force, but simply as the result of nature's tendency towards greater entropy in a secret, lower-dimensional realm.

What is this realm, though? "A major question that I think was left open by Verlinde's work is understanding what the underlying microscopic system is and what [model] of entropy one should be using," says Grant Remmen, a theorist at New York University who has previously worked on entropic gravity. In 2010, Verlinde offered no clear answer. But that changed a few years later when he drew once more on parallel developments in quantum gravity. In quantum physics, particles can become entangled, such that their behaviours appear to instantly affect each other, even when separated by vast distances. A modern trend among some quantum gravity theorists is to proclaim that an information network based on entanglement itself is the primary stuff of existence. In other words, deep down, reality is information.

This view may not be for the fainthearted, but for Verlinde it made plenty of sense. What is the fundamental part of reality that is becoming more disordered? The entanglement information network. And there were hints that Verlinde was on to something. As he worked through the equations, he found that the entanglement underlying the regions around galaxies ought to be more disrupted than the bare distribution of matter would otherwise suggest, resulting in more entropy and "extra" gravity. Incredibly, he had landed on a solution to a major problem in physics – that galaxies are observed to rotate too fast for the amount of visible matter, and hence gravity, in them. In other words, they should be tearing themselves apart. Astrophysicists are usually forced to invoke a mysterious and invisible "dark matter" to explain this, but Verlinde's approach worked without it.

Even so, most experimental physicists paid little heed, because Verlinde's hypothesis lacked any specific predictions that would enable anyone to test it. "We just wanted to know what we had to look for," says Dan Carney, a physicist at the Lawrence Berkeley National Laboratory in California. Like Verlinde, Carney was also captivated by Jacobson's early paper on entropy and gravity. One line in particular haunted him. It suggested that gravity may be no more fundamental than a passing sound wave made up of ebbing and flowing air molecules. Perhaps both are equally ephemeral, equally dependent on simpler things, with no need of a description in the primal tongue of quantum mechanics.

Remarkably simple

Carney has been musing on this for years, but only recently did he find a possible way to test it in the lab. His idea is remarkably simple. Rather than be tied to the metaphysical "information is reality" stance favoured by Verlinde, he and his colleagues posit a more generic background system – a collection of microscopic entities whose exact nature doesn't matter.

Like the molecules in a piston, this background system is thermodynamic, and conserves energy while striving to maximise entropy. Remarkably, they find that when test masses interact with it, the masses attract according to Isaac Newton's law of gravitation, even though the force of gravity isn't explicitly

included. "It shows there are other ways of thinking about gravity," says Carney.

The researchers actually considered two different models. One, which was very simple, predicted a gravity that was highly erratic, unlike anything we observe. By contrast, the other model included quantum effects, namely an ability of the bedrock ingredients of reality to be in more than one energy state at the same time, and to be entangled with one another. In this model, gravity was much more realistic – but crucially, not exactly. Since the force arises from a background system that follows the rules of thermodynamics, it would necessarily exhibit tiny jitters. In other words, if the model is right, we ought to see small irregularities in the otherwise-smooth gravitational attraction between objects.

This means that, finally, the doors are open to test entropic gravity. All physicists would have to do is seek those telltale gravitational blips. The kinds of device that would be needed already exist. For example, they could be tiny, weighted levers that would move – smoothly or in fits and starts – as a tiny mass was brought close to them. These devices are usually designed to explore other topics, such as gravitational waves or the limits of quantum behaviour. Repurposing them to detect entropic gravity would take time, but it is possible.

Carney and his colleagues are already devising an experiment consisting of a weight on a twisting pendulum next to a cloud of atoms in a quantum state. As the weight moves to and fro, traditional gravity would generate well-behaved changes in the cloud's quantum state. But if there are any random jiggles due to entropic effects, they should be detectable. All this seems interesting, says Remmen, "especially that they find an experimental signature". He points out, however, that Carney's work so far only recreates Newton's laws of gravitation, not the more advanced nuances of general relativity.

For his part, Verlinde would have preferred the model to include holography, which he believes is necessary for a truly emergent gravity picture. But he calls it a "really nice" development and cherishes the possibility of experiments. "Theorists as well as experimentalists need inspiration," he says. "They need to talk to each other – and that's where this paper is really useful. Dan connects these two worlds."

Meanwhile, other physicists are discovering the attraction of entropic gravity. Returning to Verlinde's original paper as inspiration, Kazem Rezazadeh at the Institute for Research in Fundamental Sciences in Iran wanted to refine the description of the entities on the two-dimensional holographic screen that generates gravity through rising disorder. In thermodynamics, it is known that entropy doesn't always scale in exact proportion to the energy of the microscopic components in a system. This year, applying suitable corrections to Verlinde's entropy equations, Rezazadeh found that entropic gravity over the largest scales in the universe ought to result in an accelerated expansion of space-time – an observed phenomenon cosmologists have been at a loss to explain for nearly three decades, referring to it as some vague dark energy.

"One of the biggest mysteries in physics could be nothing more than a mirage"

Amazingly, Rezazadeh's approach matches the observations that signify dark energy better than our leading description of the universe – the standard cosmological model – does. Once again, an entropic view of gravity has suggested that another great mystery of physics could be nothing more than a mirage. It is a great result, but "we need to wait for more precise observational data to be able to comment more definitively on its acceptability", says Rezazadeh.

There remains the greater question of what entropic gravity really means. No one can confidently identify the disorderly microscopic entities that supposedly produce our sensation of gravity, nor explain whether their world – their spaceless, two-dimensional screen – is truly more real than ours. But for some physicists, the question isn't so pressing. If one adopts the view that everything ultimately consists of information, then debates over what that information belongs to are more or less irrelevant. Verlinde himself believes this is fitting for our era. We use the language of information now, he says, "because that's the technological age we live in".

That might seem an oddly sociological view for a theoretical physicist, but perhaps it was ever thus. Carney says that Einstein was obsessed by relativity partly because of a problem widespread in his day: that of synchronising train times between distant cities. "We're all trying to find answers in the language of the world we find ourselves in," he says. ▮

NASA, ESA, CSA, KRISTEN MCQUINN (STSCI)

Entropic gravity could explain the large-scale behaviour of the universe

Jon Cartwright is a freelance science writer based in Bristol, UK

Wonder women

Astonishing new discoveries mean we need to rethink the power of the patriarchy, finds **Laura Spinney**

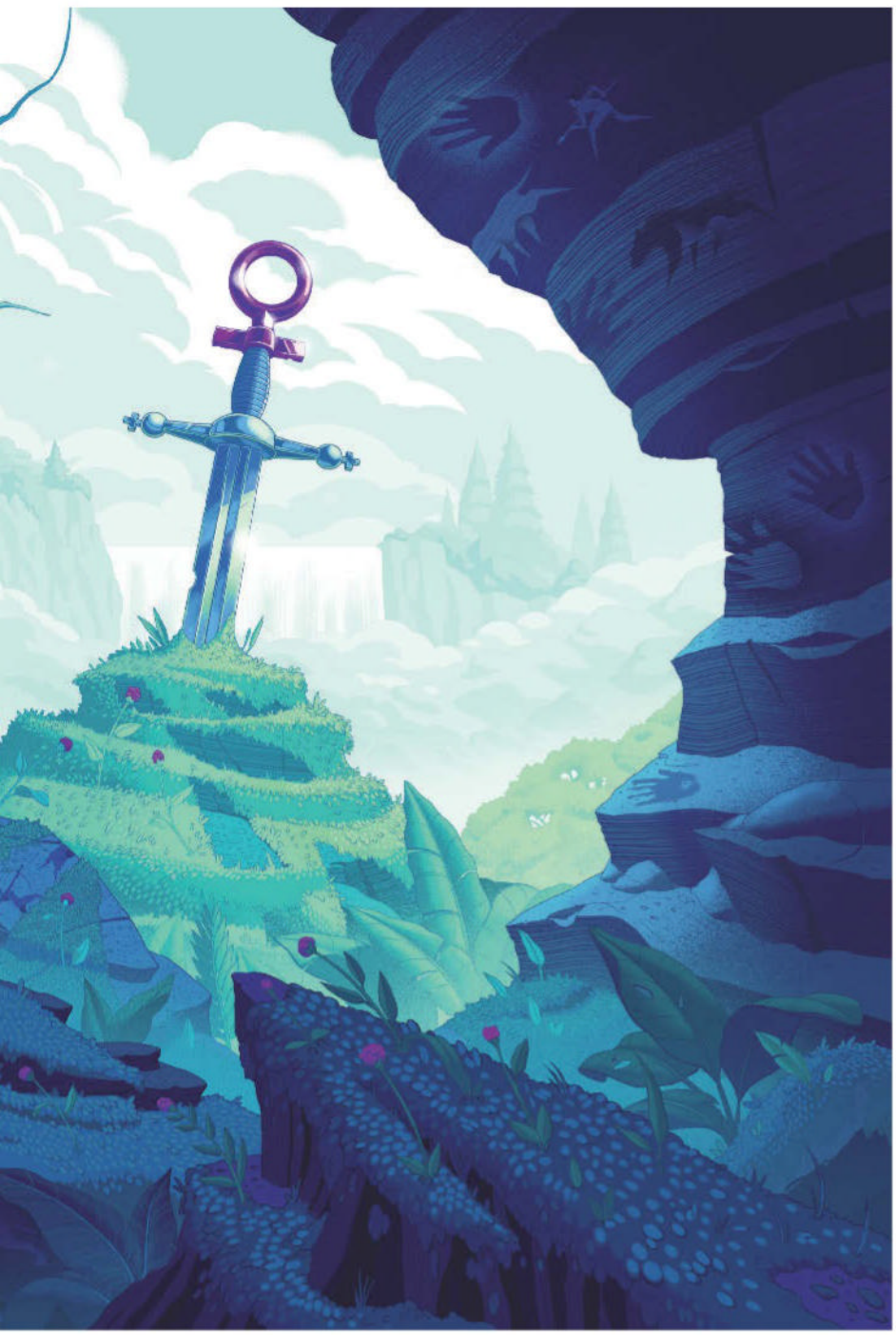
JAY GORDON

THE young man, no older than 25, had gone to the afterlife with an opulent assortment of grave goods, including an entire elephant tusk. Archaeologists who excavated his 5000-year-old remains in 2008 from a site near Seville, Spain, dubbed him the "Ivory Man" and suggested that he might have been the most important person on the Iberian peninsula in his lifetime. So it came as a shock when, 13 years later, analysis of proteins in his tooth enamel revealed that he wasn't male at all. The Ivory Man was, in fact, the "Ivory Lady".

Perhaps this re-sexing shouldn't have come as such a surprise. Of late, the ability to probe ancient biological remains has led to the discovery of prehistoric women in all sorts of unexpected places. It turns out they have occupied roles and positions that would have confounded 20th-century researchers. Whether in the form of Stone Age women spearing bison, Neolithic ones controlling the allocation of land, or the sensational case of a Viking warrior who, like the Ivory Lady, was belatedly identified as female, the new evidence is rocking our understanding of how ancient societies viewed gender roles.

Nobody is suggesting that women and men were treated as equals in the ancient world, much less that it was a feminist paradise. Indeed, man-centred societies were probably the norm. But enough exceptions have come to light to suggest a breathtaking variety of social organisation. "There's no one idea of womanhood or masculinity," says archaeologist Rachel Pope at the University of Liverpool, UK. "Instead, there's real variation in social norms across time and space." Finally, we are unearthing prehistory's powerful women.

Despite huge leaps in equality over the past century, today's societies are still largely patriarchal. Archaeologists have long been taught that this status quo got its foothold when farming became widespread, starting around 10,000 years ago. Hunter-gatherer groups are generally seen as egalitarian, albeit with men and women doing different types of work. But, the idea goes, as societies became more sedentary and began generating wealth in the form of surplus food, people started to attach importance to inheritance, and rules were established for transferring wealth from fathers to sons. With wealth came male power and female oppression. Or so argued Karl Marx's collaborator, the political theorist



“The concept of gender emerged in the Stone Age with symbolic thinking”

Friedrich Engels, in the late 1800s. “That model supported a particular political system and was based on no archaeological evidence,” says Penny Bickle at the University of York, UK.

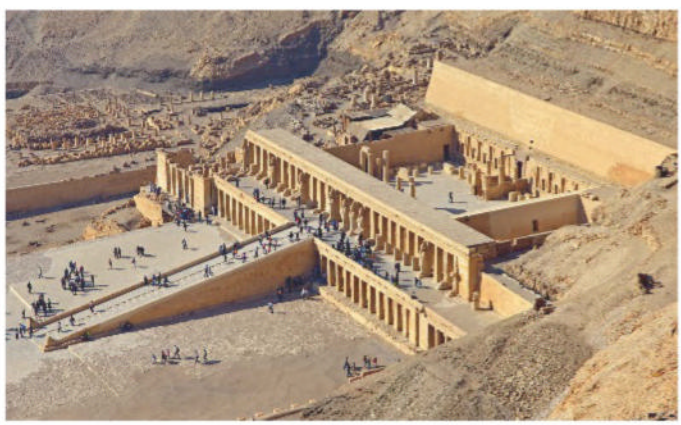
A rival idea, put forward in the 1960s by Lithuanian archaeologist Marija Gimbutas, suggested that Europe’s oldest farming societies were woman-centric and thrived until 5000 years ago, when herders arrived from the steppes and imposed their patriarchal world view. It has, however, proved equally unfounded. These grand narratives, which invoke a single inflection point, no longer fit the data, says Bickle. The advent of new archaeological tools – notably the ability to analyse not only ancient DNA (aDNA), but also proteins and isotopes, or variants of elements consumed as food – reveal both ideas to be overly simplistic. “We shouldn’t be writing origin stories like these,” she says. Instead, what’s emerging is a more complex picture, showing how economic and historical context powerfully shaped the way men and women lived – and that societies were capable of flipping from one system to another within centuries, if conditions changed.

Analysis of these societies also highlights the distinction between biological sex, including the ability to bear children, and gender, referring to our habit of assigning people distinct cultural attributes based on their sex. Archaeologist Jennifer French at the University of Liverpool thinks that the concept of gender emerged with symbolic thinking, and that early Stone Age art and burial rites suggest the first modern humans were familiar with it, as were Neanderthals. Despite this, some researchers prefer to talk about “males” and “females” in that period, rather than “men” and “women”. “To me, it seems a little dehumanising,” she says.

Nevertheless, the early Stone Age is largely a black box when it comes to gender roles. “Sexed burials with accompanying material culture, and iconographic artefacts, are either absent or rare,” says French. The tiny glimpses that archaeology and aDNA have afforded, combined with ethnographic evidence from modern or historical hunter-gatherer societies, hint that patrilocality and female exogamy were the norm. In other words, couples moved to live with the man’s family. However, because these groups tended to be small, they probably had to be adaptable, so matrilocal societies, where women stayed with their kin, may also sometimes have emerged.

Matrilocal societies tend to give women greater participation in communal life, says anthropologist Carol Ember at Yale ›

MICHAEL SVETBIRD/ALAMY



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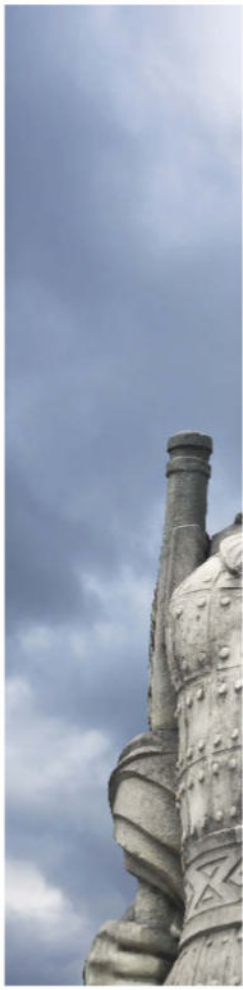


IMAGINECHINA LIMITED/ALAMY

Female Scythian warriors (left) weren't mere mythology; Hatshepsut's temple (below) reveals her as a powerful leader

University, probably because, with family around, women are less likely to be defined exclusively as wives and mothers. This is especially true if resources – importantly, land – pass through the female line. And this matrilineal system of inheritance often goes together with matrilocality. According to a hypothesis developed by Ember and her husband Melvin Ember, who was also an anthropologist, matrilocality is most likely to emerge when women are the main workers in a subsistence economy – making it preferable that daughters stay at home – and when there is no threat of war, so families have no need to keep their sons close to help defend the household. This suggests that matrilocality would have been the exception in prehistory, because intergroup violence was so common. But there are other factors favouring women-centred societies, including situations where the paternity of children is uncertain and where groups have a history of migration.

That covers the theory. On the ground, studying gender in prehistoric remains is complicated by the fact that how people were placed in burials may not reflect how they lived. Stable isotope analysis can help, by showing – through the detection of dietary changes – whether people died in the same place where they grew up. Genetics can help too, by revealing biological links among groups over generations and regions. Even then, interpreting the evidence can be tricky. Power maps onto patterns of post-marital residence and inheritance in different ways. Trickier still, says Pope, is that "there isn't a demonstrable link between grave wealth and power".

Grave goods for women

A case in point is the early farming community that inhabited the 9000-year-old site of Çatalhöyük in modern Turkey. Archaeologists consider this group to have been egalitarian, in that men and women had similar diets and did similar kinds of work. But, in a new genetic study, Eren Yüncü at the Middle East Technical University in Ankara and her colleagues show that the society was matrilocal and that young women were accorded more lavish grave goods than men. This doesn't necessarily mean that women pulled the strings at Çatalhöyük, however. "Grave goods often express the lost reproductive potential when young women die," says archaeologist Katharina Rebay-Salisbury at the University of Vienna, Austria.

Exceptional though they have been, matrilocal or matrilineal societies have now been documented on every inhabited continent in the ancient world. The first humans to reach the remote islands of Oceania, around 3000 years ago, were matrilocal, according to a 2022 study led by geneticist Yue-Chen Liu at Harvard University. The earliest farming societies in Thailand probably were, too. And in 2017, geneticists detected a high-status matrilineal group that persisted for more than 300 years in Chaco Canyon, New Mexico – an important ritual and political centre in North America around the 10th century – whose modern descendants include the matrilineal Zuni and Hopi peoples.

"In general, women have exerted their power differently from men"

But there is a paradox. "In the matrilocal, matrilineal societies that we have studied in the recent anthropological record, women were never political leaders," says Ember. They had higher status and more influence than women in patrilocal, patrilineal societies, but they didn't make the decisions. That was typically the preserve of their brothers, who were often more heavily invested in their sisters' children than in their own. This prompts the question of what we mean by power. There are famous cases of women who took on the trappings of masculine-coded hard power, with an emphasis on physical strength and domination. The Egyptian pharaoh Hatshepsut, who reigned in the 15th century BC, sported kingly regalia, commissioned monuments and initiated at least one military campaign. The Mayan ruler Lady K'awiil Ajaw of Cobá presided over a formidable group of warriors and statesmen in the 7th century and built a 100-kilometre road to display her authority. In general, though, women have exerted their power differently from men.

This is highlighted in a study by political anthropologist Paula Sabloff at the Santa Fe Institute in New Mexico, who compared the roles of royal women across eight pre-modern states. The women included queens who had acted as regents, such as Lady Fu Hao in China's Shang dynasty more than 3000 years ago, and spouses who had deputised for their royal husbands, like the wives of Zimri-Lim, who led the Mari in what is now eastern Syria in the 18th century BC. The states spanned five continents and more than 4000 years and had different cultural norms regarding inheritance, post-marital residence and female rulers themselves. Yet, Sabloff found that in all eight, women wielded power in the same ways: by influencing policy; influencing the actions of those above and below them in rank; acting as go-betweens; and patronising clients.

BOURNEMOUTH UNIVERSITY

Durotrigian graves (above) reveal a matrilocal society; Lady Fu Hao (left) exerted soft power

"That's real power, too," says Rebay-Salisbury.

Understanding this female propensity for soft power lends a different hue to some recent findings from prehistory. For instance, a man and woman found together in a grave in southern Spain, along with 30 precious metal and gemstone artefacts, are among several examples of couples who seem to have ruled jointly in the Bronze Age. They may have had equal status, while using different leadership skills. Or consider two kings who ruled over the Celtic Hallstatt culture of south-west Germany around 2500 years ago. Their graves are among the richest burials in European prehistory. A recent aDNA analysis reveals that they were probably a nephew and his maternal uncle, indicating that a woman linked them.

Hard power, soft power

But not all female power was so indirect, as new findings about another Celtic tribe make clear. The study, by geneticist Lara Cassidy at Trinity College Dublin in Ireland and her colleagues, looked at the Durotriges, who inhabited southern Britain two millennia ago – around the time that the Romans invaded. The genomic analysis of 57 individuals showed that the society was matrilocal and matrilineal, with men joining the group from outside, and that Durotrigian women went to the afterlife with more grave wealth than their male counterparts. Add to this evidence that they took up arms against the Romans and the assertion, by Roman chroniclers, that the Celtic women of Britain were fierce and liberated – most famously Boudica, who led the Iceni tribe in a revolt against the Roman invaders – and there seems little doubt that the Durotriges themselves recognised female power.

The line between male and female power isn't always clear-cut, though. Also around two millennia ago, an individual was buried on one of the Scilly Isles off the south-west coast of Britain with a mirror and a sword. "Up to the Roman period, we only find mirrors in graves that we are comfortable saying were female," says Pope. "We would tend to find swords in male graves." The combination of the two intrigued archaeologists when they discovered the grave in 1999, but they had to wait almost a quarter of a century for aDNA analysis to show that the individual was biologically female. If her grave goods reflected her role in life, a team led by osteoarchaeologist Simon Mays of Historic England concluded, she may have been a high-ranking woman who participated in active combat.

She and the Durotriges wouldn't have been the first warrior women. There are graves of indisputably female fighters in what is now Armenia, south of the Caucasus, dating from 3000 years ago. On the steppes of Ukraine, Iron Age burials identified as Scythian include a woman interred with gold and silver treasure, arrows and her horse – hinting that the Amazons may not have been entirely mythical. Likewise, the Valkyries of Norse mythology find echoes in evidence of Viking women who charged into battle – notably the individual found in a grave at Birka, Sweden, along with weapons including a sword, axe, spear and battle knife, as well as two horses. Assumed for over a century to be a man, geneticists reassigned her in 2017.

As the discoveries stack up, researchers have been asking what other roles, usually attributed to men, might have been performed by women in the past – and finding that there was really no limit. In the earliest Mexican farming villages, women oversaw ceremonies involving communication with ancestors. The so-called Siberian Ice Maiden, whose tattooed body was buried in the Altai mountains of Central Asia around 2500 years ago, is thought to have been a high-ranking spiritual leader – a shaman. And women also performed shamanic rituals in pre-farming Europe.

Other prehistoric women overturned the long-held trope of "man the hunter, woman the gatherer". One buried with hunting implements points to the presence of female big-game hunters in the Americas 9000 years ago. Millennia later, Indigenous women acted as trackers and guides to the first European fur traders in North America. Indeed, Sarah Lacy at the University of Delaware and Cara Ocobock at the University of Notre Dame, Indiana, make the case that women hunted throughout the Palaeolithic. In some ways, they say – notably a metabolism built for endurance – they were better adapted to the task than men.

Bringing all the evidence together, it is becoming clear that few roles have been off-limits to all women for all time. As new tools make fine-grained analysis possible, researchers expect more diversity to come to light. "I think it's going to be blown wide open in the next few years," says Cassidy. ▮

Laura Spinney is a writer based in Paris, France. Her latest book, *Proto: How one ancient language went global*, is out now

The back pages

Mathematics of life

A creative curve

What have holey cards and a ball of string got to do with geometry? Let's make "string art" and find out, says **Peter Rowlett**

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

WHEN she was young, Mary Everest Boole found some cards with evenly spaced holes around the edges. She laced a thread from each hole to the one opposite, covering the card with lines that crossed in the middle. When she tried connecting each hole to one not exactly opposite, she was delighted to find the threads left a symmetric curve in the middle of the card. She felt this activity gave her an intuition that helped her learn formal geometry.

Years later, in 1864, she was widowed with five children. Even though the academic system didn't value the contributions of women, she worked as a librarian and maths tutor in London.

Boole thought children should be given mathematical objects, such as her curve-stitching activities, to play with to help them develop their understanding. She linked mathematical imagination and creativity in other ways, including explaining logic and algebra using fable and history.

Now you can play, too, by making a "string art" image inspired by her work, in which you draw lines instead of threading them. Draw a pair of horizontal and vertical axes 10 centimetres long, marking the numbers 1 to 10 on each line, 1 cm apart. Now draw a straight line from point 1 on the horizontal axis to point 10 on the vertical. Then connect 2 to 9, 3 to 8, and so on. Even though each line is straight, a curve should start to appear, as the straight lines are all tangent to the curve.

PETER ROWLETT

You may have used drawing software, where the shape of a path can be controlled by setting its two end points and a third point that controls how much it bends. These are Bézier curves, now used widely in computer-aided design. They are related to Boole's early stitched curve, with the curve fixed by the end of the axes and the point where they cross.

After some practice, you should be able to draw the lines without numbering the marks – and try using different colours for them. She recommended it as a stitching exercise rather than a drawing one, especially for young children, because it is easier to stitch a straight line than to draw one. You can use thread: just replace dots with holes.

As with any mathematical concept, this idea is open to exploration. You could, say, change a pair of axes that meet at a right angle into a pair of lines that meet at more or less than 90 degrees. Or you could find out what happens if the gap between the dots is 1 cm on one line and 2 cm on the other.

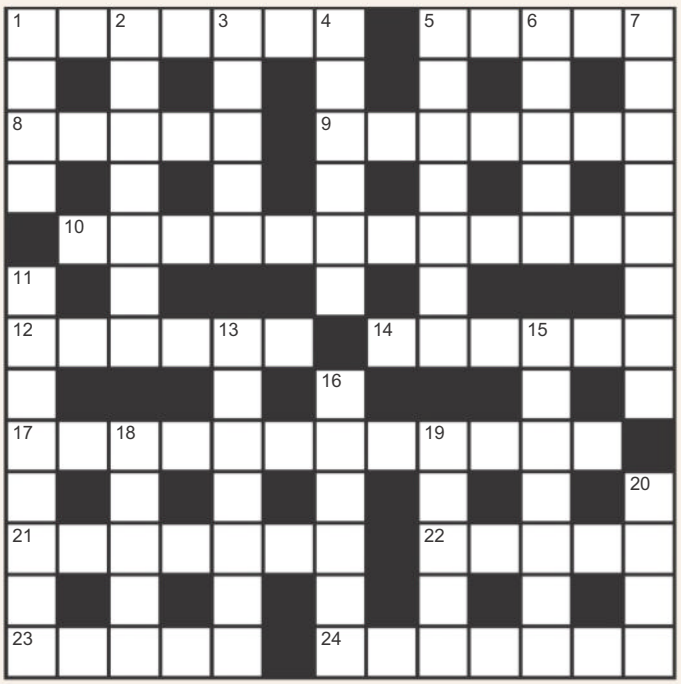
Perhaps draw a circle or another shape and place dots equidistant around it, then connect each dot to another in a systematic way – for example, connect every dot to the one 10 dots around, clockwise. You might also like to work out how to create pictures like the boat in the photo above (middle, right). What else can you create? ▮

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

Mathematics of life appears monthly

Next week
Debunking gardening myths

Cryptic crossword #167 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Badly mispronounce French endearment following objection (7)
5 Craft supply's back-ordered (5)
8 Approach either side of that celestial object (5)
9 Active dawn to dusk, having two large coffee-makers? (7)
10 Reset or return MRI disrupted by irrational problem with program (7,5)
12 Measure mid-sized crystal (6)
14 Fine-tune sales pitch prior to fair (6)
17 Eccentric non-scientist is unpredictable (12)
21 Open to having kind person's hybrid (7)
22 Dry funny man Idle, for one, pursues kiss (5)
23 Trash gown, having nothing to replace bit of embroidery (5)
24 Shut up inside very hot food-industry facility (7)

DOWN

1 Oppose infant climbing on rear of shack (4)
2 Prepared upmarket, potassium-free Japanese dish (7)
3 Start playing Little Bird after opener (3,2)
4 Tracker's housing a daughter in Italian capital (6)
5 Fried auditor's sought aid (7)
6 Proprietor put work into reversing building's makeover (5)
7 Whimsical topiary conceals terminally awful condition of a field (8)
11 Jetted country gent around central Vietnam by day (8)
13 I. Stern agitated about 1000 fiddles (7)
15 Upset runner veers for a stretch (7)
16 Steal jazz line, overwhelming quiet band (3,3)
18 Enormous vulture left unfinished home (5)
19 Rubber erasing first two extremely tactless messages (5)
20 Sore about customers harassing you for starters (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #313
set by Corryn Wetzel

1 The venom of which animal was key to developing GLP-1 medications such as Ozempic?

2 Which IBM computer defeated Garry Kasparov in chess in 1997?

3 What is the chemical formula for methane?

4 What is the term for the point in a planet's orbit when it is closest to the sun?

5 What is the approximate lifespan of a human red blood cell?

Answers on page 47

BrainTwister
set by Alison Kiddle
#84 Wild ones

Using addition and multiplication, and brackets, we can repeatedly use 1 to make the number 12: (1 + 1) × (1 + 1 + 1 + 1 + 1 + 1). This uses eight 1s.

Can you find a way to make the number 12 using fewer than eight 1s?

What is the largest number you can make using exactly nine 1s?

What is the smallest number of 1s you need to make the number 51?

Solution next week

Cleaning up

When I open my dishwasher, everything is dry except the plastic items, which remain covered with water droplets. Why is this?

David Jackson
Gosport, Hampshire, UK
When my dishwasher has finished washing and starts the drying cycle, there are two ways the water removes itself from the items: first, it simply runs off, and second, it evaporates.

There is a difference in the rate at which water runs off various items due to their surface properties, with water tending to adhere less strongly to glass (including the glazed surfaces of ceramics) and metals than it does to plastics.

As for evaporation, the final rinse of my dishwasher leaves the items very hot and then pauses for a while in the drying cycle. During this pause, the plastics experience less evaporation than the non-plastics, which hold a lot more heat energy due to their higher thermal mass.

Rinse aid is an additive that helps a lot with drying; it lowers the water surface tension so it runs off more easily, and it is also very effective if you open the machine after the final rinse and shake the water off the plastics before resuming drying. I also tip up my casserole pan and empty the water out of the hollow handles, being careful not to burn myself on the hot metal.

"Due to differing surface properties, water tends to adhere less strongly to glass and metals than it does to plastics"

David Muir
Edinburgh, UK
My dishwasher finishes its cycle with a hot rinse, which heats the dishes to help the water evaporate when the dishwasher is opened. As this rinse lasts about 5 minutes, all of the dishes will be about the same temperature (roughly 65°C or 149°F).

Two things are obvious if you open the dishwasher as soon as the cycle is completed. Metal and ceramic (including glass) tableware is very hot to the touch and plastic items feel hardly warm at all, despite being at the same temperature. The metal and ceramic dishes show little evidence of water drops, but the plastic is covered with beads of water.

Metal and ceramic surfaces are relatively attractive to water molecules, so water easily forms a thin layer over these surfaces. Plastic is non-polar, so it is unattractive to water molecules, causing them to prefer to cling to each other, forming droplets.

A material's ability to transfer heat is called its thermal conductivity. Metals have a higher thermal conductivity than plastics. The dishes that feel hot when the dishwasher is opened are very efficient at transferring heat to your fingertips, whereas plastics are not, so plastics keep their heat to themselves. This is why Styrofoam cups keep your coffee hot on the inside but don't burn your fingers on the outside.

It may sound like sacrilege, but if you drink beer from a plastic "glass" on a hot day, it will stay cold for longer. Or maybe you should just drink it straight from the bottle or can as soon as you get it from the fridge.

ROMAN LACHEEV/ALAMY

This week's new questions

Sight unseen **Is short-sightedness found in other animals? Did it affect ancient humans too?** ***Simon Pearce****, Bromley Cross, Lancashire, UK*

Space slam **Could a massive asteroid that hit Mars or the moon affect Earth? How big would it need to be, and what would happen?** ***John Rymell****, London, UK*

Can other animals be short-sighted?

To the left

Why is our heart not in the centre of our body?

Mike Follows
Sutton Coldfield, West Midlands, UK
The heart is well-placed in the upper torso to serve the major organs, which are arranged like satellites around it. It isn't displaced as far to the left as some people might imagine. However, it is rotated and twisted in that direction, resulting in the right ventricle forming most of the frontal view. The apex of the heart extends as far as a vertical line dropped from the midpoint of the left collarbone. These asymmetries form incredibly early during embryonic development.

The heart begins as a straight, midline tube comprised of segments that will form the atria, ventricles and more. This tube quadruples in length in under 24 hours when the embryo is a few weeks old. Since both ends remain fixed – at the arterial and venous poles – the tube cannot grow in a straight line. Instead, it buckles into a helical s-shape. This deformation is guided by asymmetric signalling pathways that are more active on one side of the embryo than the other. This looping is essential for correct chamber alignment, and errors in the process can cause congenital heart issues.

The looping significantly enhances the pumping efficiency of the valveless embryonic heart. Physical models show that a looped tube generates higher pressures and flow rates than a straight one. In other words, the heart loops to pump more effectively – a trait observed throughout chordates, the group of organisms that includes birds, mammals, fish, amphibians and reptiles – and so probably arose early in vertebrate evolution.

This adaptation can be

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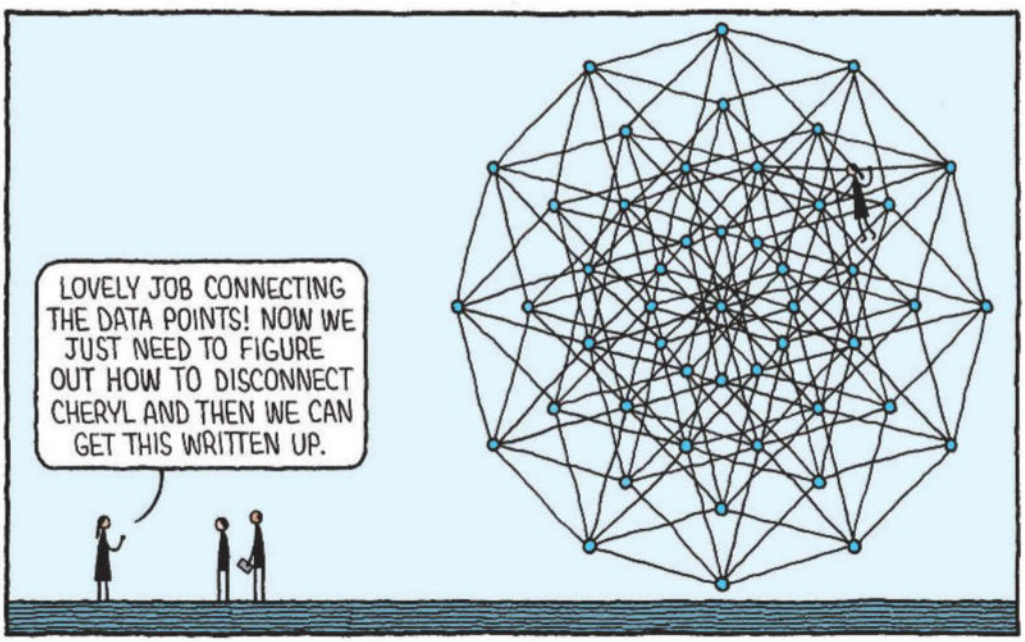
Tom Gauld
for New Scientist



compared to packing a hose into a suitcase: looping it neatly allows it to fit and function efficiently. Similarly, the internal components of a car engine are arranged asymmetrically to maximise performance and space, even if the exterior appears symmetrical. Only after this basic, efficient pump is established do further evolutionary developments arise. While chambers and other features add complexity, the primary purpose of looping appears to be biomechanical, ensuring effective pumping and compact organisation from the earliest stages of development.

Chris Daniel
Glan Conwy, Conwy, UK

The heart's position in the chest is high relative to the whole body, but quite central relative to the head and trunk, allowing efficient perfusion of the vital organs and extremities. The heart lies essentially in the middle of the thoracic cavity and is asymmetric in shape, being dominated by

"This adaptation is a bit like packing a hose into a suitcase: looping it neatly allows it to fit and function efficiently"

the powerful left ventricle that pumps blood around the whole body, which means that about two-thirds of the heart lies to the left of the body's midline. The location of the heart in the body is primarily determined by its close relationship with the lungs, which it nestles between. This means that oxygenated blood from the lungs only has a short distance to travel to the left atrium of the heart, and from there into the left ventricle to be pumped around the body with each heartbeat. The heart, being a muscle, also has first call on the oxygen that it needs to function, which is supplied via its cardiac arteries. As with the lungs, it is protected by the rib cage from everyday external trauma.

The pulse pressure – the difference between systolic and diastolic pressure – will be experienced in a similar way throughout the body. However, hydrostatic blood pressure varies, being proportional to the vertical distance from the heart, so the pressure at the ankles will typically be higher than it is at the head. For this reason, mechanisms are necessary to regulate blood flow both above and below the level of the heart. For example, pressure receptors, also known as baroreceptors, in the arteries close to the heart will detect falling blood pressure to the head, as can happen when you go from sitting to standing, and send signals to increase the rate or strength of heart contractions to restore the pressure. Veins in the legs have valves to ensure that blood continues to return to the heart and doesn't excessively pool in the feet and ankles under gravity. Muscle contractions in the legs also gently squeeze the veins, supplementing the circulation powered by the heart. ▮

Answers

Quick quiz #313 *Answers*

1 Gila monster (*Heloderma suspectum*)
2 Deep Blue
3 CH_4
4 Perihelion
5 120 days

Quick crossword #188 *Answers*

ACROSS 1 Mandelbrot set, **8** Blog, **9** Time travel, **10** Proton, **11** Tungsten, **12** Tarantula, **14** Body, **15** Path, **16** Gigahertz, **20** Matrices, **21** Arcsin, **23** Metallurgy, **24** Opal, **25** Super-spreader

DOWN 1 Malaria, **2** Night, **3** Extinct, **4** Bimetallic strip, **5** Octane, **6** Soapstone, **7** Thereby, **13** Afterdamp, **15** Planets, **17** Analyse, **18** Thin air, **19** Scalar, **22** Cloud

#83 Doubled squares *Solution*

There are many numbers that fit the bill. For instance, 289 is 17^2 and 1 more than 2×12^2.

A four-digit example is 9801, which is 99^2 and 1 more than 2×70^2.

The smallest pair of these squares where each has a different number of digits is 11,309,769 (3363^2, eight digits) and 5,654,884 (2378^2, seven digits).

Numbers n such that $n^2 = 2m^2 + 1$ form a sequence where each value is six times the previous value, minus the value before that. The sequence starts 1, 3, 17, 99...

Rings of power

Feedback is often on the lookout for a nice gift for Mrs Feedback, a task made significantly trickier by her pesky habit of pre-ordering books before we even realise they exist.

So we were briefly intrigued to learn about something called "smart jewellery". Basically, imagine wearable technology like a Fitbit or Apple Watch that can monitor your heart rate and so forth, but instead of looking like a bit of tech, it is integrated into luxury jewellery.

A recent *South China Morning Post* headline explains that "Gucci, Hermès, Tag Heuer, Vertu and other brands are combining Silicon Valley's wearable tech with exquisite European craftsmanship". For example, we could get a shiny new Gucci × Ōura Ring, which integrates "Gucci's instantly recognisable interlocking G motif" with health-tracking technology that can "discreetly monitor sleep, heart rate, temperature and activity, among other metrics". Or rather, we can't: it was a limited edition. Second-hand ones on eBay start from £390 and escalate from there.

Feedback can think of at least one way this could go wrong. As a Bluesky user who goes by Zack Pizzaz pointed out, a wedding ring that monitors its users' every emotion and movement could be the premise for a dystopian science fiction novel. It certainly sounds like the sort of thing Margaret Atwood would come up with. But surely, no business is proposing that people give their partner a smart ring and then monitor their every move?

Oh wait, our mistake, someone is proposing exactly that. Depending on your relationship status, you may or may not be aware of the dating app RAW. It requires users to submit only unfiltered photos of themselves, apparently to counter practices like catfishing. Which, OK, fine, whatever, but the company is launching a spin-off product called the RAW Ring. It is "AI powered" with "heart rate & temperature sensors" – and "voice tracking".

According to co-founder Marina Anderson, the ring is "like a bestie on a finger – keeping tabs on heart beats, body heat, and interactions around your partner. When something's up, you'll know. Simple as that". A profile of her in *The Verge* reported that she believed such emotional surveillance could deepen relationships.

Or as the RAW Ring website proudly proclaims: "Marriage evolves, and so does loyalty. Sacred vows go digital. RAW's mission? Making true love trackable."

We mentioned all of this to Mrs Feedback, and she informed us that if we buy her any of these items, we will be facing a divorce and alimony. A book token it is, then.

Twisteddoodles *for New Scientist*

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Thinking big

Here's another headline for you, this time from UK talk radio station LBC: 'Deputy Green Party Leader admits to performing hypnotherapy to "enlarge" women's breasts in the past'. Apparently, Zack Polanski of the UK's Green party worked at a London hypnotherapy clinic in 2013, where he used hypnosis with the aim of helping women grow bigger bosoms. This was reported on by *The Sun* newspaper at the time, under the inevitable headline 'Tit-notised'. Polanski has since apologised for this stage of his career.

Setting aside the ethics of this, neuroscientist Dean Burnett was sufficiently intrigued, in the same way that drivers are fascinated by crashes, to wonder if there was any potential mechanism for it. After all, the mind and body are closely linked, to the point that our mental state can influence our immune system and gut health. And Burnett notes that "there's a condition in women known as False Pregnancy, where the patient *isn't* pregnant, but legitimately *believes* she is, and so displays the symptoms of being legitimately pregnant. Including enlarged and lactating mammaries".

If you're starting to wonder if Polanski might have been onto something, stop it now. Burnett describes that line of reasoning as "a very stark example ...of how easy it is to construct a convincing-sounding argument via very selective cherry picking of useful data". He goes on to demonstrate that hypnosis is nowhere near as powerful as it would need to be to act as a breast-enlargement tool.

Also, if hypnosis really were that effective, why wouldn't the newly embiggened breasts also start producing milk?

Heroin and chips

On the ongoing theme of spurious correlations (Feedback, 5 July), Martin Couchman flags Tyler Vigen's delightful site. At tylervigen.com/spurious-correlations, you will find a vast catalogue of correlations that don't mean anything at all. For instance, the number of UFO sightings in Rhode Island correlates beautifully with successful climbs of Mount Everest, and air pollution in Iowa City has declined in lockstep with the fall in numbers of library technicians in Iowa.

Those are pretty silly, but we can go sillier. Barry Dexter writes in to tell us of a statement he used while teaching, which made it clear to his students that correlation doesn't equal causation – "at least I think it did", he adds conscientiously. The statement: "Every heroin addict started on milk."

Finally, Dan Salmons tells us of his stint working for "a well-known credit card company" at the time when chip and PIN technology was first introduced. "I was able to show my colleagues that the volume of cards in circulation was very nicely correlated with the price[s] of potatoes and steel," says Dan. "Which of course, is exactly what you'd expect, since these are what chips and pins are made of."

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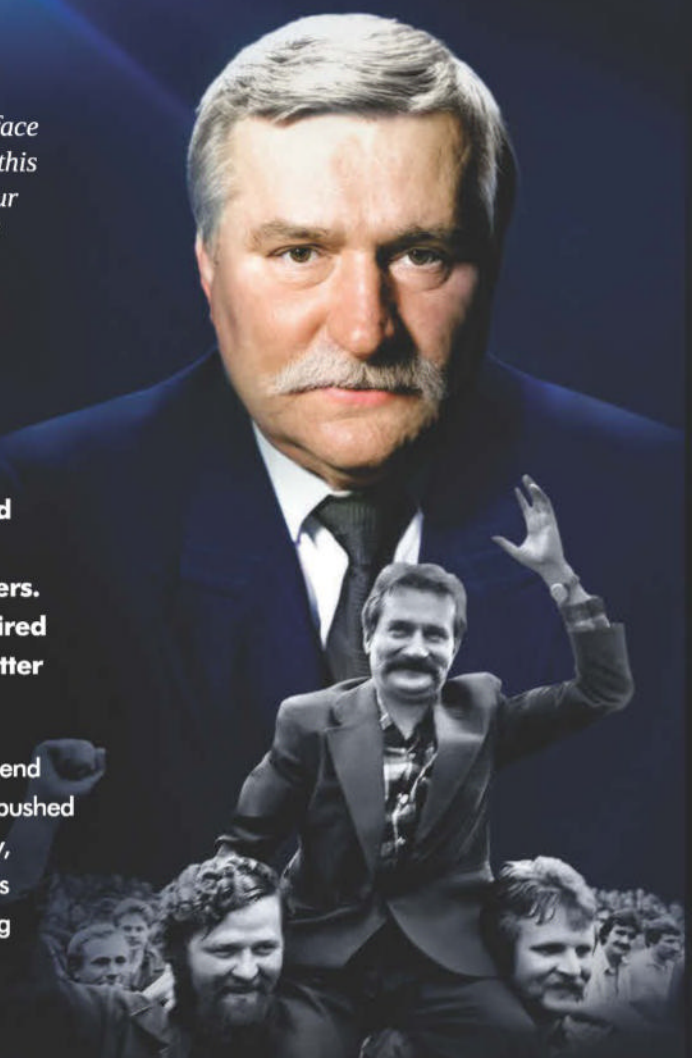

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