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WEEKLY July 15 -21, 2023

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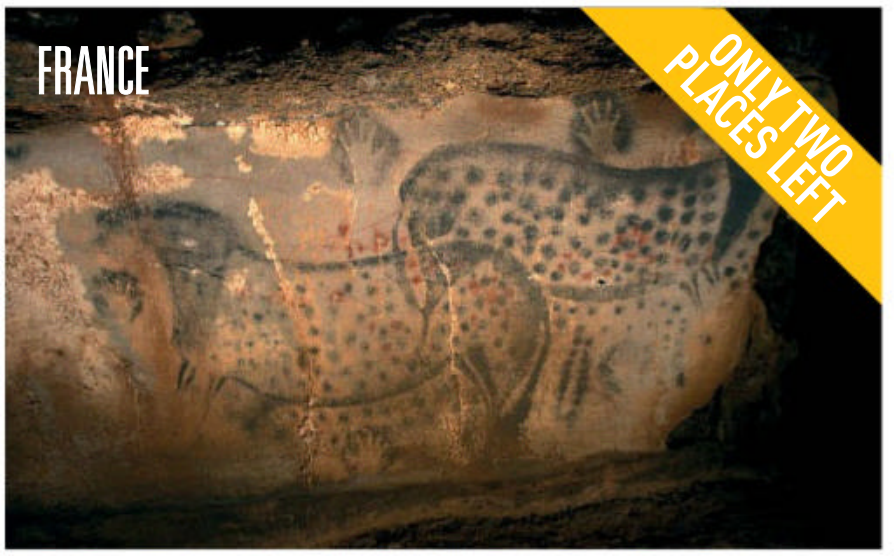

Neanderthal origins: Southern France

1 September 2023 | 10 days

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

Science of the Incas: Peru

17 September 2023 | 10 days

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Renaissance astronomy in Kepler's Prague: Czech Republic

10 September 2023 | 6 days

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

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

Learn how to be an archaeologist at Mycenae: Greece

18 September 2023 | 8 days

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New Scientist Discovery Tours

A desert adventure: Landscapes and cultures of Utah, USA

19 September 2023 | 9 days

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

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

Iron age archaeology in Talayotic Menorca: Spain

16 October 2023 | 5 days

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

The archaeological wonders of Jordan

3 October 2023 | 8 days

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

Total Solar Eclipse 2024: USA

1 April 2024 | 10 days | Albuquerque to San Antonio

3 April 2024 | 8 days | Houston to San Antonio

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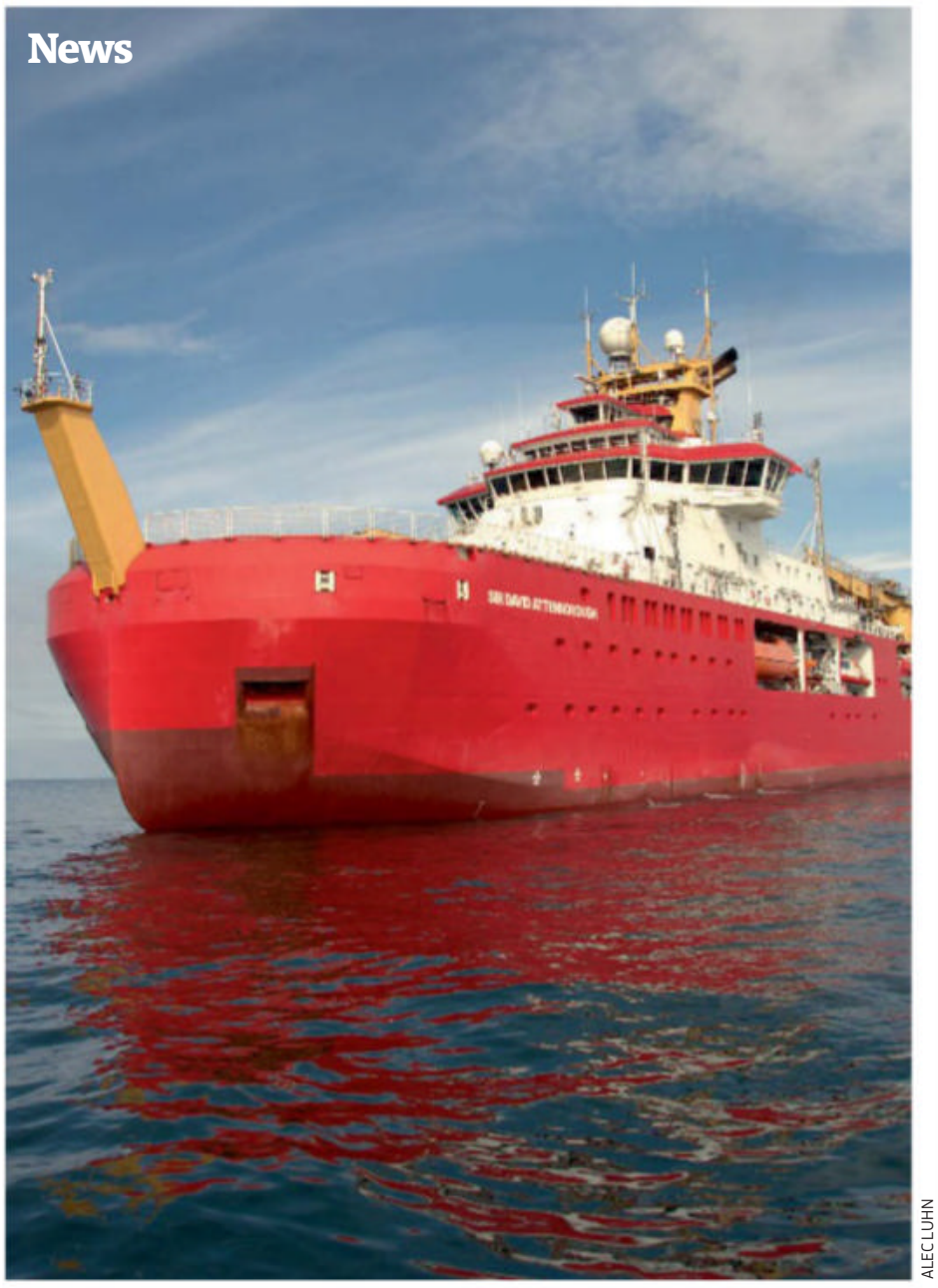

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NS Live

Towards a rational life: How thinking scientifically can help navigate today's world

The modern world is complex and unpredictable, and we stumble our way through it the best we can. At New Scientist Live on 7 October, Jim Al-Khalili will explain how to apply the scientific method to our daily lives to help us navigate the world more confidently.

newscientist.com/nslmag

Podcasts

Weekly

This week, the team are talking about how quantum technology could make self-driving cars better at navigating. They also discuss the evidence that having a higher bodyweight is less associated with early death than previously thought (see story on page 18 for more information). Plus: mind-bending physics about how we perceive time in the early universe.

newscientist.com/nspod

GABRIELLE KLEBER

Arctic emissions Groundwater springs are leaking methane

AZOOR PHOTO/ALAMY

Image of the past Explore the artwork of ancient humans in France

Video

Leaking methane

As the Arctic warms as a result of climate change, melting glaciers are exposing bubbling groundwater springs that are leaking methane. It has been estimated that these additional emissions could exceed 2000 tonnes in Svalbard over the course of a year. This under-appreciated source of potent greenhouse gas could exacerbate global warming.

youtube.com/newscientist

Newsletter

Launchpad

Last month, researchers discovered the gravitational wave background – the ripples in space-time created aeons ago that permeate the entire universe. Reporter Leah Crane explores why scientists are claiming the discovery could shake the foundations of physics.

newscientist.com/sign-up/launchpad

Podcast

"Maybe we should only start asking people to lose weight if they reach a higher BMI, of 30?"

Essential guide

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Weight watchers

Judgements around using the new weight-loss drugs are unhelpful

THESE days, any celebrity with a newly svelte figure has to face speculation about whether their secret weapon is the weight-loss drug semaglutide (also known as Wegovy or Ozempic). Gossip like this might give the impression that these injections are chiefly a cosmetic treatment, but the celebrity examples are a distraction from their intended use.

Such treatments have the potential to reverse the decades-long trend of rising obesity rates – especially as future versions look set to be more potent still (see page 32). But in some quarters of the media and the medical community, using these drugs is condemned as an unwise "quick fix" or even as cheating.

This reaction is illogical. Doctors have been wringing their hands for years about rising obesity. Unfortunately, it is very difficult for most people to lose weight and keep it off through diet and exercise alone. Now, we have a pharmaceutical aid that helps people stick to their diet.

And yet those who really need the drugs are being judged for taking them.

"Using these drugs has been condemned by some as an unwise 'quick fix' or cheating"

When a UK minister recently announced that England's health service would be expanding access to the medicines, critics said the government should instead push to change the food industry to make it easier for people to eat healthily and lose weight the natural way. The trouble is that many governments have tried a range of tactics to reverse the obesity epidemic, from clearer food labelling to bans on junk food marketing. Nothing has worked.

That isn't to say governments should stop trying. But if we ever do find an effective dietary nudge, it is likely to be only one part of the solution.

Of course, as with any new class of drug, there are unknowns and well-founded concerns. We must also be wary of their potential impact in promoting unrealistic and conformist beauty ideals.

However, turning around the obesity juggernaut will take all the tools available, so to reject the first effective one for decades would be the height of foolishness. If these new medicines do turn out to be a quick fix, doctors should be cheering. ▮

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US Newsstand **Tel** +1 973 909 5819
Distributed by Time Inc. Retail, a division of Meredith Corporation, 6 Upper Pond Road, Parsippany, NJ 07054

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Post New Scientist, PO Box 3806, Chesterfield MO 63006-9953

New Scientist ISSN 0262 4079 is published weekly except for the last week in December by New Scientist Ltd, England. New Scientist (Online) ISSN 2059 5387. New Scientist Limited, 51 Astor Place, New York NY 10003

Periodicals postage paid at New York, NY and other mailing offices. Postmaster: Send address changes to New Scientist, PO Box 3806, Chesterfield, MO 63006-9953, USA. Registered at the Post Office as a newspaper and printed in USA by Quad, 555 South 108th Street, West Allis, WI 53214-1145

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Healthy weight
Being 'overweight' isn't linked to earlier death p18

S. CORVAJA/ESA

Space flight

One last ride for workhorse rocket

This was the final flight of the Ariane 5 rocket, blasting off from the Kourou spaceport in French Guiana on 5 July. The launch vehicle has been Europe's main route to space since the late 1990s, lofting almost 250 craft across 117 launches, including the James Webb Space Telescope. Its replacement, Ariane 6, is still in development.

Climate change

A week of record-breaking heat

Unusual winds, the growing El Niño climate pattern and human-driven climate change have combined to produce extraordinary temperatures, finds **Madeleine Cuff**

WE HAVE just experienced the hottest week on record. As *New Scientist* went to press, the average global air temperature recorded 2 metres above Earth's surface for every day from 3 to 10 July was hotter than any previously seen since instrumental records began in the 1850s. Further records this month are likely.

A record high occurred on 6 July, reaching 17.23°C (63.01°F), according to preliminary data from the National Oceanic and Atmospheric Administration compiled by the University of Maine's Climate Reanalyzer. That surpassed the joint record set on 4 and 5 July of 17.18°C (62.92°F), which itself had smashed the record set on 3 July of 17.01°C (62.62°F).

Karsten Haustein at Leipzig University in Germany says the last time Earth was this warm was

"Temperature rises can either get a little bit worse than now or an awful lot worse than now"

in the Eemian interglacial period, around 120,000 years ago.

The records were confirmed by data from the European Union's climate monitoring service Copernicus and the World Meteorological Organization. Although the exact temperature varied, the trend is clear. "We are in uncharted territory," said Christopher Hewitt at the WMO, in a statement.

Prior to this record-breaking week, the next highest temperature was recorded jointly in August 2016 and July 2022, when average global air temperatures reached 16.92°C (62.46°F), according to Climate Reanalyzer.

The high global temperatures are being driven by a combination of climate change and an unusually wavy band of strong winds, known as the jet stream, high over the North Atlantic.

Piers Forster at the University of Leeds, UK, says the searing heat experienced across Canada, the US and Mexico in the past few weeks – where temperatures have soared above 46°C (115°F) in some places – is partly to blame.

Wavy weather

The persistent heatwave has been caused by an "omega" pattern in the jet stream, which is holding the hot weather in place and helping to drive record-high global air temperatures. This "wavy" jet stream pattern may be a secondary effect of climate change, says Forster, which could mean that such runs of record-breaking air temperatures could become more common in the future.

"It's very peculiar," he says. "We are certainly observing the impacts of climate change increasing the Earth's surface temperature – that is absolutely occurring and part of what's going on. But there could potentially also be the effect of secondary climate change on the circulation as well, and that is potentially quite worrisome because that would suggest we could get into these long periods of extreme heat more often."

An accelerating El Niño climate pattern, where higher temperatures in the Pacific Ocean drive warmer, more extreme weather across the world, could mean there is further record-breaking weather to come later this year, says Robert Rohde at Berkeley Earth in California. This year is "more likely than not" to be the hottest on record, he says.

Warmer than usual winter temperatures in Antarctica, which have driven record low levels of sea ice this year, will also have pushed global average temperatures higher than normal, says Haustein. That factor, coupled with the arrival of El Niño and ongoing human-caused climate change, means it is "quite obvious that you should expect a new record", he says. "It is, in fact, unavoidable."

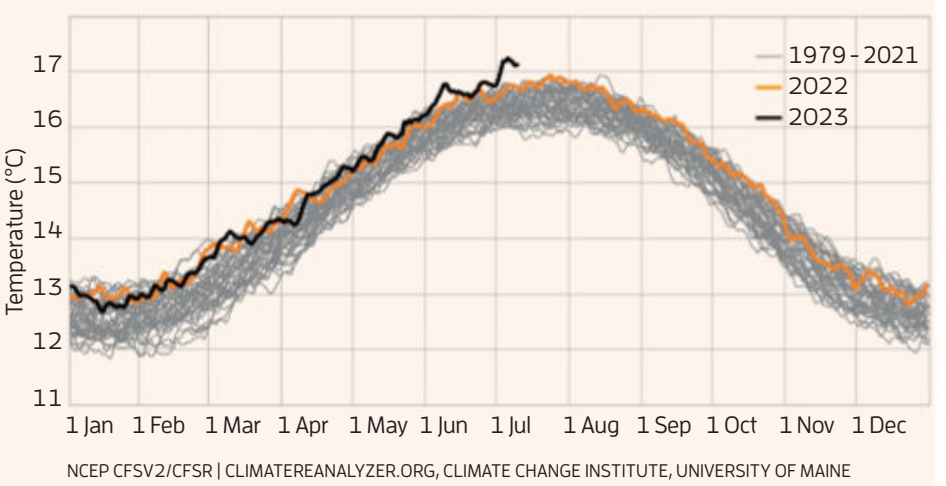
Following the end of El Niño, which is likely to be in around two years' time, global average temperatures will dip back towards normal levels, says Forster. But climate change means there will be a "continually warming baseline" to contend with. Cutting greenhouse gas emissions as far and fast as possible is the best route to minimising the occurrence of record-breaking heat in the future, he says.

"We can really change in a positive way how much temperature increase there is over the next two decades," he says. "It can either get a little bit worse than now or an awful lot worse than now." ▮

ANGEL GARCIA/BLOOMBERG VIA GETTY IMAGES

Temperatures in Seville, Spain, reached 45°C (113°F) on 5 July

Average global air temperature



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Health

Death toll of 2022's heatwaves in Europe finally pinned down

Chen Ly

MORE than 61,000 people are estimated to have died as a result of the heatwaves that swept across Europe last year. Without efforts to shield the most vulnerable, we might see a similar figure this year.

Summer 2022 was the hottest season on record in Europe, with temperatures reaching new extremes around the continent, especially in western and central regions. Europe also saw high levels of excess deaths over this time, but exactly how many were due to the heat was unclear.

"Extreme heat is one of the most deadly natural hazards," says Vikki Thompson at the Royal Netherlands Meteorological Institute, because it worsens pre-existing cardiovascular and respiratory conditions.

Joan Ballester at the Barcelona Institute for Global Health in Spain and his colleagues investigated this link by looking at the number of deaths logged by the European statistical office Eurostat for 35 European countries, along with temperature records.

The team found that between 30 May and 4 September last year, 61,672 deaths were related to heat – with the largest numbers in Italy, Spain, Germany and France. After adjusting for population size, the team found that heat-related deaths were disproportionately high in some Mediterranean nations, including Spain, Italy and Greece (*Nature Medicine*, doi.org/kjdz).

Ballester hopes this study will raise more awareness of the deadly effects of heat. With 2023 already shaping up to be one of the hottest years on record (see "A week of record-breaking heat", left), we might expect similar excess deaths this year, though Ballester declined to make a specific prediction. "Given the same vulnerability, we can expect a given number of heat-related deaths," he says. ▮

Geology

Canadian lake chosen to mark the start of the Anthropocene

GEOLOGISTS have selected a lake in Canada as the best site to mark the start of a new epoch dominated by humanity's influence on Earth, known as the Anthropocene.

The announcement marks a big development in a long-running effort to declare that we have entered a new geological epoch, although there are three more votes before the site can be formally ratified by the International Union of Geological Sciences.

Earth's current epoch, the Holocene, began when the last glacial period ended around 11,700 years ago. Human civilisation has thrived during this time, but since the middle of the 20th century, our impact on the planet has grown dramatically – a shift known as the Great Acceleration. Some scientists believe that this event heralds the beginning of a new epoch dominated by humans.

For the past few years, a team of researchers called the Anthropocene Working Group (AWG) has been trying to pinpoint the place on Earth that offers the best geological evidence for the Anthropocene.

"We looked at a very diverse array of natural environmental archives, from a coral reef in Australia to a peat bog in Poland," says Simon Turner at University College London, who is secretary of the AWG.

1950

Approximate start date proposed for the Anthropocene

At the International Congress of Stratigraphy in Lille, France, on 11 July, the group announced that Crawford Lake in Ontario, Canada, is its chosen site. The layers of sediment at the bottom of the lake, which sits in a protected area and remains undisturbed by the outside world, record precise data about the time during which they were deposited.

"Crawford Lake has this annual chronology that has a very nice record of markers that we've suggested tie into the Great Acceleration," says Turner. Sediment cores from the lake show a spike in plutonium-239, the radioactive fallout from nuclear weapons testing, dating back to the early 1950s that coincides with the surge in human activity at the time.

Other sites under consideration included Sihailongwan Lake in China and Beppu Bay in Japan. Ultimately, approval from the Indigenous community in the area and the protected status of the region clinched it for Crawford Lake, says Colin Waters at the University of Leicester, UK, who heads up the AWG.

Not everyone is convinced that the Anthropocene needs to be defined as a geological epoch. "Humans have been impacting natural environments going back about 40,000 years," says Philip Gibbard at the University of Cambridge. Instead, Gibbard and others propose that we define the Anthropocene as an event. "It's a broad term that allows us to say in parts of the world, human impacts began much earlier than they did elsewhere," he says.

Crawford Lake will be put forward in a formal proposal later this year as the reference point for the start of the epoch. As part of the proposal, the AWG will need to nail down the exact year the Anthropocene started, which will probably be between 1950 and 1953, says Francine McCarthy at Brock University, Canada, another member of the group.

"It is our hope that if the stratigraphic commission draws that line and formalises the time in Earth's history when the planet has been so impacted by humans, it will hopefully convey a sense of urgency to people to act now to look after our planet," says McCarthy. ▮ CL

Crawford Lake is in a protected area in Ontario, Canada

WILDNERDPIX/ALAMY

Animal behaviour

Sex between two males is extremely common in wild macaque monkeys

Christa Lesté-Lasserre

HOMOSEXUAL behaviour appears to be widespread among male macaque monkeys in the wild and the trait may be at least partially passed down in genes from father to son. Such behaviour may provide evolutionary advantages stemming from strong male alliances, says Vincent Savolainen at Imperial College London.

"They form bonds, and they help each other in a fight," he says. "And then the idea is that if they do this, then they might also have access to more females and, in effect, have more babies."

Occasional same-sex touching has been observed in numerous animal species, but it is generally thought to be rare. Savolainen has often questioned a popular belief known as the "Darwinian paradox of homosexuality", which implies that because homosexual behaviour doesn't lead to reproduction, it has no benefit and any genes that promote it should be eliminated by natural selection.

To investigate homosexuality in primates, Savolainen and his colleagues decided to study a colony of 1700 wild rhesus macaques (*Macaca mulatta*) on the Puerto Rican island of Cayo Santiago. The colony has been followed by scientists every day for the past 67 years and DNA-tested for paternity since 1992. In 2017, 2019 and 2020, the team observed 236 of the colony's males for 7 hours a day over 72 days.

A pair of male macaques in Cayo Santiago, Puerto Rico

C COXSHALL

The researchers found that 72 per cent of the males mounted other males, while only 46 per cent were observed mounting females (*Nature Ecology & Evolution*, doi.org/kjd2). Because they didn't want to interfere with the animals, the scientists only visually observed the animals from a distance and couldn't always see actual penetration, although they sometimes observed sperm plugs – which form after ejaculation – in the anuses of some males.

The family history of the monkeys revealed that same-sex mounting was 6.4 per cent heritable – meaning genetics may play a small role in addition to other factors, says Savolainen. The behaviour appeared to have no negative consequences on reproductive success, he adds. On the contrary, males engaging in same-sex mounting tended to have slightly more offspring.

The activity is unlikely to be simply a show of dominance, says Savolainen, since the monkeys mounted higher-ranking males nearly half the time. "They have erections sometimes; they have penetration sometimes; and they even have ejaculation sometimes," he says. "So I think it's enough to call it sex, and not dominance."

The study helps to dispel the notion that same-sex behaviour is somehow unnatural, says Jon Richardson at the University of Minnesota. "I am hopeful that we really are starting to move away from the antiquated idea that [homosexuality] in animals is an evolutionary paradox or aberration," he says. ▮

Technology

Robot skilfully injects drugs into back of the eyeball

A ROBOTIC arm that can accurately inject drugs directly into tiny veins at the rear of an eyeball could help treat a condition that causes degenerative blindness.

Retinal vein occlusion occurs when blood clots block veins in the retina. It affects more than 16 million people worldwide and can eventually lead to blindness. An experimental treatment called retinal vein cannulation (RVC) involves injecting drugs to dissolve these blockages, but it is a tricky procedure because the veins are just 60 to 120 micrometres in diameter.

"You have to insert a needle into a blood vessel that's the size of human hair, and the needle itself is even smaller than that," says Ji Woong Kim at Johns Hopkins University in Maryland. "And your hand tremor exceeds the diameter of the needle itself in amplitude."

Previous work on using robotic arms for RVC has focused on aiding the accuracy of a human surgeon, but Woong Kim and his colleagues have developed the Steady Hand Eye Robot (SHER) to perform the procedure autonomously.

The robot is controlled by an artificial intelligence that was trained on video of human surgeons and learned to spot visual cues that occur when a needle touches a vein, presses against it and eventually pierces it. When directed to a point by a human operator, SHER inserts a needle just 15 micrometres wide into the eye through a small incision in the sclera, the white outer layer, and into a vein at the back of the eye.

"You insert a needle into a blood vessel the size of human hair, and the needle itself is even smaller"

In 24 experiments performed on eyes removed from pigs, SHER was able to navigate to target veins with an accuracy of 22 micrometres in under 35 seconds and puncture them without damage – exceeding the ability of trained human surgeons (arXiv, doi.org/kh34).

Woong Kim says operating on live animals or humans is more complex, as the robot would need to accurately track micromovements from breathing, but he is confident that SHER is up to the task. ▮

Matthew Sparkes

Gravitational waves

Hunting for source of cosmic hum

A series of exotic options have been put forward to explain the discovery of low-level ripples in space-time that appear to be spread throughout the universe, reports **Alex Wilkins**

THEORETICAL physicists have leapt upon the recent discovery of a background hum of gravitational waves permeating the entire universe, with some claiming the signal could be a sign of dark matter or even shed new light on the earliest moments of existence.

"There has been a lot of excitement in the high-energy physics community," says Andrea Mitridate at the California Institute of Technology, who is part of the team that discovered the gravitational wave background. "To be honest, I have had some trouble to follow all the papers that have appeared."

On 29 June, astronomers at the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) announced they had detected low-frequency ripples in space-time across the entire universe. The leading explanation for this background hum is that it comes from the merging of colossal black holes found at the centre of many galaxies. These ripples affect every massive object, including fast-rotating neutron stars called pulsars, which act like near-perfectly timed galactic lighthouses. Astronomers can use these stars to find gravitational waves by looking for tiny timing differences they create in the pulsars' light.

The pattern of timing differences seen by NANOGrav is a very close match to the one predicted by Albert Einstein's general theory of relativity, which says the timing from pulsar pairs should become broadly less similar as the angle between them grows, but the strength of the signal also grew unexpectedly at higher frequencies of gravitational wave.

"What these pulsar timing array observations show is qualitatively consistent with what the models predicted, but not precisely with the original predictions," says John Ellis at King's College London. "That frequency dependence wasn't quite what was expected."

SAKKMESTERKE/ALAMY

Gravitational waves are ripples in space-time made by massive objects

In physical terms, it appears the supermassive black holes are producing more, or more powerful, gravitational waves as they move closer to merging, but it isn't clear why this should happen. Ellis and his colleagues have suggested that the black holes may initially be having to plough through nearby gas and stars as they begin to merge, causing them to lose energy that would otherwise have been emitted as part of the gravitational waves. But as the black holes spiral ever closer, and the frequency of the gravitational waves increases, the gas and stars have less of an effect and more energy goes into the waves (arXiv, doi.org/kh9v).

Other explanations are more exotic, like a shroud of dark matter around the merging black holes. Tom Broadhurst at the University of the Basque Country and his colleagues simulated this idea using an earlier NANOGrav data set and found a close match, but they struggled to produce the high-frequency data seen in the most recent measurements.

A further wrinkle in the data is what appears to be a small peak at the lower end of NANOGrav's frequency range, in what is otherwise a relatively smooth line. While it isn't statistically significant enough for astronomers to be certain it is real, it is unexpected, says NANOGrav team member Nihan Pol at Vanderbilt University in Tennessee. This spike could be from an unknown nearby supermassive black hole merger emitting that particular frequency, but confirming this will require at least five more years of data-gathering, says Pol.

"There has been a lot of excitement in the high-energy physics community"

But if these explanations don't bear out, theorists might need to turn towards very different sources. One possibility being looked at is cosmic strings, theorised objects that are light-years long, but with a width less than that of a proton. These strings, if they exist, would have been produced when the early universe went through a dramatic phase transition, similar to the cracks that form when water freezes into ice. Ellis and his colleagues have predicted that, when these strings collide, they should produce a gravitational wave signature detectable by groups like NANOGrav, but again the stronger signal at higher frequencies doesn't quite fit the bill (arXiv, doi.org/kh9w).

Primordial black holes – another theorised denizen of the early universe formed from clusters of subatomic matter so dense that they collapsed space-time – are also being considered as a possibility. These black holes would have produced their own unique gravitational wave signal, different from the proposed supermassive black hole mergers of today.

In simulations, Kai Schmidt-Hoberg at the German Electron Synchrotron and his colleagues found primordial black holes can only match the observed NANOGrav signal if they are distributed in clumps through the early universe, rather than found uniformly across the cosmos, but it is unclear why this would happen (arXiv, doi.org/kh9x).

There is also the possibility that several of these scenarios are true at once, but disentangling them will require new tools that have yet to begin operation. One such tool is the Laser Interferometer Space Antenna (LISA), a set of three spacecraft designed to detect higher frequencies than NANOGrav. At these frequencies, the predictions from cosmic strings and supermassive black holes are very different, says Ellis, but as LISA won't launch until the late 2030s, we could be waiting for some time. ▮

Field notes The North Sea

RRS Sir David Attenborough gears up for Antarctica

State-of-the-art equipment on the polar research ship is being tested in the North Sea before its first science voyage. **Alec Luhn** joins the crew

ON THE Antarctic research ship Sir David Attenborough, engineers are gathered around a 4-metre square opening in the hull, known as the moon pool. A white robot floats in the water, its headlights illuminating the sides of the pool.

"Now push it forward and drop it to the bottom," says Jamie Neilson, an engineering supervisor at Seatronics, the maker of this remotely operated vehicle .

With a press of a joystick, the thrusters whirr into life and the robot disappears beneath a spurt of bubbles. Its job is to scour the hull of the ship for damage or invasive species and perform tasks with its controllable arms, like installing cameras on the bottom of an Antarctic ice shelf.

This isn't Antarctica, however, but the North Sea, where the Attenborough is testing key equipment before its maiden science voyage to the Southern Ocean. Though the ship has been on the water for two seasons, bringing supplies to research bases and undergoing polar sea trials, this November it will finally start doing real research in Antarctica.

"It's much better to spend a month now testing than to go all the way down south only to find out that there's actually a critical problem, and we can't deploy our instrumentation," says Carson McAfee, the ship's electronics engineer.

These sea trials, which begin with a safety announcement recorded by David Attenborough himself, are the first time that journalists have been on this ship at sea. As it leaves the Rosyth Dockyard near Edinburgh, UK, the Attenborough's diesel engines are burning hydrotreated vegetable oil, made of leftover cooking oil and animal fat. If that is successful, the British Antarctic Survey (BAS) could decide to run the ship on this oil all the way to Antarctica, which would slash emissions by up to 95 per cent, but also double fuel costs.

£200m
Cost of the RRS Sir David Attenborough

The bright red vessel slowly navigates through a narrow lock and under three bridges. Its dynamic positioning system, a set of four thrusters that keep the ship positioned exactly on a GPS coordinate or route, is also being tested in these trials.

The Attenborough is 129 metres long, weighs 15,000 tonnes and can break through ice more than 2 metres thick. With 12 decks, 13 laboratories and even an experimental aquarium, it has as much space for research as the entire BAS headquarters in Cambridge.

Its greatest strength, however, isn't its size, but its complexity. Scientists helped design the £200-million ($258-million) vessel's state-of-the-art operational systems and research equipment. The next few months will test not only whether all that equipment works, but also whether the crew of 30 knows how to use it. In August, they will practise taking different sediment cores from the deep seafloor between Shetland and the Faroe Islands.

"Once we start to go into full-capacity science on board, which we're doing this year, we're going to learn so much more about what it can do," says laboratory manager Aisling Smith.

Some of that science will be for the BIOPOLE programme, a £9-million project to study how the cycling of nutrients from the poles to the oceans is changing. Researchers are testing a rig of 12 electronically operated nets that will help them take samples of a type of zooplankton called a copepod in Antarctica this November.

Copepods are typically no bigger than a lentil, but they are so numerous that they collectively weigh 10 times more than all humans put together. They also have a big impact on the climate. When sea ice melts in spring, it sparks a phytoplankton bloom that absorbs carbon dioxide from the atmosphere. Copepods eat these phytoplankton, then sink to the sea floor, where the carbon can remain for centuries.

In this way, the tiny creatures sequester at least 1 billion tonnes of carbon per year. The fear is that, as Antarctic sea ice retreats, fewer nutrients will be available for phytoplankton and, in turn, copepods to grow.

"It's really important that we can understand just how much carbon [copepods] are capable of drawing down to depth," says ecologist Nadine Johnston at BAS. The moon pool will play a major role in that. "Normally, when we get to the sea ice, that's where our science kind of stops," says Johnston. "But because this ship has a moon pool, once we get down into the sea ice, we can gather data in places where we've never been able to get it before." ▮

UPPER: CARSON MCAFEE; LOWER: ALEC LUHN

The RRS Sir David Attenborough (top); a submersible robot in the ship's moon pool (left); engineers guiding the robot (right)

Solar system

Radioactive mystery buried beneath the moon's surface

Leah Crane

THE far side of the moon is hiding radioactive evidence of an enormous ancient volcano, though exactly how the volcano could have formed remains a mystery.

For more than 20 years, we have known that an area on the far side of the moon called Compton–Belkovich was a bit strange. It had some odd topography, and the upper metre of soil seemed to have more thorium than its surroundings.

Now, Matt Siegler at the Planetary Science Institute in Arizona and his colleagues have used data from China's Chang'e 1 and Chang'e 2 orbiters to determine that there is an area 50 kilometres across and several kilometres thick that is unexpectedly hot. The only way to produce all this heat on the moon is through the decay of radioactive elements such as thorium and uranium, and the best way to form such a concentration of those elements is through repeated melting of the rock via volcanism (*Nature*, doi.org/gsfpgc).

"That little bit of thorium we saw at the surface is the tip of the iceberg of a huge body below the surface that was the plumbing system for this volcano," says Siegler. "It pushes the boundaries of what we know about how volcanoes form and specifically how they form on the moon."

The topography of the area suggests the volcano last erupted about 3.5 billion years ago, so all that molten rock will have cooled and solidified by now into an enormous slab of granite called a batholith. There are a few similar areas on the near side of the moon, but they aren't as large and none of them are quite as radioactive as the one at Compton-Belkovich, probably because they didn't go through as many cycles of melting and cooling – each melting cycle concentrates the radioactive elements in the resulting magma. ▮

Health

Microdosing LSD extends sleep the following night

Alice Klein

WESTEND61/GETTY IMAGES

TAKING small doses of the illegal drug LSD increases the duration a person sleeps the following night, according to the largest study of its kind. The unexpected finding may help to explain why the practice has been associated with improved mental health.

Microdosing involves regularly taking psychedelic substances like LSD or psilocybin at doses that are too small to produce hallucinations but may still boost creativity and well-being.

"We became interested in LSD microdosing because lots of people are doing it and claiming mental health benefits," says Suresh Muthukumaraswamy at the University of Auckland in New Zealand.

Microdosing may aid sleep by improving mental health

As a preliminary investigation, Muthukumaraswamy and his colleagues randomised 80 men aged 25 to 56 without mental health conditions to take a microdose (10 micrograms) of LSD or a placebo every third morning for six weeks.

The men filled out daily questionnaires about how they felt and wore Fitbits to track their physical activity and sleep. "It was very exploratory, we had no hypotheses, we just thought we'd try to measure everything we possibly could," says Muthukumaraswamy.

The LSD group reported feeling happier and more connected and creative on the days they microdosed, consistent with previous studies of people who regularly do so.

A more curious finding was that the LSD group slept for the same length of time as the placebo group when they had microdosed that day, but went to bed earlier and slept for an extra 24 minutes on average the following night, even though physical activity levels were the same between the groups (medRxiv, doi.org/kjdx).

"No one was expecting to sleep more and no one even seemed conscious of it, so it's hard to explain as a placebo effect," says Muthukumaraswamy. One explanation could be that the psychoactive effects of LSD stimulate extra processing in the brain that increase its sleep requirements the next day, but "we don't know yet", he says.

Interventions that boost sleep by more than 20 minutes are generally considered clinically relevant, meaning that they can be beneficial for people who are sleep deficient, says Sean Drummond at Monash University in Melbourne, Australia.

"But I don't get why the extra sleep happens the night afterwards," he says. "Typically, whatever we do during the day affects synaptic connections in our brain today and affects our sleep tonight."

Closer monitoring of LSD microdosers' sleep using electroencephalography, which measures the brain's electrical activity, may help to unravel the mechanisms, says Drummond.

Muthukumaraswamy believes the extra sleep gained by LSD microdosing might explain why people with depression have reported feeling better after taking up the practice, since the condition is often closely tied with sleep problems.

Later this month, his team will begin a placebo-controlled clinical trial of LSD microdosing in 110 people with depression to see if they also experience improvements in mood and sleep, and if so, whether the two are linked.

Many existing antidepressants, including selective serotonin reuptake inhibitors, cause sleep disturbances in some people, so there is a need for alternative treatments that improve sleep, says Muthukumaraswamy. ▮

24 mins

Average amount of extra sleep the night after taking a small dose of LSD

History

Englishman stole metal innovation

A crucial industrial revolution process for turning scrap metal into strong iron was really devised by Black metallurgists who were enslaved and taken to Jamaica, finds **Michael Marshall**

A METALLURGICAL process that was crucial to the industrial revolution was invented by Black metallurgists, many of whom were enslaved – and not by British entrepreneur Henry Cort, who took the credit.

"This innovation is the basis of suspension bridges, iron ship building, textile mills," says historian of science Jenny Bulstrode at University College London. "This innovation was in fact stolen by Henry Cort."

Despite his importance to the industrial revolution, Cort is a mysterious figure; even his date of birth is unknown. He was a banker who, in 1775, took over a Portsmouth foundry owned by one of his debtors, and lost a lot of money. Then, in 1780, he secured a contract with the Royal Navy to supply iron hoops for barrels.

However, the contract was a bad one. "Basically, they'd screwed him," says Bulstrode. Cort had agreed to take on large quantities of the navy's scrap metal, but there was no profitable way to turn this into high-quality iron on a large scale to make the hoops.

Then, in 1783, Cort patented a process in which bundles of iron were heated in a modified furnace and fed through grooved rollers. The individual processes and elements already existed, but they were combined in the patent in a novel way. While the resulting metal was still fairly impure, it was far stronger and could be used to build huge structures.

Cort's plan didn't work out. He had funded the business through a loan from a navy employee, Adam Jellicoe, who had embezzled navy funds. When Jellicoe died in 1789, Cort was held liable for his debts, went bankrupt and lost control of the patents. "An extremely valuable process that was patented in Cort's name is suddenly free to use and you suddenly get it taken up all over Britain," says Bulstrode.

WORLD HISTORY ARCHIVE/ALAMY

***Coalbrookdale by Night* by Philippe Jacques de Loutherbourg depicts an English village that was a centre of iron smelting**

How Cort devised the process has always been a mystery. "There is absolutely no sign of any experiments, of what work he did to get there," says Bulstrode.

The answer, says Bulstrode, is theft. She came across an archaeological report of a foundry site in Jamaica that was using the Cort process before he was supposed to have invented it. After trawling through records, she has assembled a hitherto-unknown sequence of events (*History and Technology*, doi.org/khx6).

1772
When Reeder's Pen metal foundry was established in Jamaica

1782
The year machines from Reeder's Pen arrived at Portsmouth, UK

1783
The year Henry Cort patented the machines' metal-working process

In 1772, an Englishman named John Reeder established a foundry in Jamaica, then a British colony. "Reeder's Pen" supplied equipment for the sugar trade and was operated by 76 Black metallurgists. Many were taken from Africa by the British and enslaved, although some were Jamaican Maroons, a group who had freed themselves from slavery decades earlier.

According to Reeder's account, the foundry workers' "perfect" skills enabled them to convert 3000 tonnes of scrap metal into bar iron, using furnaces and rolling mills. The grooved rollers used were standard in sugar cane processing but hadn't previously been used for metalworking.

The foundry was illegal under British colonial law, because anti-slavery rebellions had relied on weapons forged illicitly in such foundries. As a result, a decade later, it was shut down.

Bulstrode also found a link from the foundry to Cort. In spring 1781, his cousin John Cort arrived in Jamaica. At the time, the biggest news on the island was that a freedom fighter named Three-Finger Jack had been killed – by Kwasi, one of the Maroons working in the foundry. John Cort almost certainly heard the story.

Exploitation

Later that year, John Cort's ship ran into difficulties and was forced to divert to Portsmouth, where he arrived in November 1781 and found Henry struggling. There is no record of their conversations, but in spring 1782, Reeder's foundry was dismantled and loaded onto ships set for Portsmouth. "The next thing you get is sugar rollers in Henry Cort's foundry in Portsmouth," says Bulstrode.

The story reflects an under-appreciated aspect of the trade in enslaved African people, says Bulstrode: it exploited their expertise and inventiveness as well as their physical labour. The regions of west and west-central Africa targeted by the British slave trade are "some of the most significant iron-working regions in world history", she says.

"If you are someone enslaved, then your labour, your intellectual inputs, your knowledge, your skills and everything, they are owned by the person that owns you," says Shadreck Chirikure at the University of Oxford.

This was a recurring pattern, says Chirikure. Some of the people enslaved from what is now Angola were chosen for their copper smelting skills. "They made significant contributions to copper mining in Cuba, copper mining in Brazil and in other places," he says. ▮

Ecology

Eating tainted meat may deter jaguars from killing livestock

Christa Lesté-Lasserre

JAGUARS have been trained to dislike the taste of cattle, sheep and dogs by feeding them tainted meat, suggesting a way to spare the lives of domestic animals and help protect the predators that prey on them.

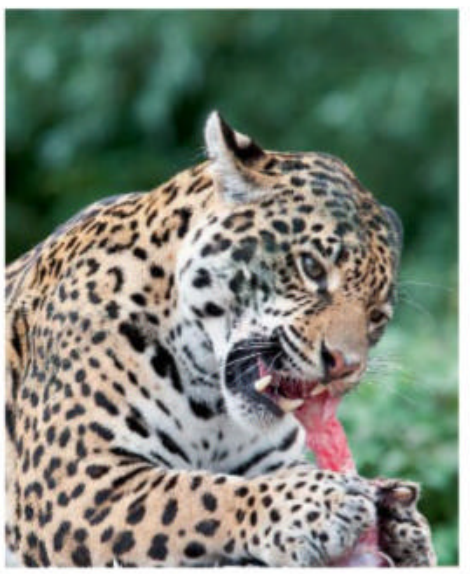
An endangered species, jaguars (*Panthera onca*) roam freely under wildlife protection laws in Mexico and parts of Central and South America. But their attacks on livestock and pets have led to illegal shootings by angry owners.

By treating meat with high doses of deworming medication and wrapping it in the skin of domestic animals, scientists may have successfully thwarted attacks on livestock and pets – and hence lethal repercussions on the wild cats, says Ivonne Cassaigne at Primero Conservation in Mexico City.

In 1974, researchers reported trying to prevent coyote attacks on sheep by taking advantage of the "food poisoning" effect that occurs in people when we experience nausea and abdominal pains after a bad meal and then find the same food disgusting later. This reaction, called conditioned taste aversion, evolved in most animals as a way to avoid toxic food, says Cassaigne. Unfortunately, early taste-aversion studies in wild predators generally failed because the animals could smell the poison in the meat, she says.

In 2009, Ron Thompson at Primero Conservation in Pinetop, Arizona, found that

Jaguars get a stomach ache after eating meat tainted with thiabendazole



ANDREW ROBERTS/ALAMY

thiabendazole – an odourless, tasteless deworming medication – gave two captive pumas a safe but serious stomach ache when injected into the skin-wrapped meat of desert bighorn sheep. The cats later refused to eat any desert bighorn sheep meat, he says.

Hoping to put jaguars off hunting domestic animals, Cassaigne, Thompson and their colleagues recently added high but non-lethal doses of powdered thiabendazole into 2 kilograms of mutton or pork wrapped in the animals' own skin. They fed this meat to six captive jaguars in three Mexican wildlife refuges.

Within 3 hours, the cats became lethargic and sometimes howled, says Cassaigne. Some later vomited and had diarrhoea for a few hours.

The next day, the jaguars had good appetites and eagerly ate beef. But none of them ate the pork or mutton offered to them. "[One female] grabbed it and had it in her mouth, but then she spit it away," says Cassaigne. Their aversion to those specific meats lasted at least a month, which is when the experiment ended.

Later, Cassaigne and her colleagues injected thiabendazole into the carcasses of a calf and a feral dog that had been killed and then left by two wild jaguars in Mexico. In both cases, the wild

"A reaction called conditioned taste aversion evolved in most animals as a way to avoid toxic food"

males came back to continue eating the spoils. One didn't attack another calf over the next seven months. The other killed one dog – but didn't eat it – and never attacked again over the following year of monitoring (*Applied Animal Behaviour Science,* doi.org/kh9h). This jaguar might have been attacking dogs for years already and was used to hunting them, making it harder to stop the habit, says Cassaigne.

While the tests in the wild were inconclusive, those in captive jaguars showed great promise and the idea should be tested further, says Jorge Tobajas at the University of Córdoba in Spain. ▮

Health

Genetic early risers less likely to show signs of depression

BEING genetically predisposed to be more active in the morning than the evening may reduce your risk of having symptoms of depression.

Researchers have previously found that night owls may be at greater risk of having symptoms of depression than early birds. But it is unclear whether staying up late increases the risk of such symptoms or if the symptoms tend to lead people to become evening people.

To find out more, Anne Landvreugd at the Free University in Amsterdam and her colleagues analysed genetic data from more than 14,000 people living in the Netherlands. The participants had an average age of 43 and 63 per cent were female. In addition to providing genetic data, participants took part in surveys in which they reported details of their lifestyle and how strongly they experienced 14 potential symptoms of depression, such as "I do not have much energy" and "I have trouble making decisions". None had been clinically diagnosed with depression.

The researchers looked for about 350 genetic variants in the participants' genomes that have been previously linked to how active people feel in the morning compared with the evening and calculated a "morningness" score for each person. They found that individuals more likely to be morning people, according to their genetics, were less likely to have trouble making decisions, to feel worthless or have feelings of low energy (medRxiv, doi.org/khx3).

"Changing people's daily rhythms could treat some mental health conditions"

"This suggests that having higher morningness really does lower your risk of depressive symptoms because the link can't happen in reverse – having depressive symptoms can't change the genetic variants you have," says Landvreugd.

The findings hint that changing people's daily rhythms could treat some mental health conditions, says Amy Ferguson at the University of Edinburgh, UK. Doing this may also help prevent depression symptoms, says Landvreugd. ▮

Carissa Wong

Archaeology

Coded messages in runes appeared earlier than thought

Joshua Howgego

PEOPLE living in Scandinavia may have written encrypted messages in runes – the alphabet later used by the Vikings – several centuries earlier than previously thought.

In runic writing systems, each rune can represent both a sound and a word. For example, in an early runic system called the Elder Futhark, the rune that corresponds to the letter S also means "sun".

It is generally possible to translate runes into modern languages. But we have long known that in the Viking period, starting in roughly AD 800, runes were sometimes encrypted, so the text isn't decipherable. One of the most famous examples is the Rök runestone in Sweden, which was erected in the late 800s and contains a lengthy, encrypted runic text. No one has been able to convincingly decipher it.

Now, historian Sebastian Zimmermann at the University of Lorraine in Nancy, France, is suggesting that encryption practices started much earlier. He carried out a survey of objects and documents bearing runes, including weapons and jewellery, dating from the 1st to the 7th centuries AD. Zimmermann presented his findings last month at the HistoCrypt 2023 conference in Munich, Germany.

He found what he says is clear evidence of encryption on very old objects. One of these is the Hogganvik stone, discovered by a resident of the eponymous Norwegian town while gardening in 2009, which dates to the 4th or 5th century AD. It contains runic inscriptions that can be translated and make sense, together with a section of apparent gibberish that translates as "aaasrpkf aarpaa".

Unnatural repetition

Zimmermann thinks this may be a substitution code, in which units of one or more runes are replaced by a different unit. What gives it away, he says, is the unnatural repetition of letters and the use of "p", a rarely employed rune.

He also highlights two other runestones found in Sweden that he says show evidence of encryption. One is the Noleby runestone, dated to about AD 600. The other is the Ellestad stone (pictured), dated to between AD 500 and 700.

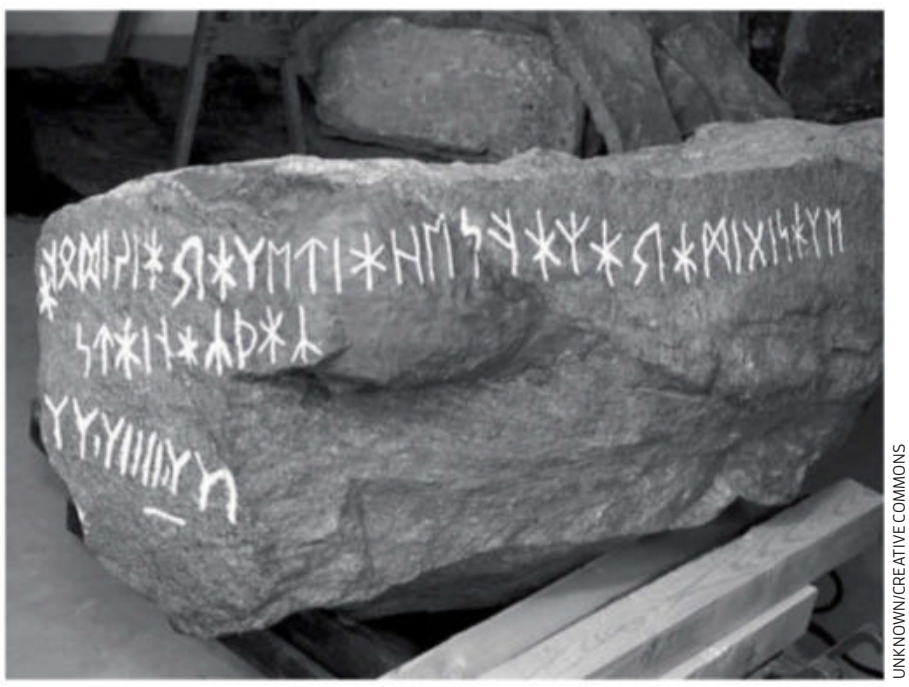
Jonas Nordby, a senior curator at the Museums in Akershus group, Norway, says it isn't unreasonable to think that people encrypted runes this long ago. In 2018, he published an extensive study of runic cryptography in use from around AD 800. One cipher system from the time involved using pairs of runes to encode another single rune. The repeated pairs of letters (such as "aa" and "rp") on the Hogganvik stone, for example, could represent a similar cipher pattern, he says.

Nordby's previous research showed that by around 800, several rune cipher systems were in use. He concluded that they were probably used as an exercise to help people learn to write, in a society where writing and reading was uncommon.

Though we have little evidence of it, he says this kind of thing must have been going on for at least 100 years previously – it couldn't have appeared from nowhere. Actually proving this would be extremely difficult, though, as it would involve finding the key to the cipher, he says. "It's a likely assumption that cryptography was in use back then, but we cannot prove it." ▮

1500

The earliest runic cryptography is at least this old, in years



UNKNOWN/CREATIVE COMMONS

The Ellestad stone, inscribed between AD 500 and 700

Technology

Green screen gets a magenta makeover from Netflix

Matthew Sparkes

NETFLIX researchers have come up with a new type of AI-powered green-screen technology that can produce realistic visual effects for film and television in real time.

NETFLIX EYELINE STUDIOS

In normal green-screen use, actors are filmed against a bright green background, which is easily removed digitally. This process can be done automatically, but can be thrown by items of green clothing or by transparent or fine objects, like wisps of hair.

Now, Netflix has created a method it calls Magenta Green Screen. Actors are filmed against a background of bright green LEDs while being lit from the front with red and blue ones, which together create a magenta glow (see above).

Because digital cameras take an individual red, green and blue value for each pixel, this technique has the effect of creating a green channel that records only the background, with the foreground appearing black, and red and blue channels that record only the foreground, leaving the background looking black. Together, these create the magenta and green look (arXiv, doi.org/kh9j).

Film editors can replace the green channel in real time, realistically and instantly placing the actors in the foreground of another scene, with even potentially tricky areas, such as transparent bottles or the section around strands of hair, working without problems. An artificial intelligence then corrects the magenta-coloured actors, using a photograph of them lit normally as a reference. ▮

European Union's plan to curb the destruction of forests is flawed

Sustainability researchers have doubts about whether the EU's new law will succeed in stopping the clearing of trees, says **Jason Arunn Murugesu**

THE European Union is aiming to stop vast swathes of tropical forest from being destroyed or degraded with a new law that came into effect on 29 June. But researchers have told *New Scientist* that the law doesn't address systemic issues that cause deforestation, and it is uncertain how effective it will be.

Large to medium-sized companies registered in the EU now have 18 months to ensure their products haven't been produced on land deforested after 2020; smaller firms have 24 months. The law applies to seven commodities: cocoa, coffee, palm oil, rubber, soya, cattle and wood.

The EU anticipates that it will prevent more than 70,000 hectares of forest loss annually by 2030, reducing carbon emissions by 31.9 million tonnes per year.

But the law has faced a backlash from countries such as Malaysia and Indonesia, which say they weren't consulted on the regulations until after they were adopted by the European parliament in April and fear that they could hit their economies.

"It's great that the EU is taking responsibility for the environmental issues involved," says Rachael Garrett at the University of Cambridge, but she says there isn't much clarity about how the law will be implemented.

Studies show there are limits to supply chain interventions to reduce deforestation, says Garrett. A recent study she conducted looked at the impact of global firms' zero-deforestation commitments on beef production in the Brazilian Amazon. It found that a commitment made by the four largest cattle meatpacking firms in 2009 only cut deforestation related to beef production in the region by 15 per cent. "That's because many big cattle companies don't actually sell internationally and they don't have zero-deforestation commitments," she says.

RICHCAREY/GETTY IMAGES

NEJAH/SHUTTERSTOCK

Rainforests are cleared (left) in many parts of the world to grow crops like cocoa (above), soya beans or oil palms

While the EU is a major buyer for many of the commodities specified, it isn't the only one, says Garrett. There is the potential that intermediaries will just sell goods linked to deforestation to other markets, she says. "There's really complex reasons why people deforest," she says, and cutting off access to one market isn't enough to stop clearing.

"Countries that are going to be affected by this law were caught on the back foot"

Anthony Alexander at the University of Sussex, UK, points to soya beans from Brazil, where the EU only buys 10 per cent of the total exports. Most are sold to China, he says. "This law could just mean farmers sell more soy to unregulated markets," he says.

Garrett says companies will also struggle to tell whether the products they buy are linked to deforestation. "It's really hard to trace to individual farms when so many middlemen are involved," she says. This is especially challenging for products like soya, where beans from many growers are often blended by distributors before being sold, says Alexander.

The EU Commission says producers will be required to collect the geographical coordinates of where the commodities they sell were produced. But Constance McDermott at the University of Oxford says many farmers don't have smartphones to do this.

Even when the EU is a major buyer, the law doesn't address the systemic issues that cause deforestation, says McDermott. For example, Ghana is the second biggest producer of cocoa. Most cocoa farming in Ghana is done by small-scale farmers, she says, who only receive about 6 per cent of the value of a chocolate bar.

"If you have lots of cocoa farms near a forest reserve [which is at risk of deforestation], the easiest thing for a company to do is just draw a big, wide circle around the reserve and [say] we won't buy from there any more," she says. These farmers may then switch to other environmentally damaging ways to make money, such as gold mining, says McDermott.

The way the law was drawn up was also problematic, she says. "Countries that are going to be affected by this law were caught on the back foot and only now are consultations happening."

The EU Commission says it is in dialogue with producer countries to facilitate the implementation of the new law and jointly address the root causes of deforestation and forest degradation.

Garrett says a better solution would be to force companies to pay farmers more and help build up their infrastructure for producing these commodities.

"The main driver of deforestation and forest degradation is the expansion of agricultural land which is linked in particular to the production of a series of commodities such as soy, beef, palm oil, wood, cocoa, coffee or rubber," says an EU Commission spokesperson. "The regulation is an opportunity to enhance trade in deforestation-free products and boost opportunities for sustainable actors around the globe." ▮

Health

‘Overweight’ BMI may not be so bad

People who are a bit heavier have a lower risk of dying in a set period than slimmer people

Clare Wilson

BEING “overweight” may not be so bad for your health after all. The latest evidence comes from a large study in which people classed as overweight, but not obese, had a lower rate of dying within a certain time period than people with a supposedly ideal weight. This suggests that the threshold at which individuals are classed as overweight has been set too low.

It is uncontroversial that being very heavy is bad for health, but it is unclear at what point health risks begin. Doctors usually advise people to lose weight if they have a high body mass index (BMI), which is someone’s weight in kilograms divided by the square of their height in metres.

In most countries, a healthy weight is defined as a BMI between 18.5 and 24.9. Having a BMI between 25 and 29.9 is classed as overweight and 30 and above as obese. These thresholds became the medical orthodoxy after being cited in a report from the World Health Organization in 1997.

Previous research made waves when it found that people whose BMI was somewhat over the “healthy” threshold of 25 may have a slightly lower death rate than those who are slimmer. But many of the studies are fairly old and were done when people were mostly slimmer, and those taking part weren’t ethnically diverse, says Aayush Visaria at Rutgers Institute for Health in New Jersey.

“BMI isn’t a good indicator of mortality risk – other factors, such as body fat distribution, play a role”

To address those issues, he and Soko Setoguchi, also at the Rutgers Institute, analysed data from a more recent study, which began in 1999 and tracked the survival of about 500,000 ethnically diverse US adults of known height and weight for up to 20 years.

Having a BMI between 25 and 27.4 carried a 5 per cent lower risk of death in this time period than a BMI within the healthy weight category of 22.5 to 24.9. A slightly higher BMI, of 27.5 to 29.9, seemed even better, linked with a 7 per cent lower risk of death.

One criticism of this kind of study is that the apparent benefit of being overweight could be an artefact caused by people who lose weight when they are ill being more likely to die. But in the new research, the pattern was seen even if people who died within two years of entering the study were excluded from the figures (*PLoS One*, doi.org/gsfph2).

Visaria says it would be premature to conclude that having a BMI currently classed as overweight is better than being in the healthy category, because population studies can have biases that distort the results. “We are not clear that this is truly interpretable yet,” he says. “A more appropriate message is that BMI overall is just not a good indicator of mortality risk – other factors, such as body fat distribution, also play an important role.”

Katherine Flegal at Stanford University in California, who was one of the first researchers to show that being classed as somewhat overweight carried a lower risk of death, says the current thresholds for being overweight or obese are arbitrary. “Nature does not organise itself with nice, neat numbers – these are clearly digit preferences when you have numbers like 25 and 30,” she says.

In June, the American Medical Association advised doctors that BMI shouldn’t be used in isolation to assess people’s weight-related risk, but should be considered alongside other measures such as waist circumference.

Roy Taylor at Newcastle University in the UK says BMI was developed as a way to assess the health of populations and shouldn’t be used to give health advice to individuals. ▮

To read about the new generation of potent weight-loss drugs, see page 32

Zoology

Crows grasp probability just like primates do

CARRION crows can make decisions according to the likelihood of getting a reward – a cognitive feat known to mathematicians as statistical inference.

“‘Bird brain’ is often used as an insult, but that’s not really the case,” says Melissa Johnston at the University of Tubingen in Germany.

Her team trained two carrion crows (*Corvus corone*) to peck at nine, different-coloured symbols to receive a reward: a small food pellet or worms. Over hundreds of trials, they were taught that each symbol was associated with a different probability of getting a reward, ranging from 10 to 100 per cent per peck.

The crows were then given the chance to choose between two options: for example, the green circle with a 90 per cent chance of a reward versus the blue square with a 70 per cent chance.

Both crows pecked on the shapes with the highest probability of yielding them a reward more than seven times out of 10. In a second part of the experiment, shapes with lower probabilities were shown more often. While the crows could have pecked these shapes more times and received the same amount of reward, they still chose the shapes with the higher probability of getting them a treat.

SHUTTERSTOCK/RUDMER ZWERVER

Carrion crows know when the odds are in their favour

“They knew that even though it was shown less often it was more valuable,” says Johnston.

This suggests the crows have the ability to use limited information about the probability of something happening and apply it in a new situation, she says.

When tested a month later, the crows still chose to peck the shapes with higher probabilities more often (*Current Biology*, doi.org/khx2). “That’s pretty incredible,” says Johnston.

These findings add to “a growing body of fascinating evidence on remarkable cognitive capacities” in corvids, says Hannes Rakoczy at the University of Göttingen in Germany.

Rakoczy says such complex numerical abilities have primarily been seen in primates until now. ▮

Sofia Quaglia

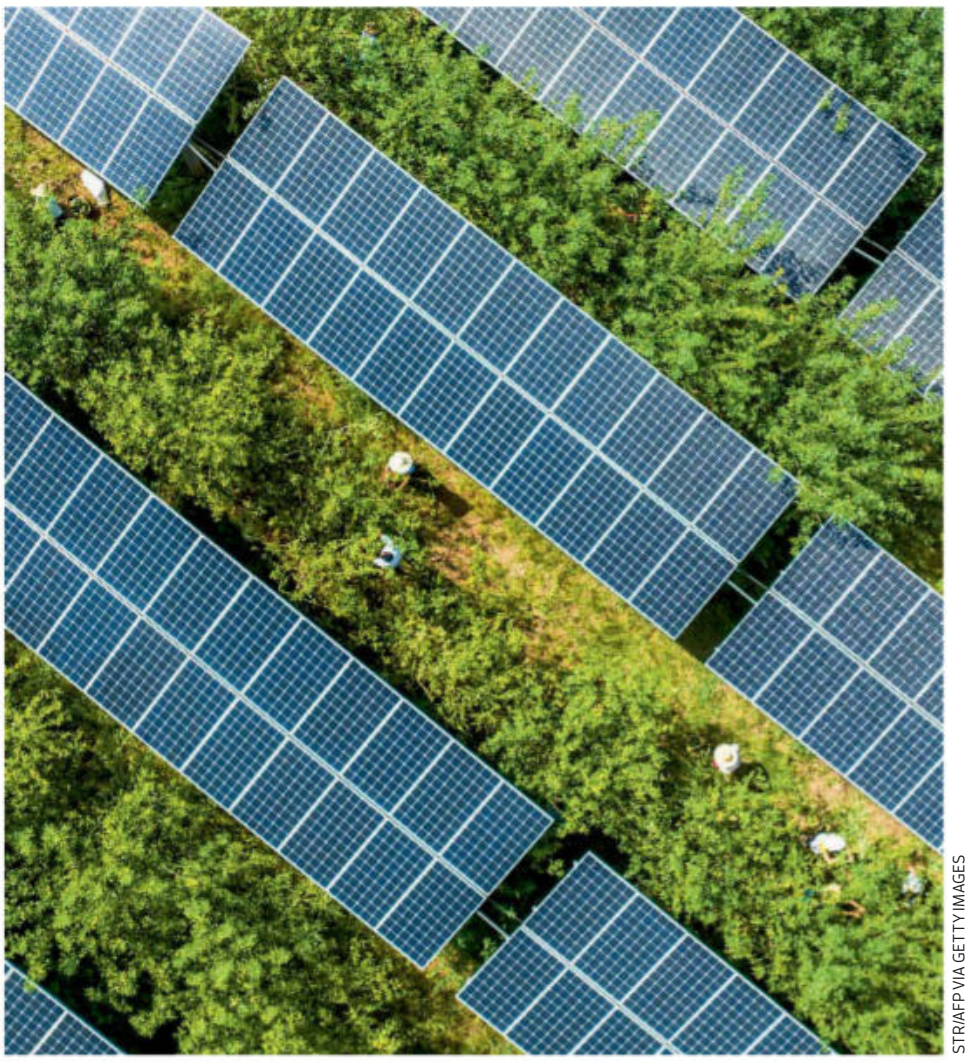
Animal behaviour

Male mites peel off their mates' skin

MALE spider mites closely guard juvenile females and tear off their outer skin as they approach sexual maturity so they can be the first to mate with them.

Two-spotted spider mites (*Tetranychus urticae*) shed, or moult, their outer skin when they transition from juvenile nymphs to adults. Adult females can have multiple sexual partners, but only the sperm of their first partner fertilises their eggs.

Peter Schausberger at the University of Vienna in Austria and his team found that males guard females and pull off their outer skin just as they near maturity so they can inseminate them before other males swoop in (*iScience*, doi.org/kh4w). This is the first species in which the behaviour has been experimentally noted, says Schausberger. **Alice Klein**



STR/AFP VIA GETTY IMAGES

Archaeology

Rethink on sex of Copper Age leader

ONE of the most prominent figures in an ancient Iberian society was female, not male as thought, says a new analysis.

The Iberian Copper Age dates back roughly 4000 to 5000 years in what is now Spain and Portugal. In 2008, researchers at Valencina in Spain unearthed the remains of an individual from this era whose tomb was adorned with lavish goods. Based on an analysis at the time, it was deduced that this was probably a male who died aged between 17 and 25 years old.

Now, Leonardo García Sanjuán at the University of Seville in Spain and his team have determined the figure was in fact female, based on a protein called amelogenin found in tooth enamel (*Scientific Reports*, doi.org/khx8). People produce different versions of amelogenin based on which sex chromosomes they have. **Chen Ly**

Materials

Improved solar cell can harvest even more energy

A NEW kind of solar cell has broken a theoretical limit on the efficiency of silicon-based units, which could let us get more energy from sunlight.

Almost all commercial solar cells are made from silicon. These can only convert a narrow frequency band of sunlight to electricity. Light that is too far outside this range either passes straight through or is lost as heat, which gives silicon cells a theoretical efficiency limit of around 29.4 per cent.

This could be higher if another material that generates electricity from light in a different frequency range is stacked on top of the silicon. Perovskite, a titanium and calcium crystal, is well suited to this because it is better at absorbing light closer to infrared frequencies. But making it efficient has proven hard because wayward electrons are reabsorbed before being turned into current.

Now, two research groups have found ways to pair perovskite with silicon to achieve a higher efficiency.

To make the materials work together, Xin-Yu Chin at the Swiss Federal Institute of Technology Lausanne and his colleagues used a two-step process. The silicon cell is first coated in a layer of precursor chemicals, before a second layer of chemicals is added that reacts with the precursors to form perovskite. This causes fewer defects in the silicon-perovskite interface, says Chin, and so increases the number of electrons available for current. The device has an efficiency of 31.2 per cent (*Science*, doi.org/kh3b).

In a separate study, Silvia Mariotti at Helmholtz-Zentrum Berlin and her team added liquid piperazinium iodide to the perovskite layer, which also improved the cell, giving an efficiency of 32.5 per cent (*Science*, doi.org/kh3c). Alex Wilkins

Really brief

VICTOR J. BLUE/BLOOMBERG VIA GETTY IMAGES

Corn vulnerable to extreme heat

The huge amounts of maize grown in the US Midwest could be under threat from climate change. Growing trials conducted between 1934 and 2014 show that breeding has resulted in varieties that give higher yields when it is moderately hot, but are less tolerant of severe heat (*PLoS Genetics*, doi.org/kh3r).

Seabirds feed at plastic hotspots

Threatened seabirds are foraging around floating garbage patches in the ocean, according to data from tracking devices. International action to tackle plastic pollution, which can be ingested by wildlife, is urgently needed, say researchers (*Nature Communications*, doi.org/kh3s).

Water can be carved to make tiny devices

Microfluidic chips made from water could be used to create new materials or detect pathogens. When water is added to a gel of nanoparticles of silicon dioxide, it forms a pancake-shaped blob. The water can then be cut with a laser into shapes that hold their form (*Nature Communications*, doi.org/kh3t).

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Culture columnist
Simon Ings on enigmatic sci-fi horror *Cerebrum* p30

Comment

Are the kids alright IRL?

Social media can pose a "profound risk of harm" to the mental health of young people. But there are benefits too, says **Jennifer Abbasi**

THERE is a scene in the 2020 documentary *The Social Dilemma* that has stayed with me. A tear rolls down a girl's face as she appraises herself in the mirror, her sadness a result of harmful body image comparisons rife on social media. The dramatic recreation depicts just one of the potential harms highlighted in a recent US Surgeon General's Advisory on social media use and youth mental health.

The advisory, a report "reserved for significant public health challenges that require the nation's immediate awareness and action", summarises some of the "ample indicators" that social media can pose a "profound risk of harm to the mental health and well-being of children and adolescents". It cites a study of more than 6000 US adolescents published in *JAMA Psychiatry*. The study found that those who spent more than 3 hours per day on social media platforms were at heightened risk of mental health problems, including symptoms of depression and anxiety.

That amount of use isn't unusual, research has shown. In 2021, 13 to 14-year-olds and 15 to 16-year-olds in the US spent an average of 3.5 hours on social media per day, according to the University of Michigan's Monitoring the Future survey.

As I reported last month in *JAMA*, doctors are certainly concerned about social media's effects on kids. Six major US medical groups endorsed the new advisory. When I spoke with Jeremy Veenstra-VanderWeele, a child and adolescent psychiatrist at Columbia University Irving Medical Center in New York, he discussed the staggering amount of time young people spend on social media and said the platforms can be all-consuming.

SIMONE ROTELLA

"From a circumstantial evidence perspective," he said, "we are seeing a marked rise in youth anxiety and depression over the same period of time when social media has become so widely used."

Matthew Davis, chair of the paediatrics department at the Ann & Robert H. Lurie Children's Hospital of Chicago, told me that, among healthcare providers, "there is a strong sense that the harms outweigh the benefits for our patients".

But what's this about benefits? The potential harms seem clear, yet what we may not recognise is that social media can also have upsides for many young people, something the advisory not only acknowledges but emphasises. Yes, young people may be harmed by cyberbullying, explicit content and other serious pitfalls. But they can also find positive connections and social support that they may not have, as the young folks say, in IRL (in real life).

Veenstra-VanderWeele said patients have told him how vital their online community is, "particularly for teens who may not fit in easily with peers".

The advisory underscores gaps in our knowledge around social media's effects on youth well-being and calls on society to take action now. It will be important to understand the two-way nature of associations between social media use and mental health issues, for example. The ultimate goal should be to harness the potential benefits of online social connections, while decreasing the potential harms.

To achieve this, young people must be involved, says Tammy Chang at the University of Michigan, who directs the MyVoice national youth poll in the US. "When youth have input and buy-in on initiatives meant to change their behaviours, those initiatives are more likely to succeed," she told me.

My three teenage nephews say that at least some of the kids are alright. They know that whether social media is helpful or harmful depends on how it is used. Social networks are communities, after all, with both positive and negative elements – whether virtual or IRL.

Jennifer Abbasi is a journalist and news editor at *JAMA*

No planet B

Line in the sand

Saudi Arabia's zero-carbon linear city has been dismissed as greenwashing, but there is some truth to the claim the country wants to be more sustainable, finds **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *Mustn't Grumble: The surprising science of everyday ailments*. He is the winner of the 2023 PPA Writer of the Year award. You can follow him @grahamlawton

Graham's week

What I'm watching
Tour de France: Unchained *on Netflix.*

What I'm reading
Inn Search of Birds: Pubs, people and places *by John Lawton. He is my dad.*

What I'm working on
A feature about human adaptation to extreme climates.

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

WHEN I told people I was going to Saudi Arabia to do some reporting, many assumed I was visiting Neom, or some variation on "that weird city in the desert". I wasn't. I went to report on a project called Deep Climate, which is researching human adaptation to extreme conditions, such as the brutal heat of the Arabian desert. But I found out plenty about Neom, and some of the other changes afoot in Saudi Arabia, while I was at it.

I first heard about Neom in detail in 2021 at COP26, where its executive director of energy, Jens Madrian, talked about his task of delivering a 100 per cent renewable energy system for the project. Like many people, I had conflated Neom and the futuristic linear city that most of us have heard of, officially called The Line, but they aren't one and the same. Neom is the overarching concept of several green projects that also include an airport, an industrial complex and, er, a ski resort.

Madrian described Neom as "the largest green infrastructure project worldwide" and a "living laboratory for the future of urban development, an accelerator of human progress". The Line, set to be 170 kilometres long, 500 metres tall and just 200 metres wide, is the flagship of the scheme. Work on it started in late 2021.

This vast urban structure, if it ever rises from the sand, will supposedly be zero-carbon and car-free, with transportation set to be provided by a high-speed underground railway. There will be accommodation for 9 million people, which would make it Saudi Arabia's most populous city and the most densely populated in the world, with 265,000 people per square kilometre.

You have to applaud the sustainability goals, especially in a country enriched and sustained by oil revenues. But what I still don't understand is why it is being built in a line. One reason given is that it will reduce the impact on nature, but that is arrant nonsense. Linear barriers, such as fences, are a major obstacle for wildlife. A city this long will slice the desert in two.

The Line will also be bad for people. According to a recent analysis, two citizens of The Line chosen at random would be 57 kilometres apart, compared with 30 or so for a big metropolitan area. The railway will require at least 86 stations, greatly reducing travel speed. Why not build a city-shaped city instead?

"Linear barriers, such as fences, are a major obstacle for wildlife. A city 170 kilometres long will slice the desert in two"

Nonetheless, The Line is being built. On the airport shuttle bus, I got chatting to a British engineer on his way to take up a job there. He was unsure what he had let himself in for, but they had offered to quadruple his salary. He signed a nine-year contract.

The Line has been criticised, ridiculed and dismissed as greenwashing. I have no idea whether it will ever really see the light of day, but I do think there is some truth to the claim that Saudi Arabia wants to change its ways – to some degree.

Over lunch on my final day in the country, I got talking to a woman who worked for the Ministry of Culture (she asked not to be named in this piece). She wanted my impressions of her country and how it is viewed in the UK. I told her I was pleasantly surprised, especially by what appear to be better relations between men and women. But I also told her that the UK perception of Saudi isn't good; most people back home view it as a repressive and vicious theocratic dictatorship hooked on oil and medieval punishments.

Yes, she said – but the improved status for women was a sign of a broader liberalisation of Saudi society over the past few years under the leadership of crown prince Mohammed bin Salman Al Saud. The widely hated religious police, technically the Committee for the Promotion of Virtue and the Prevention of Vice, had their powers significantly curtailed in 2016 – a statement confirmed by news coverage in the Saudi press, though I am not sure how independent their reporting is.

I asked her about environmental consciousness among the general population and she said it was improving. The energy minister Abdulaziz bin Salman Al Saud launched the Saudi Green Initiative in 2021, pledging that half of the country's electricity will come from renewables (largely solar power, of course) by 2030 and vowing to hit net zero by 2060.

I knew I was being subjected to part of the charm offensive that this country has been waging for a number of years, and I took it with a pinch of sand. But the evidence of my own eyes suggests that Saudi Arabia is moving in a more progressive direction, especially on the environment.

But it will never be a progressive society. Atheism remains deeply frowned upon, though there are atheists. And those who rule have red lines they will never cross. One is the recognition of LGBTQ+ rights. The other is legalising alcohol. Oh, how I longed for a cold beer with my lunch. ▮

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Sewer art

Tideway

THIS vibrant oasis lay deep under London in the Thames Tideway Tunnel, more commonly known as the city's new "super sewer". Every year, around 40 million tonnes of raw sewage end up in the river Thames. But the new 25-kilometre-long concrete sewer, which runs along the river, should prevent 95 per cent of spills, providing a healthier environment for the surrounding wildlife when it becomes fully operational in 2025.

"We wanted to do something to celebrate and symbolise the environmental benefits that the project will have," says Taylor Geall at Tideway, the firm building the sewer, of the temporary multi-sensory art installation, which was in place until 14 July. Playfully dubbed *Loo Gardens*, it is admired here by sewer engineer Jason Lyon.

In collaboration with Thames21, a charity dedicated to improving the health of the Thames, Tideway worked with artists to replicate the distinctive flora and fauna that can be found around the river. Created with repurposed waste cleared from the banks of the Thames, such as plastic, polyester and steel, replicas of grass, moss and colourful flowers like campanulas and buttercups lined a 10-metre stretch of the tunnel floor. Hanging around the 7-metre-wide arc were ivy, ferns, wisteria and weeping willows.

Composer Rob Lewis produced a bespoke soundscape to bring the garden to life, with a symphony of birdsong from native species such as swifts and house martins, punctuated by sounds of flowing water and rustling trees.

Aromas of grasses and wetlands also swirled around the tunnel – the finishing touch to this subterranean sanctuary.

Chen Ly

Editor's pick

AI may be a gift to forces that seek to control us

1 July, p 21

From Robert Peck, York, UK

Mhairi Aitken does well to argue against claims of sentient artificial intelligence independently bringing about humanity's doom, but, like so much discussion around AI, there is no mention of the most dire threat.

Throughout history, censorious, authoritarian and surveillance-obsessed governments have always found their abilities limited by what percentage of a population they can employ to keep the rest under observation and control. With AI, this limitation is removed and totalitarians can expand their apparatus of control with nothing more than the addition of extra racks to a server farm.

Follow the money for the real story of civilisation

1 July, p 32

From John Fewster, London, UK

The role of money as an enabler to other emergent forces in the rise of civilisations is underplayed.

History shows that once in power, the rich get richer. Access to goods, services, information and even the environment is now monetised, controlled and manipulated by elites acting largely in their own interests.

While a few civilisations in history may have changed to avoid this, only a sudden cataclysm is likely to shift the current global politico-economic paradigms.

How to solve farming-conservation conflicts

1 July, p 22

From Iain Climie, Whitchurch, Hampshire, UK

Graham Lawton makes some good points about food security clashes with conservation, but isn't food waste the simplest target for a solution? In 2013, the Institution of Mechanical Engineers report *Global Food: Waste not, want not* said that over 30 per cent of food never reaches shops or markets.

From Rob Christie, Latheron, Caithness, UK

Livestock farming – intensive or otherwise – is a very inefficient way to put calories on people's plates and has a huge carbon footprint.

The farmers in the UK I know are incredibly hard-working and astute business people. How they farm is governed by the grant system. They would quickly react to changes in the, mostly perverse, incentives. This was shown when payments for sheep were changed from per capita to per area. The number of sheep quickly fell.

From Graham Cooper, Crediton, Devon, UK

Each year, the UK imports around half its food and animal feed plus millions of tonnes of timber and finished timber products.

Not only is agriculture highly polluting of atmosphere, land and watercourses here, but we are also responsible for an equally polluting effect in the nations supplying our shortfall. In addition, animal farming and the provision of its feed supply are highly inefficient uses of land for food production.

If we are to feed the UK from our own resources, return a realistic area for rewilding and clean up the country, we need a mix of things. One is to cease animal farming, instead growing organic vegetable matter for human consumption.

It all went wrong with the pursuit of cheap food

24 June, p 36

From Michael Hampden-Smith, Newmill, Cornwall, UK

Madeleine Cuff reports that over the past few decades, "pressure from supermarkets to provide plentiful food at low prices has pushed farmers to boost livestock numbers, use more fertilisers and pesticides" etc. These are the very attributes that make intensive farming, intensive. This may have been a welcome policy in terms of people's wallets, but it has been anything but for biodiversity.

Coffee grounds are good for keeping slugs at bay

17 June, p 44

From Pamela Manfield, The Narth, Monmouth, UK

James Wong warns against using coffee grounds on gardens. For over 15 years, I have been putting a light dusting of coffee grounds around newly planted seedlings. This very effectively repels slugs and snails, presumably because the tiny granules get stuck to their bodies and they find it really uncomfortable. I haven't noticed any deterioration in soil fertility, but I do regularly add compost or organic manure or both.

Why net zero is far from the solution to our issues

Leader, 24 June

From Colin Summerhayes, Scott Polar Research Institute, Cambridge, UK

The real problem with the concept of net zero is that by taking as much carbon dioxide out of the air as we put in, we maintain the amount of this greenhouse gas present when net zero takes effect. Hence the CO_2 level, while not increasing, remains high. That means continued warming, ice melt and sea level rise.

During the last interglacial, 125,000 years ago, sea level rose due to natural warming. Over some 2000 years, by certain estimates, it rose perhaps about 15 metres above present levels. By retaining high amounts of CO_2 in the air, we are headed for the same.

To counter this, we must go for negative emissions, to bring down the level of CO_2 in the air. And we must do that soon, to stop CO_2 rising to the levels we might expect to see by 2050. We have run out of time and must act now.

Yes, there will be a high cost, but there will be an even higher one for remedying the situation we will find ourselves in as sea level rise reaches and passes the 1 metre mark (above 1900 levels) on its way to higher rises.

Packing it in right can be the wrong solution

10 June, p 44

From Graham Langford, Clayhidon, Devon, UK

Packing in stuff to make best use of available space – the subject of your recent maths column – isn't always the best approach when it comes to unpacking, as seen in the Falklands war.

The rapid loading of rations, ammunition, helicopters and other vehicles into all sorts of shipping over the Easter weekend in 1982 for the trip to the South Atlantic was a masterful logistics exercise. But it took a few days at Ascension Island to reorder the loads to allow the rapid unloading of items needed immediately on arrival. Royal Marines developed software for this.

Noisy room problem: just keep it down please

17 June, p 13

From Martin van Raay, Culemborg, The Netherlands

Jason Arunn Murugesu reports on why you can stay focused on conversations in a noisy room. This made me wonder why people, if you gather more than, say, 10 in a room, start raising their voices.

If everyone spoke at a normal level, no one would have to shout. So STOP SHOUTING! Please. ▮

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Culture Club? How meat grown from animal cells could reduce agriculture's environmental impact

Every plausible path to the world's net zero and biodiversity targets relies on less livestock farming. Is part of the solution is lab-grown 'cultured meat', where muscle tissue is produced from animal stem cells for human consumption?

"While eating less meat overall is a crucial step in tackling climate change, how we go about it makes a huge difference to the impact on farmers. Whether cultured meat goes mainstream is one of many factors at play." says Professor Tom MacMillan, Elizabeth Creak Chair in Rural Policy and Strategy at the Royal Agricultural University.

Some studies have indicated that cultured meat will emit less carbon, and use less land and water, than conventional farms. However, other research has indicated the opposite.

"The jury is out at the moment." says MacMillan.

"We can be sure this will get more resource efficient than the prototypes companies are producing now, but much hinges on how fast and how far a whole load of things change, from the ingredients that go into the cell growth media and how well they can be recycled, to the types of bioreactors they're grown in." he added.

Tom and his team are working with farmers and cultured meat companies to test whether theory is likely to stack up in practice. Will cultured meat release land and, if so, would it actually be put to nature conservation? How would this affect different types of farm, and what could be the unintended side effects of the ways they adapt their businesses?

"This technology is at a stage where we can shape how – even if – it develops. So it's crucial we work with from farmers and others at the sharp end to understand how it could play out on the ground." MacMillan says.

You can find out more by joining Tom MacMillan at New Scientist Live this October. He'll be on the 'Our Planet' Stage at 11.55am on Saturday 7 October. **Find out more at: newscientist.com/future-of-agriculture**

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Into the depths

In the 1930s, the Bathysphere submersible ventured deeper into the ocean than ever before. **George Bass** reads a vivid account of its voyages

Book

The Bathysphere Book

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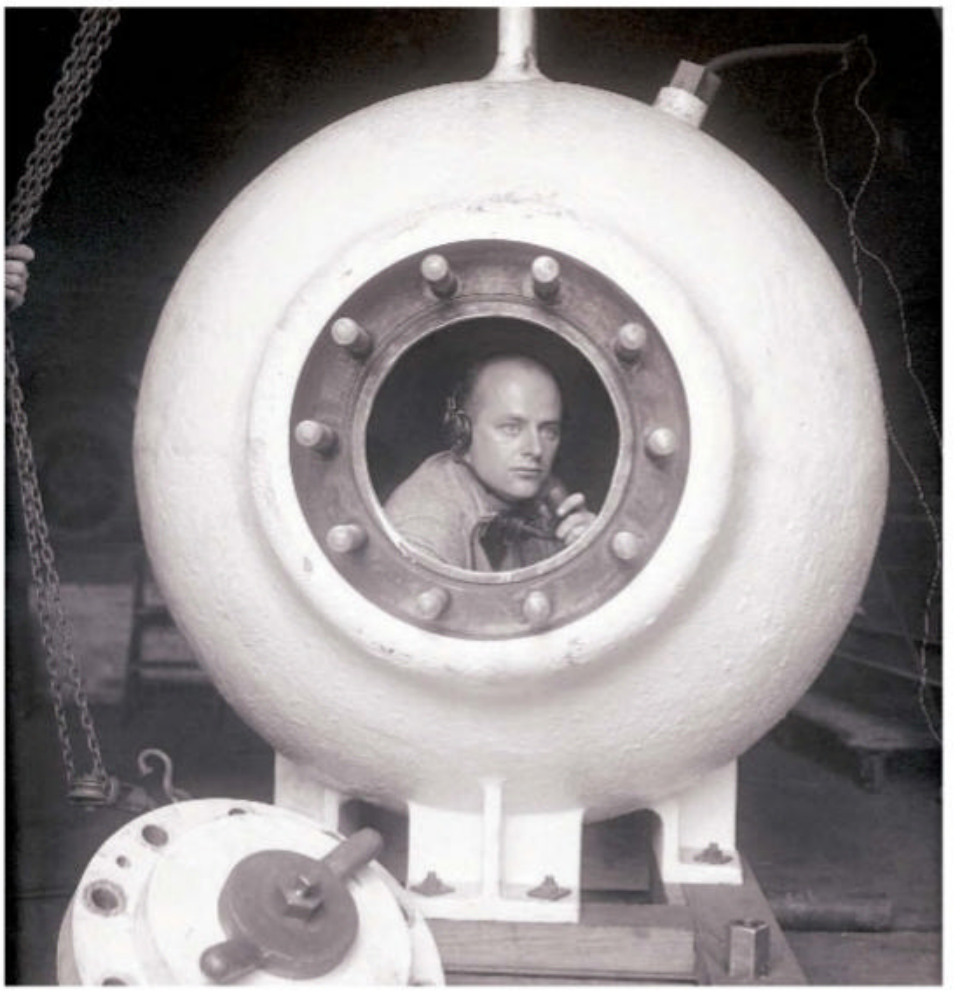

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Otis Barton in the tank he invented for William Beebe's explorations

DECADES before Trieste, a deep-submergence vehicle, entered the Mariana trench in the western Pacific Ocean, a new kind of prototype submersible was lowered into the Atlantic waters off Nonsuch Island, Bermuda, more than 14,000 kilometres away. The Bathysphere, a simple steel ball 1.45 metres in diameter, was designed to document creatures rumoured to live at depths no human had visited.

The story of the amazing sub and its record-breaking 900-metre dives between 1930 and 1934 is given the scientific and colourful retelling it deserves in *The Bathysphere Book: Effects of the luminous ocean depths* by Brad Fox. Designed by diver and engineer Otis Barton, the Bathysphere was created in response to an article written by William Beebe, a swashbuckling biologist who had previously published accounts of tracking pheasants as they migrated around the planet.

Beebe's desire to catalogue deep-sea life is presented as one of his many quirks. Fox paints the zoologist as a high-society playboy, having tea parties with A. A. Milne and receiving fan mail from Arthur Conan Doyle, who was keen to know whether he could find proof of Atlantis.

Beebe and Barton are described as well-matched, the latter having discovered Beebe's submersible sketches while he was a postgraduate engineering student at Columbia University in New York City.

Barton had been fascinated with the idea of visiting the sea bed ever since he watched pearl divers in Asia as a young boy. Later, as a student, he replaced Beebe's first cylindrical design with a sphere, reasoning that it would be better at distributing the high pressure experienced during deep dives.

"Beebe was bewitched by what he saw. How could fragile jellyfish survive 700 metres underwater?"

Using an inheritance, Barton was able to pay for some extras: a 180-kilogram door; boxes of soda lime to absorb the carbon dioxide exhaled by the Bathysphere's occupants; and a telephone battery to allow communication with the surface via the craft's connecting lifeline.

Although there were two men staring out of the Bathysphere's quartz windows during dives, Fox stresses it was the scientist hired by Beebe, Gloria Hollister, who kept the team going from above. She transcribed their sightings and arguably possessed the most rational mind of the three.

Fox outlines how Hollister went from playing with an air hose as a child in the Mahwah river, which weaves in and out of the states of New York and New Jersey, to breaking the ocean descent record for women in 1930.

She had carried out cancer research at the Rockefeller Institute before joining Beebe's team at the Department of Tropical Research within the New York Zoological Society, now the Wildlife Conservation Society.

Hollister would go on to solo scientific distinction herself, trekking more than 300 kilometres through the Guyanese jungle to catalogue tropical birds and frogs.

The dives are covered in exquisite detail. Aware that the lethal pressure around him meant a crack in the hull wouldn't just drown the voyagers, but shred them, Beebe was bewitched by what he saw. How could fragile, ghost-like jellyfish survive around 700 metres underwater?

Fox doesn't appear to have missed out a single one of Beebe's sightings, describing wonders such as darting fluorescent fish ("the stars gone mad", wrote Beebe) and the black swallower, a small predator whose distended stomach allows it to eat prey 10 times its own weight.

Although Beebe wrote up his descents in a book of his own, *Half Mile Down*, Fox's account is vivid enough to merit a reappraisal of the zoologist's work. Beebe was always ambivalent about his studies, imagining his finds would eventually be naturally erased, like pictures drawn in sand. But while the scientific community of the day was sceptical about his sightings, two fish species Beebe saw, *Bathysidus pentagrammus* and *Bathyembryx istiophasma,* today take their names from his voyages.

And while the Bathysphere's depth records may have been quickly surpassed by postwar underwater vessels, the craft in which they were set lives on. The Bathysphere was exhibited at the 1939 New York World's Fair and used by the US Navy during the second world war. Today, it can be seen in *Titans of the Deep*, a 1938 B-movie retelling of Beebe's dives using footage shot by Barton. ▮

George Bass is a writer based in Kent, UK

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Pod (see right) is the latest pick for our book club.
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Our microbial world

A doctor's view of the microbiome gives a tantalising glimpse into the future of medicine, finds **Claire Ainsworth**

Book
Dark Matter
James Kinross
Penguin Life

IT HAS been 30 years since my appendix and I parted company. As I lay debilitated and miserable in hospital, I told myself the surgeon hadn't removed anything vital, just a functionless relic. And an antibiotic drip was cleansing me of my foes, bacteria – after all, they had inflamed my appendix. Such thoughts stopped me feeling sorry for myself, but as James Kinross relates in *Dark Matter: The new science of the microbiome*, we now know how wrong they were.

Kinross is a colorectal surgeon at St Mary's Hospital in London and an expert on the human microbiome, the dizzyingly complex ecosystem of microbes that live on and in our bodies. Like most clinicians, he saw them as the enemy. But the rise of non-communicable conditions, such as allergies, autoimmune diseases and obesity, and their links with changes to the microbiome has led many to seek a more sophisticated view of our relationship with the microbial world. The book is the story of Kinross's conversion to this new view and a call to action.

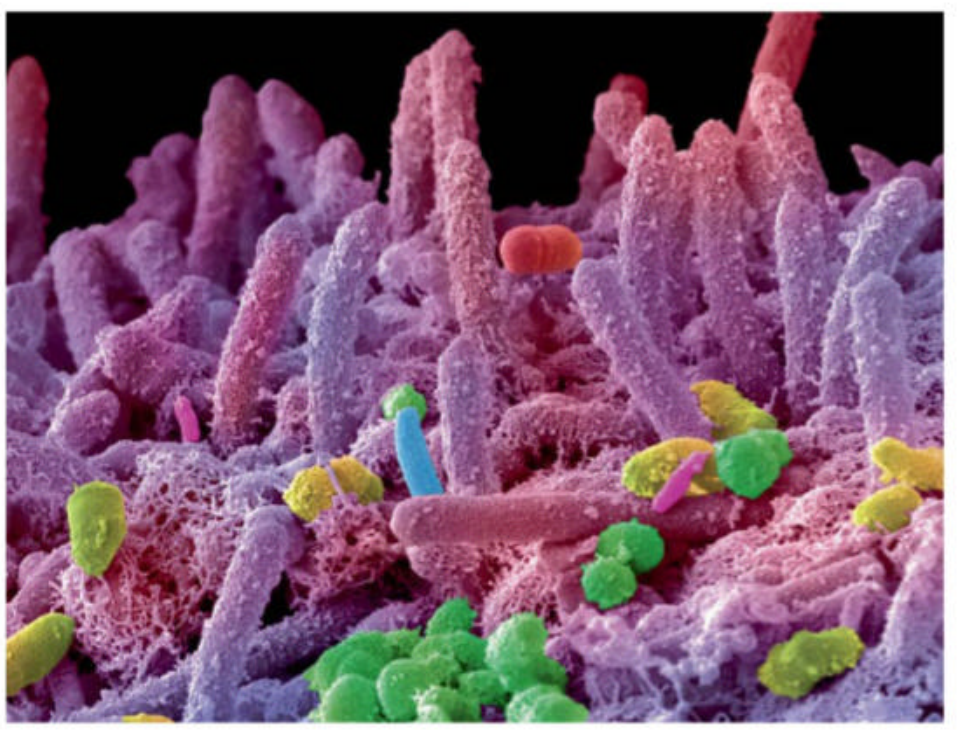
He sets out his thesis in three parts, starting with the analogy he draws between the mysterious cosmological dark matter and the microbiome. The latter appears to have a large influence on our health, though one not accounted for in the "standard model" of medicine, and we still know relatively little about it.

Together with our human bodies, goes the new view, microbial ecosystems form the human "holobiont", seeded at birth and moulded by our environment and our immune system. This neatly reframes the role of the immune system from one focused solely on defence to one that cooperates with the microbiome to shape our immune responses. The appendix, for example, is now seen as an important immunological organ that acts as a reserve of gut microbes. When this cooperative arrangement falls apart, the result can be allergies and other immunological problems.

Next, Kinross turns to the "exposome", describing how we and the environment affect the microbiome. This makes sobering reading as he explains the impact of overusing antibiotics and the loss of biodiversity in the gut microbiomes of people in industrialised countries. Diet is a key factor, but so are wider changes, including microplastics in the environment and the effects of climate change. He also points to how the microbiome affects the action of medicines and, in turn, how they alter the microbiome. Doctors aren't just treating the patient when they prescribe drugs.

In the final section, Kinross writes about how the exposome has changed our microbiomes over generations. Fixing this will be a tall order: a future in which we can manipulate our gut microbiomes with microbial transplants (natural or synthetic) is exciting, but distant. Meanwhile, we must guard what we have. "Our guts are an ecosystem worthy of protection – exactly like a rainforest," writes Kinross. "We can only improve things if we take collective responsibility."

This isn't the first popular science book about the human microbiome, but Kinross's approach is engaging, and there are always new things to say in a fast-moving field. For me, though, his book really stands out in revealing the microbiome through the eyes of a clinician who sees each patient not just as a human, but as a human entwined with a complex, dynamic ecosystem. It envisions a future where a doctor-patient relationship is more like that of ecologist and holobiont, where we no longer tilt indiscriminately at microbes, but prize biodiversity in our bodies and the wider world.



STEVE GSCHMEISSNER/SPL

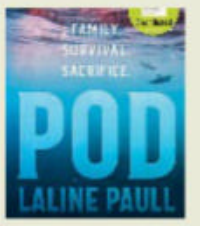
The influence of the human microbiome on our health is complex and unfolding

Claire Ainsworth is a science writer based in Hampshire, UK

New Scientist *recommends*

Eleanor Parsons
Chief subeditor
London

I have been immersing myself in nature books recently, and my latest discovery has been ***Pod*** by Laline Paull (our latest book club pick, see top of page). It was shortlisted for the 2023 Women's



Prize for Fiction, and I can see why. Told mainly from the point of view of a spinner dolphin called Ea, it is at times violent and disturbing, but also the most affecting portrayal of humanity's actions on the oceans and the creatures that live there that I have read.

I got a very different perspective reading ***An Island Ecology*** by Sarah Thomas, in which she describes seeing a whale hunt on the Faroe Islands in the North Atlantic. This thought-provoking essay appears in ***Women on Nature*** – edited by Katharine Norbury – an enjoyable and eclectic collection of memoir, poetry, fiction extracts, diary entries, recipes and more that I have been dipping into all year. I have savoured reading the many ways women have engaged with and thought about nature since the 14th century, in their own words.

The film column

Working it out An enigmatic sci-fi horror sees William return home to recover after a terrible car accident leaves his world in pieces. Great performances and a chilling script make for an intriguing debut, says **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on Instagram at @simon_ings

SIGNATURE ENTERTAINMENT

Amelia (Ramona Von Pusch) and her son William (Tobi King Bakare)

Film
Cerebrum
Sebastien Blanc
Digital platforms from 3 July

Simon also recommends...

Books
A Book of Dreams
Peter Reich
John Blake
This 1973 memoir by Peter Reich beautifully captures a father-son bond forged at the edges of reality. His psychoanalyst father was Wilhelm Reich, later notorious for his discovery of (fictional) "orgone energy".

Chocky
John Wyndham
Penguin
Surely 12-year-old Matthew is too old to have an imaginary friend? John Wyndham gives late-1960s dinner-table anxieties a sly extraterrestrial spin.

A YEAR after the car he was driving span off the road and into a tree, William is shown into an almost empty room on the ground floor of a house. There is a camp bed and a TV. It isn't his old bedroom – it might not even be his home it is so anonymous – but it will have to do.

William is still learning to walk and talk again, and the stairs are too much. This is a shame because he wants to see his mother, who never comes downstairs to visit him and is, it seems, constantly "under the weather". William scribbles a message to Richard, the man who brought him here: "Is she angry?" Richard protests just that little bit too much.

Already we feel we shouldn't be watching, not because there is anything bad going on, but because the script, by first-time feature director Sebastien Blanc, absolutely refuses to acknowledge our presence.

The camerawork is no guide, either. Shot in the pseudo-factual style of a British soap opera, *Cerebrum* views everything with the same dispassion. No jump scares. No plangent chords. We will have to figure this out for ourselves.

And so we do. Richard is more than William's carer. The house indeed is (or was) William's family home. Richard is digging deep holes in the garden. And just where is William's mother? "You have no idea what I am doing to fix what you have done,"

> **"Shot in the pseudo-factual style of a British soap opera, *Cerebrum* views everything with the same dispassion"**

says Richard in a rare moment of lost temper, and astute viewers will have no difficulty predicting what happens next.

It is a gutsy move, placing suspense over surprise. We know our *Frankenstein*. We know what happens to the mad professor in the attic. We watch, with growing excitement and gathering horror, as the denouement approaches, and Ramona Von Pusch, playing Amelia, William's mother, gets the briefest moment in the limelight.

Tobi King Bakare's turn as William, damaged in both body and mind, is visceral to a fault. Best of all, he never plays for sympathy: William hates himself so much we rather hate him too, at least at first.

Steve Oram, who plays Richard, is a frequent presence on British television, but nothing prepares us for this performance. It is impossible to keep in mind that he is acting. Richard is a terrifying creation: a quiet, unimaginative man building his very own road to hell.

When the floodgates finally crack, and Richard sits William down for a spot of family therapy, things take a very dark emotional turn. "I want you to visualise what is troubling you," says Richard, "and then I want you to laugh openly at it." At which point half of me wanted to cheer, the other half to run screaming from the room.

Cerebrum isn't an important movie. It is a no-budget labour of love that gives writer-director Blanc something to talk about in pitch meetings. Structured around suspense, the film can't help but leave us disappointed in the final reel, though I can't help but feel any extra twists would have felt tacked-on.

The script, which gives a Black twentysomething white adoptive parents and then hands everyone plenty of conversational opportunity to drop themselves in it, suggests Jordan Peele's superbly queasy 2017 debut *Get Out* – but the threads here aren't gathered nearly so tightly or so cleverly.

Instead, watch *Cerebrum* for its performances, chillingly spare script and the trust it puts in its audience. ▮

LISA SHEEHAN

The end of obesity?

The next generation of weight-loss drugs may well be twice as powerful as Wegovy and could finally reverse the world's expanding waistlines. How do they work and what does the future hold, asks **Clare Wilson**

THERE are TikTok hashtags with millions of followers, endless column inches over celebrities' waistlines and streams of media coverage when trial results come out. It is rare that a new medicine gets so much attention. Then again, it is even rarer that a licensed drug causes safe and rapid weight loss with minimal effort.

A year ago, most people hadn't heard of semaglutide, a drug developed to treat type 2 diabetes around a decade ago under the brand name Ozempic. Then, in 2021, it was approved in the US as a weight-loss aid under the name Wegovy. The medicine can cause people to lose a whopping 15 per cent of their body weight.

The impact of this new class of medicines could be unprecedented – potentially bringing to an end the world's growing obesity epidemic. "I don't think it's fully sunk in yet," says Jonathan Campbell at Duke University in North Carolina, who investigates how these drugs affect the body.

For one thing, Wegovy was just the start. The next generation of these drugs is in development and will be cheaper, easier to use and, crucially, even more potent. What's more, emerging evidence suggests Wegovy and its ilk work better when given at a younger age, so doctors are exploring their use in teenagers and young children. This raises the prospect of switching from obesity treatment to prevention. "We have watched the obesity landscape change dramatically over the last 40 years," says Campbell. "Now, maybe we're at a turning point where that goes backwards."

The rise in obesity has been happening since about the 1970s in the US, with other nations soon following suit. Today, more than two-thirds of adults in the US and the UK have obesity or are overweight. The same pattern is being seen in any low and middle-income countries where people are shifting to Western lifestyles, and the number of people who are overweight is rising nearly everywhere.

> "We may now be at a point where the obesity trend starts going backwards"

The precise reason for this trend is still debated, but most agree it is probably something to do with changes to diet. Our early ancestors had to spend a large part of their waking life scrabbling to get enough to eat, coping with swings from famine to feast by hanging on to every calorie they could. As a result, our bodies are designed to store fat for a rainy day. Today, for most of the world, those rainy days seldom come and instead we live with an abundance of high-fat, high-sugar, highly processed foods. "In the US, roughly two-thirds of the population has some intrinsic susceptibility to become [overweight] if they're in an environment that predisposes to that," says Michael Schwartz at the University of Washington in Seattle, who researches the causes of obesity. "And our environment does predispose to that, based on the type of foods that are available, the cost of the food and the amount of physical activity [people do]."

Doctors may not agree on the causes of obesity, but they do agree on its alarming consequences. Being overweight predisposes people to a multitude of other health problems, ranging from heart attacks to worn-out hips and knees, fatty livers and asthma. It also makes the body less sensitive to the hormone insulin, which regulates blood sugar, often leading to type 2 diabetes, where blood sugar gets too high.

Numerous initiatives have been trialled in order to slow the obesity juggernaut, with tactics including taxes on unhealthy food and drinks, changes to food labels, junk food advertising bans and teaching schoolchildren about healthy eating. Nothing has worked.

This shouldn't be surprising, considering that weight control is so hard at an individual level. Most people who lose weight eventually regain it and often end up heavier than when they started. By some estimates, only a quarter of people who lose weight avoid regaining it after five years (see "Keeping it off", page 35).

Until recently, there was little doctors could do to help unless someone was willing to have weight-loss surgery, such as a gastric bypass. This operation can be very effective, with people typically losing around 30 to 40 per cent of their weight within about two years. But it is a major procedure, with the associated risks, and to avoid malnutrition afterwards, ›

people have to take several vitamin or mineral tablets daily for the rest of their lives. The operation is taken up by fewer than 1 in 100 of those eligible in most countries.

A medicine that could do the same as surgery would be a different ball game. Semaglutide drugs, which are given through injections, exploit the fact that the body releases a slew of hormones in response to eating, including one called GLP-1. Its effects include triggering the release of insulin, which is helpful for treating diabetes, but also slowing food passage through the gut – which leads to feeling full – and acting on the brain to suppress appetite.

Weekly jab

The drugs mimic this hormone, and when trialled as a treatment for blood sugar control in people with diabetes, they led to lower appetite and weight loss. Unsurprisingly, the pharmaceutical industry leapt to investigate their use explicitly for weight loss in people without diabetes. In fact, these medicines generally cause more weight loss when used in this group – perhaps because people with diabetes are less sensitive to insulin's effects.

The first GLP-1 mimics were less appealing as they had to be injected once or twice daily. But Wegovy only needs to be administered once a week. The impressive 15 per cent weight loss happens within about a year, and then plateaus and is maintained at that level if people keep taking the drug. By comparison, most weight-loss interventions – such as diet and lifestyle counselling – would be considered successful if someone lost around 5 per cent of their body weight.

The injections are no magic wand and people still need to try to eat healthily and in moderation, says Michael Lean at the University of Glasgow, UK, who has prescribed them for many of his patients. But when people do so, their efforts are no longer sabotaged by constant hunger pangs. "They take away the drive to eat," says Lean. "They are very, very effective."

Wegovy doesn't suit everyone. Nausea and diarrhoea are the most common side effects, but are usually transient and can be alleviated by starting with a smaller dose and raising it slowly, says Lean. There is variability in how people respond and, for unknown reasons, some people barely lose any weight, but they are in the minority – about 1 in 10 people, according to one study.

Another caveat is that if people stop the injections, slowly but surely the weight returns. According to one trial, once people stop, they regain two-thirds of the lost weight over the following year. Essentially, that means taking Wegovy is a lifetime commitment.

What kind of impact would a 15 per cent weight loss have? If a person is very heavy, it won't be enough to make them slim, but if someone begins treatment while hovering just on the threshold of obesity – with a body mass index (BMI) of 30 – it would lower their BMI to 25.5, within a hair's breadth of the healthy weight category, defined as a BMI of 25.

This means that to truly reverse the growing obesity trend, we need more. And that is where the new generation of drugs comes in. GLP-1 is just one of several hormones released after eating. Others include GIP and PYY, made by the gut, and glucagon and amylin, produced by the pancreas. At least some of these seem to have similar effects to GLP-1 in terms of quelling appetite and slowing digestion. Multiple drugs now in development target the natural receptors of two or three of these hormones in concert, with these medicines known as dual and triple agonists, respectively.

> "The drugs take away the drive to eat. They are very, very effective"

The closest to the clinic is one called tirzepatide (branded Mounjaro), which mimics both GLP-1 and GIP and is already used as a treatment for diabetes. When given to people without diabetes, it leads to 21 per cent weight loss on average, according to a large trial that was reported last year.

Then there is CagriSema, a mix of semaglutide and an amylin mimic. In one early-stage trial, it caused weight loss of 16 per cent after eight months – but this was carried out in people with diabetes, suggesting there would be greater weight loss in those without the condition.

Another contender is a triple agonist called retatrutide, which stimulates receptors for GLP-1, GIP and glucagon. Nicknamed "Triple G", this has led to an average 24 per cent weight loss in people with obesity after 48 weeks, with the trend over time suggesting there would be further weight loss if the trial had continued for longer. Manufacturer Eli Lilly has predicted

DPA PICTURE ALLIANCE/ALAMY

Ozempic and Wegovy are fast becoming household names

JORGE FERNANDEZ RUIZ/ECPO

Healthy habits are an adjunct to the weight loss drugs

that the percentage weight loss will be in the high 20s and it has been touted as the most effective weight-loss drug to date. "When you combine these agonists, you start to get into additive effects," says Aaron Kelly at the University of Minnesota in Minneapolis. "We might get near to 30 per cent."

If the predictions are right and a drug becomes available that can result in weight loss of 30 per cent, the impact would be profound. That would lower someone with a BMI of 35, well into the obese category, down to 24.5, classed as being in the healthy weight category. "We start getting into the range of [weight-loss] surgery," says Kelly. "It's transformative."

At the moment, price is the main barrier to these hormone mimics. Injections of Wegovy can cost several hundred dollars a month in the US, depending on insurance coverage. In other countries, the price can be lower thanks to partial state reimbursement of drug costs, but it can still be over £100 a month to the user and most countries are saying that only the people who are heaviest should be eligible for such financial help. In almost every country, whether healthcare comes through private insurance or state-backed schemes, policy-makers are fearful of the potentially large sums involved in medically treating such a common condition.

The funding question is mired in long-standing societal judgements about fatness and the use of weight-loss drugs, in a way that doesn't happen for people who need other lifelong medication, says Paul Gately at Leeds Beckett University in the UK, who runs an obesity clinic. "There's an attitude of: it's their own fault, they need to sort themselves out, they're just lazy and greedy."

Cheaper options?

However, in the longer term, the cost-benefit balance is likely to tilt more in favour of the drugs. The price of new medicines tends to fall over time, especially as competitors arrive and then, as patents expire, cheaper generic versions come to market.

Another game changer would be hormone mimics that could be taken orally, currently in trials. These would be easier to administer and could be cheaper than injectable versions. While a low-dose tablet form of semaglutide has been available since 2020, it was announced in May that a more potent, higher-dose version works as well as Wegovy injections, although its price hasn't yet been set.

Healthcare funders will look more favourably on these medicines if firms can produce evidence that they will save money overall by alleviating conditions such as heart disease and joint damage. One large study from 2016 found the rate of heart attacks and strokes was cut by a quarter in people with diabetes after two years of semaglutide injections and other trials looking at different health outcomes are ongoing.

So far, the focus has been on treating people who are already obese. But the success of Wegovy has prompted the question of whether we could prevent people from becoming so heavy in the first place.

Last year, a trial showed that Wegovy is at least as effective in teenagers as in adults, and perhaps more so. Weight loss in drug trials in teens is judged slightly differently than in adults, because their weight should nudge up over time as they grow taller. One measure is the difference between the percentage of body weight lost in the treatment group and those who got the placebo jabs. In what was the first trial of semaglutide in 12 to 18-year-olds, this ›

Keeping it off

Most people who lose weight by going on a diet eventually put it all back on. "It's a biologically defended level and if you try to change it by restricting calories, it tends to be resistant to change," says Michael Schwartz at the University of Washington in Seattle.

One reason is that dieting causes people's metabolism to slow, and this can persist for years after the initial weight loss. Researchers have also measured differences in the levels of hunger hormones including leptin and ghrelin.

The brain changes too, notably the hypothalamus, which is important in controlling appetite. Animal research shows that brain cells in that area called AgRP neurons – which normally drive appetite when blood sugar gets low – become overactive after weight loss.

Drugs like Wegovy dampen activity in these neurons, which helps explain why people avoid the normal hunger response to weight loss if they are taking these medicines, says Schwartz. "But if you stop taking the drug, all of a sudden, the brain is saying: wait a minute, my weight is way below where it's supposed to be."

figure was 17 per cent, while in a similar trial in adults the equivalent figure was 12 per cent.

There is good reason to consider earlier treatment, says Kelly. It seems to be harder for people to lose weight than it is for them to avoid gaining it in the first place. It may therefore be better for teenagers who are overweight to begin taking weight-loss drugs earlier in life than to wait until they are obese as adults. "If you allow the pounds to go on, it's harder to draw back," says Kelly. In other words, avoiding severe obesity is better than trying to reverse it.

DREAMER COMPANY/SHUTTERSTOCK

Without medication, people tend to have bigger appetites after weight loss

Early start

Why stop at 12-year olds? Pharmaceutical firm Novo Nordisk is about to start a further trial in children with obesity as young as 6. "Obesity does start very early," says Daniel Weghuber at Paracelsus Medical University in Salzburg, Austria, who is involved in this trial. "There's data showing that 80 per cent of those living with obesity during adolescence had already been living with obesity when they were preschoolers. It tracks from childhood to adolescence to adulthood."

In May, Novo Nordisk opened a research department specifically focused on obesity prevention rather than treatment. The firm declined to answer questions from *New Scientist* about whether this involves GLP-1 mimics or other drugs, but has stated that the aim is to interrupt biological processes that promote weight gain before people get to the point of being obese.

What might such processes be? There is growing evidence that people with obesity have long-term changes to appetite-regulation networks in the brain that mean it takes more food to make them feel satisfied. After a meal, for example, they have less activity in the "reward network" involving the signalling chemical dopamine. In theory, this could have been the cause of obesity rather than the consequence, but the fact that this difference at least partly disappears two years after people lost a lot of weight with gastric bypass suggests it is more likely to be a consequence, says Mireille Serlie at Amsterdam University Medical Centers in the Netherlands, who was involved in this research. And it could help explain why it is so hard for most people to lose weight and keep it off.

If obesity does change the brain, offering people medication before they get very heavy could let them maintain a healthier weight on a lower dose. "You might want to prevent people from gaining more weight and getting in more trouble," says Serlie. She stresses, however, that the science isn't yet settled on how permanent the brain changes are, nor do we know how well the hormone mimics work in the long term: "Are they going to be effective after five years? Ten years? We don't know."

> "We should get tough on the food industry rather than use drugs as a quick fix"

There could be other downsides to the widespread use of weight-loss drugs from an early age, says Gately – for example, it could disincentivise young people from adopting healthy habits around diet and exercise.

Despite such concerns, if the cost does fall, it is possible that wide use of these medications will change the curve of the obesity epidemic. There are already signs that policy-makers are waking up to their potential impact, even in England's cost-conscious National Health Service (NHS). The initial decision on Wegovy in England was to restrict its NHS use to people attending hospital weight-loss clinics. But, in June, a large pilot scheme was announced to broaden access by letting family doctors prescribe it. A UK government statement said this would lead to "wider economic benefits".

But there is already pushback. Anorexia charities have flagged that the weight-loss drugs could be harmful to those with eating disorders. And campaigners say that governments should be getting tougher on the food industry to tackle the root causes of obesity, rather than using prescription medicines as a quick fix. "As a doctor, I would always try and avoid drugs if I possibly could," says Roy Taylor at Newcastle University, UK, who has led research showing that people can put type 2 diabetes into remission if they manage to lose enough weight through dieting.

However, Campbell sees the benefits of being more proactive. He makes the analogy with modern dentistry aiming to keep people's teeth in good shape through preventive measures such as regular descaling and putting fluoride in the water. "I don't know if obesity will become the same, where you can treat it in a prophylactic way, rather than a reactive way," he says. "But it is exciting to envision a world where there is effective management of obesity, simply because these drugs are so efficacious. At the moment, we are just starting to scratch the surface." ▮

You should always consult your doctor before taking or changing medications.

Clare Wilson is a senior medical reporter for *New Scientist*

A chemical crisis

One of the most crucial concepts in chemistry is disintegrating into meaninglessness. But incredible discoveries could arise from the chaos, says **James Mitchell Crow**

IN 1862, a chemist nodded off in front of a fire and began to dream. August Kekulé had been pondering the most pressing question in his field at the time: what was the chemical structure of a curious compound called benzene? As Kekulé slumbered, the atoms danced in his mind and organised themselves into a vision of a snake eating its own tail. That was it! The carbon atoms of benzene were joined together in a ring.

It may not have quite the drama of Archimedes running through the streets naked, but, in its own way, it was a eureka moment. Benzene turned out to be the archetype of a compound with a property called aromaticity, now recognised as among the most important ideas in chemistry. Instead of standard bonds, aromatic molecules contain dynamic, ring-shaped bonding that endows them with incredible stability and a raft of other handy properties. Two-thirds of known molecules are aromatic, including components of DNA and proteins, the building blocks of life.

Recently, though, the dream has turned into a nightmare. We have been discovering new kinds of aromaticity everywhere – to the point where there are dozens of competing definitions. It may be one of the most important concepts in chemistry, but no one can agree on what it means any more. It isn't all bad news, though. The confusion has prompted chemists to think deeply about aromaticity and this has led to a raft of new ideas about how we can put it to use.

Chemistry is the science of atoms, bonds and molecules and the craft of cajoling those molecules to react with one another. Today, the fruit of that labour is all around us, in the form of the wondrous substances that make up everything from clothes to toothpaste. And the ground rules of chemistry are well established. We know, for instance, that basic chemical bonds involve two atoms sharing a pair of electrons.

But there are molecules that don't play by the usual rules. The biggest group of these first came to light in 1825, when Michael Faraday was experimenting with the compressed gas used to light the lamps at the Royal Institution in London where he worked. He managed to isolate a sweet-smelling substance called benzene. This was confusing stuff, chemically speaking. Besides its sweet smell, the molecule's defining characteristic was its strong bonding, which made it unexpectedly stable. Soon, other molecules with this aberrant behaviour were found and they became collectively known as "aromatics" in a nod to the characteristic aroma of several founding members.

By careful experimentation, chemists gleaned that benzene molecules were composed of six carbon atoms and six hydrogen atoms. That was odd, since most compounds of hydrogen and carbon had roughly twice as many hydrogen atoms as carbon ones. And so, for almost 40 years, the structure of benzene remained enigmatic – until Kekulé published his ring idea a few years after he had dreamed it up.

Strong and stable

Later generations of researchers deduced that Kekulé was more or less right. Benzene is a flat, hexagon-shaped ring of six carbon atoms with a hydrogen atom attached to each. Crucially, not all the electrons in the molecule are shared between two atoms. Some, known as pi electrons, are "delocalised" over the entire ring, meaning they can flow around it. It is this factor that gives benzene its famous stability. Other aromatics, which might have different sized rings, for example, also have these delocalised electrons.

A century or so ago, then, everything seemed to be falling neatly into place. A molecule was aromatic if it was flat, made of ›

carbon atoms arranged in a ring structure, and contained the right number of pi electrons. The "right number" was defined by Hückel's rule, named after chemist Eric Hückel, who worked on the idea in 1931. Technically, the rule says a ring of atoms is aromatic if it is flat and has 4n + 2 delocalised electrons (where n is any positive whole number). In practice, this means rings made of six, 10 or 14 carbon atoms, for example, can be aromatic, but rings of say four, eight or 12 can't.

Alas, things wouldn't remain so straightforward. "In the second 100 years of aromaticity research, there was this explosive development in what we understand as aromaticity," says computational chemist Judy Wu at the University of Houston, Texas.

It was quickly realised, for instance, that one of the carbon atoms in benzene could be swapped for one of a few other elements, such as nitrogen, without losing its stable aromatic character. Flatness was another factor to be questioned. In 2003, Rainer Herges at the University of Kiel, Germany, and his colleagues created a molecule shaped like a Möbius strip – a twisted ring that is far from flat – that nonetheless had those delocalised electrons. This Möbius molecule also trampled on Hückel's rule. The twist in the ring skews the orbits of the electrons so that, in these systems, rings with 4n delocalised electrons are stable.

Do you even need a ring? One of the more recent actors on the aromaticity stage is buckminsterfullerene, a molecule that looks like a rough sphere made of hexagons and pentagons, akin to a soccer ball. When Harry Kroto discovered it in 1985, he suggested it might be the first spherical aromatic molecule. He was close, says Miquel Solà at the University of Girona, Spain. The molecule itself "is not particularly aromatic, but if you remove 10 of its electrons, it is very aromatic". With that magic number of delocalised electrons, "buckyballs" gain a stabilising coating of these charged particles that circulate in a sphere rather than a ring. Andreas Hirsch at the University of Erlangen-Nuremberg in Germany and his colleagues devised a set of rules to capture this aromaticity subtype in 2000.

But whether these unusual molecules are truly aromatic is to some extent a matter of opinion. "Aromaticity is not like melting point, there is no single, direct experiment I can do to measure how aromatic a molecule is," says Solà.

That said, one indirect method for defining aromaticity quantitatively has gained some traction. If you put an aromatic molecule in a magnetic field, the delocalised electrons will start to circulate around the ring, generating a tiny magnetic field. This then affects how other nearby atoms show up when measured using a technique called nuclear magnetic resonance spectroscopy.

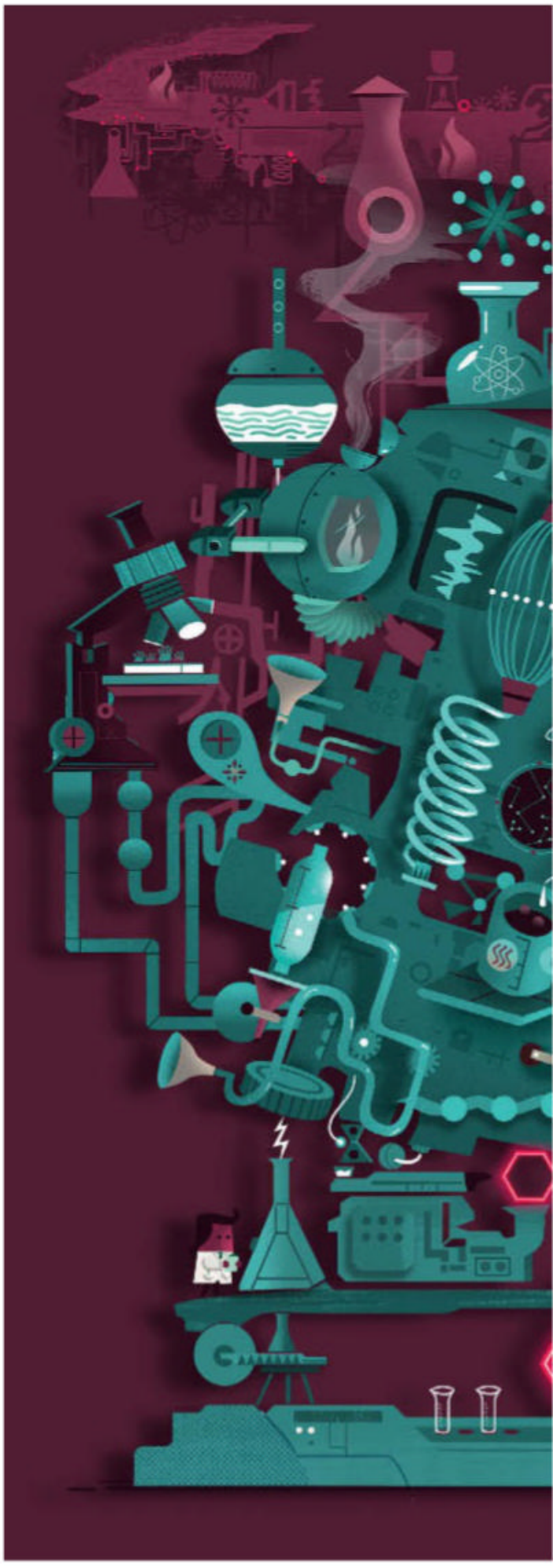
It is usually too finicky to measure this effect in practice. But in 1996, Paul Schleyer and his colleagues at the University of Erlangen-Nuremberg developed a computational method that simulates the experiment and spits out a single value that indicates how aromatic any given molecule is. It is a neat trick that has helped bring some order to the debates around aromaticity. But it is just a simulation, not a direct observation. And for very complex molecules even the simulations cease to work.

Strange prisms

Meanwhile, reports of unusual aromaticity have kept coming. In 2022, Stefanie Dehnen at the University of Marburg, Germany, and her colleagues claimed to have found a new form of this bonding in a prism-shaped cluster of bismuth atoms. It was bold, given that this molecule had no carbon atoms at all or any pi orbitals. Dehnen's reasoning was that the cluster's electrons were being spread across the molecule in an orbit that had a different geometry to the classic pi orbitals and this explained its unusual stability. "I'm not particularly sure that this claim is correct," says Solà, who has co-written a counter-argument to the claim with Dariusz Szczepanik at Jagiellonian University in Kraków, Poland.

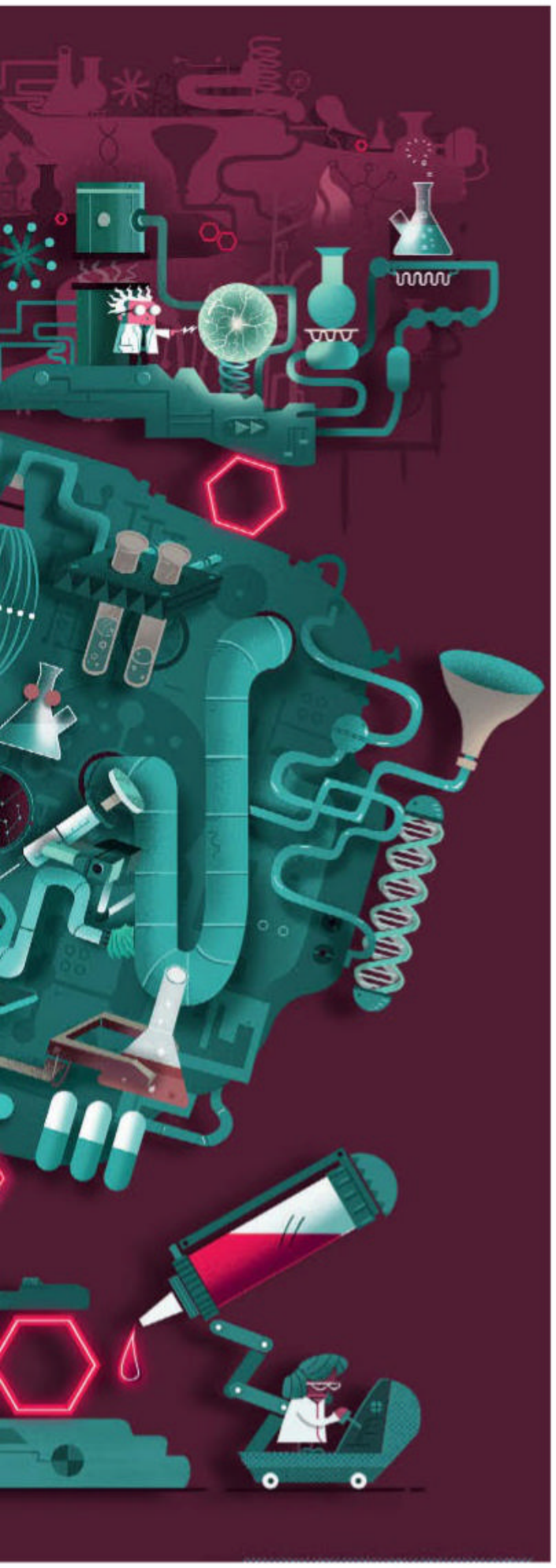
In all, more than 45 subtypes of aromaticity have now been put forward, leaving chemists despairing. In one recent review article, a number of them declared the ruckus around aromaticity had reached crisis point.

For some, it is time to move on. We could keep expanding the definition of aromaticity, but that would leave an already vague concept next to meaningless. This is certainly Wu's view. She says the question we need to focus on now is how to make use of aromaticity. Ranana Gershoni-Poranne at the Technion -



GRAHAM CARTER

"Aromaticity may be a crucial concept in chemistry, but no one can agree what it means"



Israel Institute of Technology shares that view.

Chemists have, of course, made use of aromaticity to create strong and stable molecules for years – but that barely scratches the surface of its useful properties. One neat thing about aromatic molecules is that they can be joined together like beads on a string. The delocalised electrons can then escape their rings and spread out along the string. The result is a material that conducts electricity like a wire, but is soft and stretchy. "They're lightweight and made from atoms that we have in abundance on Earth, rather than from metals that we might have a limited supply of," says Gershoni-Poranne.

But rather than simply use them as stretchy wires, she and her colleagues hope to harness them in a new kind of silicon-free computer chip. Computers require semiconductors, materials whose electrical conductivity can easily be switched on and off. "We're using artificial intelligence machine-learning models to try to design better semiconducting organic molecules," she says. Her models are already beginning to identify aromatic structures with promising semiconducting properties. Such systems might be used, for example, as smart biosensors that could be placed in the body and that biodegrade after use.

Aromaticity is also being deployed in medicine. Aromatics are great at absorbing light and, if you decorate the rings in different ways, for example by attaching different groups of atoms, that changes the wavelength of light they absorb. This includes wavelengths that penetrate the body. One application involves sealing a drug inside an aromatic "photocage" that can be cracked open with light. Doctors could shine light on a particular location, such as the site of a tumour, to release the drug. In a recent animal study, cancers were selectively targeted in this way.

Jekyll and Hyde

We have long known that the superpower of aromaticity also has a dark side: antiaromaticity. Find ways to manipulate this alter ego and it could help tackle one of the world's biggest problems: climate change.

Antiaromatic molecules are rings with delocalised electrons, but in this case they are less, not more, stable than expected. Take the simplest antiaromatic, a ring of four carbon atoms called cyclobutadiene. It is so reactive that it took chemists 60 years to find a way to trap it and prove it could really exist.

If the extreme reactivity of antiaromatics can be corralled – say by bonding them to their aromatic counterparts – they can be useful. Increasingly, that is possible. In 2019, Jorge Juan Cabrera-Trujillo and Israel Fernández at the Complutense University of Madrid in Spain ran calculations showing stabilised antiaromatics react rapidly with carbon dioxide, offering a way to capture the greenhouse gas.

We have also recently begun to master the art of converting aromatic molecules into antiaromatic ones, like turning Jekyll into Hyde. When an aromatic molecule absorbs light of a suitable wavelength, the captured energy can kick one of its delocalised electrons into a high-energy orbit, which makes the molecule antiaromatic. When benzene becomes antiaromatic, it rearranges its bonds to form a molecule that is under so much strain that it explodes at the slightest scratch.

Aside from explosives, the power to flip a stable aromatic molecule into an unstable antiaromatic one offers almost endless possibilities. Chemists have already suggested using light-triggered antiaromaticity to break down drug molecules in wastewater to eliminate their environmental damage, for example, or as a controlled way to depolymerise plastics back into their starting materials, ready for reuse.

By the same token, molecules that are normally antiaromatic become aromatic when they absorb light. This could be ideal for building a special type of solar cell that makes use of a process called singlet fission. Singlet fission occurs when a molecule that has just captured a photon of sunlight interacts with and passes some of that captured energy to a neighbour. Molecules that become aromatic when they absorb light will be more stable in that state and have a greater chance to pass on energy. "With one excitation, you generate two excited states – two for the price of one," says Henrik Ottosson at Uppsala University in Sweden. In other words, a singlet fission solar cell could generate almost 50 per cent more power from the same amount of sunlight.

Two centuries after benzene's discovery, defining the concept of aromaticity looks more tricky than ever. "I'm not sure if we will ever solve it," says Gershoni-Poranne. But for those interested in real-world applications, the new attention on aromaticity may ultimately prove to be a winning situation. ▮

James Mitchell Crow is a science writer based in Melbourne, Australia

The weird laws of life

A handful of arcane rules describe the way evolution plays out on the ground, in trees and in the seas. They also offer clues about how animals might adapt to a warming world, says **Colin Barras**

JASON FORD

A RAFT full of elephants and rats gets stranded on a remote island. The animals survive and reproduce. But as the generations pass, something odd happens: the elephants shrink to the size of Shetland ponies and the rats grow to the size of cats. They have found themselves at the mercy of one of evolution's weird rules.

Most of us are familiar with evolution by natural selection, in which species change and diverge over time as those that successfully adapt to their environment pass on the genes that helped them flourish. What you might not be aware of, however, is that evolution's work is in some places governed by a handful of rules that can have some pretty surprising results.

Near the poles, for instance, animals tend to grow larger than you might expect. In the tropics, meanwhile, birds often have strikingly big beaks, while their feathers may be unusually dark. And on islands, evolution gets very peculiar indeed – which explains why Sicily in Italy was once home to dwarf elephants just a metre tall and why rats in New Zealand are about twice the size of their mainland counterparts.

Many of the biological "rules" behind these patterns were proposed in the 19th century and it hasn't been entirely clear whether they stand up to modern scrutiny. In the past decade, however, biologists have not only confirmed that many of these rules hold true, but also revealed the intriguing details of how and why they work. In some cases, researchers have even begun to use the rules to predict how species will evolve as the world warms.

Cope's rule:
The bigger, the better

Edward Drinker Cope knew a thing or two about big beasts. A palaeontologist famed largely for his role in discovering a host of huge dinosaurs in the late 19th century, Cope also analysed North America's ancient mammals and spotted a trend in the fossil record: mammals evolve larger body sizes over geological time.

The idea has since been broadened out to cover all sorts of life on land and in the sea, but it has been controversial. The late palaeontologist Stephen Jay Gould thought we were just imagining it because of our tendency to fixate on big things and ignore little ones. But in 2015, a team led by Jonathan Payne at Stanford University in California put it to the test using a vast data set of 17,000 different types of marine animal that existed over the past 542 million years. The upshot was that the rule is real, in the marine realm at least: all manner of sea creatures, from cephalopods to fish, have tended to become larger as the aeons have passed.

Why remains a mystery. There appears to be some sort of inherent advantage to being large, but we don't know exactly what it is. "My sense is it's more about there being empty ecological space for large species," says Payne. "There are things you can do when you're big that no one else is doing." Some whales, for instance, can hunt cephalopods that are too large for other animals to eat, so they face less competition.

Cope's rule, then, suggests the oceans may continue to be a good place for giants to live far into the future. And while predicting what those giants will look like isn't easy, Payne suggests it may be no coincidence that the very largest marine creatures – from whales to marine reptiles – are or were air breathers. "There is just so much more oxygen in air than in water, and air is less viscous so it's easier to breathe," he says. "If you can get oxygen to your tissues easily, it makes it easier to get bigger."

Allen's rule:
Shape-shifting to keep cool

In the 1870s, zoologist Joel Asalph Allen noted something unusual about the birds and mammals of North America. Roughly speaking, as you travel north, hares and foxes have ever-shorter ears, while crows and woodpeckers have ever-shorter beaks. We now know that Allen had stumbled on a global rule linking the size of bodily appendages to temperature. "Just look at the toucans," says Matthew Symonds at Deakin University in Australia. The toco toucan of the Amazon has an enormous beak. "But a mountain toucan from the cooler Andes has a [relatively] little, stubby beak," he says.

The explanation for Allen's rule is that tropical animals, which are at risk of overheating, evolve big appendages with a high surface-area-to-volume ratio and use them to more efficiently dump body heat into the environment. Polar species, by contrast, need to conserve body heat, so their appendages are smaller. ›

Predicting evolution

Can we use the patterns of evolution described by "biological rules" (see main story) to predict the appearance and behaviour of animals in the future?

Some argue that it could be relatively easy. "If climates become warmer by this or that amount, we can predict something about how certain groups of animals will evolve," says Mike Benton at the University of Bristol, UK. In 2020, he and Li Tian at the China University of Geosciences, Wuhan, used a relatively straight reading of the rules to suggest most birds and mammals may evolve some combination of smaller bodies, larger appendages and darker fur or feathers in the future.

Matthew Symonds at Deakin University in Australia, however, has reservations. "Does changing its appearance help an animal cope with climate change? Or does it screw up the rest of its internal biology and lead the animal into a decline?" For instance, a bird may have adapted to forage for insects using a small, delicate beak. If, in a warmer world, it follows Allen's rule – which says hotter conditions favour bigger appendages – and evolves a larger beak, it may have trouble finding food.

"One thing we're trying to do at the moment is look at the way animals are changing and see how that translates into population numbers," says Symonds. "Even within a species, there may not be a uniform way of responding to climate change."

But there are other ways for animals to lose or retain body heat. In the 1840s, biologist Carl Bergmann noted that species tend to have smaller bodies in warmer climates and larger ones in colder climates – a pattern that has been suggested to hold true for all manner of animals, from blue jays to salamanders. Intriguingly, Bergmann's rule has a similar explanation to Allen's rule. A tropical animal that needs to lose body heat can boost its surface-area-to-volume ratio by simply evolving to be smaller.

Earlier this year, Symonds and his colleagues published an analysis of the interplay between both rules across 99.7 per cent of the world's bird species. "The two rules interact," says Symonds. For instance, Bergmann's rule predicts that species should shrink as the temperature rises. But large birds can stay large, violating Bergmann's rule, if they evolve particularly large appendages to enable heat loss.

And there is a final twist. As the world warms, Allen's rule may cause animals to grow larger appendages to stay cool. But eventually, air temperatures in some regions will exceed animal body temperatures – whereupon the rule no longer applies. "At that point, having a big beak becomes a liability because it actually absorbs energy from the environment," says Symonds. So, while appendages may grow in the short term, they may shrink again in the longer term.

Foster's rule:
The strange power of islands

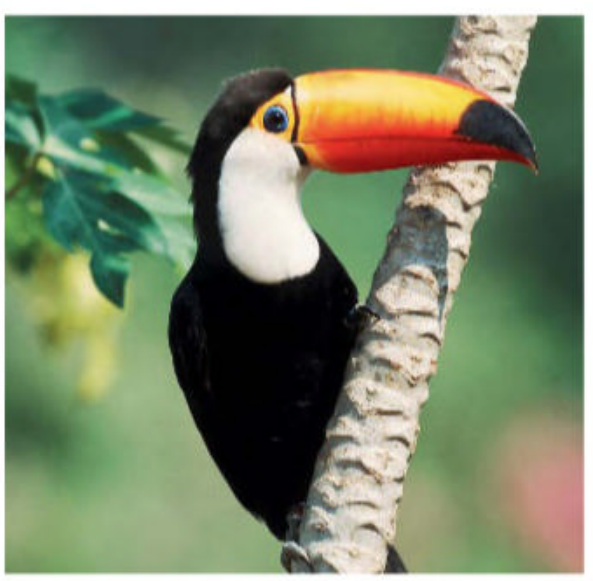
The time Charles Darwin spent in the Galapagos Islands was crucial in the development of his theory of evolution by natural selection. But there was something about islands that he didn't notice: animals living on them often evolve to be unusually large or small.

There is a good reason why Darwin was unable to spot what is now known as the island rule or Foster's rule, named after J. Bristol Foster, who wrote about it in the 1960s. It only becomes obvious once you can reconstruct the evolutionary relationships between species on islands and on continents. Doing so suggests that members of large animal species that become isolated on islands tend to shrink, while small animal species tend to grow. The kakapo, for instance, is a large flightless parrot in New Zealand that evolved from smaller ancestors – while some Indonesian islands are home to Burmese pythons that are half the size of their 5-metre-long relatives on the mainland.

However, critics argue that size changes are just as likely to occur on continents, meaning the island rule only exists if you cherry-pick the data. "That's what intrigued me and made me want to investigate," says Ana Benítez-López at the Doñana Biological Station in Spain. For a paper published in 2021, she and her colleagues analysed body size data for more than 1000 species of island-dwelling animals and a roughly similar number of their continent-dwelling relatives to assess the level of support for the rule. They concluded that the island rule holds widely among extant mammals, birds and reptiles. What's more, the effect is more pronounced on smaller, more remote islands.

There are probably several reasons why the rule exists, says Benítez-López. A small island might not have enough food to sustain a population of large animals, for instance, making it more beneficial for them to shrink. Islands may also be free of predators, however, and some ecologists argue that this reduces the pressure on small animals to hide – so they grow larger, as this helps them compete better for food or mating partners.

Benítez-López also points out that the mysterious island rule is just one part of a broader phenomenon called the island syndrome. In the absence of land predators, island birds, for example, tend to evolve into



ROLF NUSSBAUMER PHOTOGRAPHY/ALAMY

ANDY ROUSE/NATUREPL

The toco toucan (left) has a bigger beak than the mountain toucan

flightless forms and often lose their fear of predators, rendering them tame. This helps explain why island species can be particularly vulnerable to extinction by hunting. "The dodo couldn't fly, and it was easy for humans to catch," says Benítez-López.

Van Valen's law:
Inescapable extinction

In the 1970s, the late biologist Leigh Van Valen reached a surprising conclusion: a species that has been on Earth for a few million years, proving itself to be a successful survivor, is just as likely to go extinct as a species that appeared just a few thousand years ago. Van Valen came up with an explanation for this "law of constant extinction", or Van Valen's law. He argued that a species can never improve its survival odds because it is always in competition with other species. Cheetahs, say, might evolve to run faster, but because the antelopes they hunt are also evolving to run faster, cheetahs don't become more likely to catch the prey they need to survive.

The rule might seem even more surprising given that, although a new species is typically confined to a handful of individuals living in a small area, its population then expands such that it might comprise millions of individuals across an entire continent. How can it always remain just as likely to vanish?

A few years ago, Indrė Žliobaitė at the University of Helsinki, Finland, and her colleagues sought to address this question. They built a computer model that shows extinction rates remain the same because of an interplay between biological competition and non-biological factors – natural disasters or climate change, for instance.

A newly evolved species might carry a new innovation in the way it feeds or moves that means it faces relatively little competition. But because the population is small and confined to a tiny geographical area, it is at heightened risk of extinction from local events, such as a volcanic eruption. In contrast, a mature species spread across a wide area is at less risk from a localised natural disaster. Then again, if that species is no longer largely isolated, as time passes it faces an ever-greater risk of extinction through biological competition as new species evolve. The threat can even emerge from related species: for instance, as modern humans spread around the world, they may have contributed to the extinction of many ancient human species.

ALEX MUSTARD/NATUREPL.COM

Blue whales are the largest animals that have ever lived

Žliobaitė and her colleagues suspect their work might even offer us insights into society. They recently began to explore whether their computer models can explain the rise and fall of industrial companies, human languages or even music genres. "We want to know how entities replace one another," she says.

Gloger's rule:
A duller future?

Species at the equator tend to be darker in colour than their relatives nearer to the poles. For instance, *Drosophila melanogaster* flies in sub-Saharan Africa are darker nearer the equator. Constantin Gloger was one of the first biologists to notice this, in the 1830s. But quite why this pattern exists is still up for debate.

A 2019 study reviewed the evidence and suggested it may be a side effect of evolution. The idea is that, since parasites and pathogens are more numerous in warm and humid habitats, animals living nearer the equator evolve to have stronger immune systems than those living elsewhere. By chance, the immune system genes are linked to those coding for darker-coloured bodies.

But that isn't the only reason why colour might vary with latitude. The tropics also typically receive more ultraviolet radiation from the sun than areas nearer the poles, says Matthew Koski at Clemson University, South Carolina. In principle, then, some species nearer the equator might be darker because they carry UV-absorbing pigments that protect biological tissue from radiation damage.

In 2015, Koski and his colleague Tia-Lynn Ashman at the University of Pittsburgh, Pennsylvania, revealed that this may be the case for a plant called silverweed (*Argentina anserina*). Although its flowers appear yellow to our eyes, under UV light they have a black "bullseye" due to the presence of UV-absorbing pigments – and the bullseye is larger for flowers growing nearer the equator.

This clear latitudinal pattern might break down in future because shifts in the pattern of cloud cover induced by climate change could alter the levels of UV radiation reaching Earth's surface. A 2020 study offers evidence that plants in different regions can change the appearance of their flowers rapidly when conditions shift. The worry is that this might confuse insect pollinators as they forage.

Already, Koski and Ashman have demonstrated that some insects are less likely to visit flowers with larger bullseyes, suggesting such flowering plants may go unfertilised. "That's not great for plant reproduction," says Koski. More broadly, it might be an ominous sign for the ecosystems across the world that ultimately rely on the success of plants. ▮

Colin Barras is a science writer based in Ann Arbor, Michigan

The back pages

Puzzles
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Mathematics of life

Escape the labyrinth

You thought the maze looked fun, but now you can't find your way out. Luckily, maths is here to help, says **Katie Steckles**

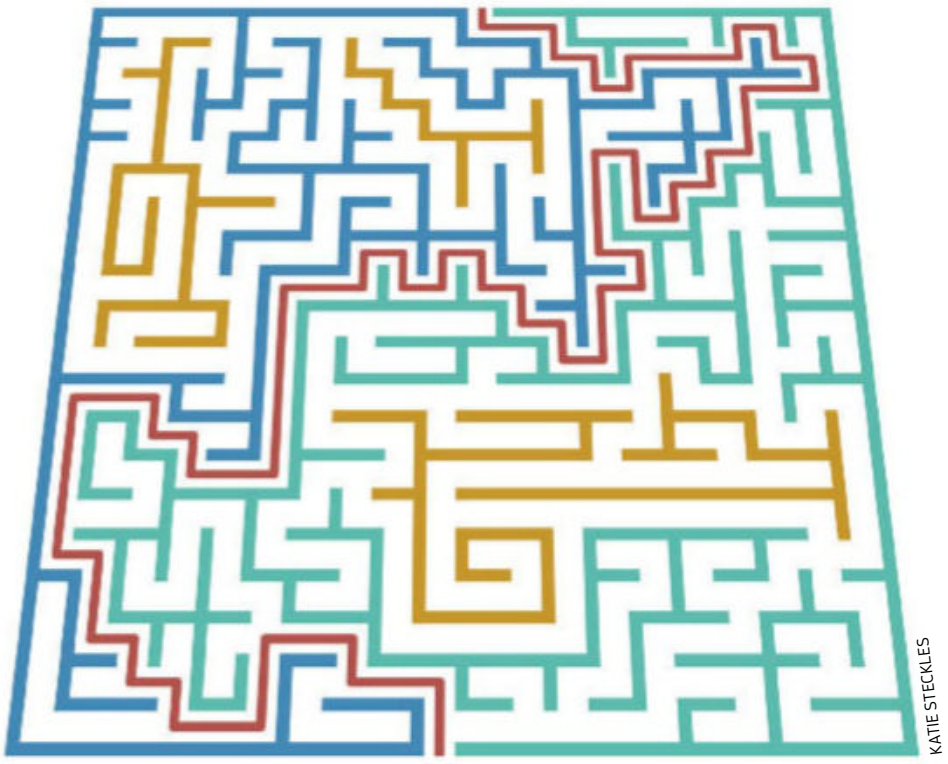
Katie Steckles is a mathematician, lecturer, YouTuber and author based in Manchester, UK. Follow her @stecks

GETTING lost in a maze is no fun, and on that rare occasion when you find yourself stuck in one without a map or a bird's-eye view, it can be difficult to choose which way to go. Mathematics gives us a few tools we can use – in particular, topology, which concerns shapes and how they connect.

The most devious mazes are designed to be as confusing as possible, with dead ends and identical-looking junctions. But there is a stunningly simple rule that will always get you out of a maze, no matter how complicated: always turn right.

Any standard maze can be solved with this method (or its equivalent, the "always-turn-left" method). To do it, place one hand on the wall of the maze as you go in, and keep it there. Each time you come to a junction, keep following the wall – if there is an opening on the side you are touching, take it; otherwise go straight. If you hit a dead end, turn around and carry on.

The reason this works is because the walls of any solvable maze will always have at least two distinct connected pieces: one to the left of the optimal solution path (shown in red), and one to the right. The section of wall next to the entrance is part of the same connected chunk of maze as the wall by the exit, and if you keep your hand on it, you will eventually walk along the whole length of the edge of this object – no matter how many twists and turns this involves – and reach the part at the exit.



KATIE STECKLES

While it is guaranteed to work, this certainly won't be the most efficient path – you might find you traverse as much as half of the maze in the process, or even more depending on the layout. But at least it is easy to remember the rule.

Some mazes have more than two pieces. In these, disconnected sections of wall (shown in yellow) inside the maze create loops. In this case, if you start following the wall somewhere in the middle of the maze, there is a chance it could be part of an isolated section, which would leave you walking around a loop forever. But if you start from a wall that is definitely connected to the outside, wall-following will still get you out.

It is reassuring to know that even if you are lost in a maze, you can always get out by following some variation on this rule: if you notice you have reached part of the maze you have been to before, you can detect loops, and switch to the opposite wall.

This is especially useful for mazes where the goal is to get to the centre: if the centre isn't connected to the outside, wall-following won't work, and you will need to switch walls to get onto the centre component. But as long as there are a finite number of pieces to the maze, and you keep trying different ones, you will eventually find a piece that is connected to your goal. You might, however, miss the bus home. ▮

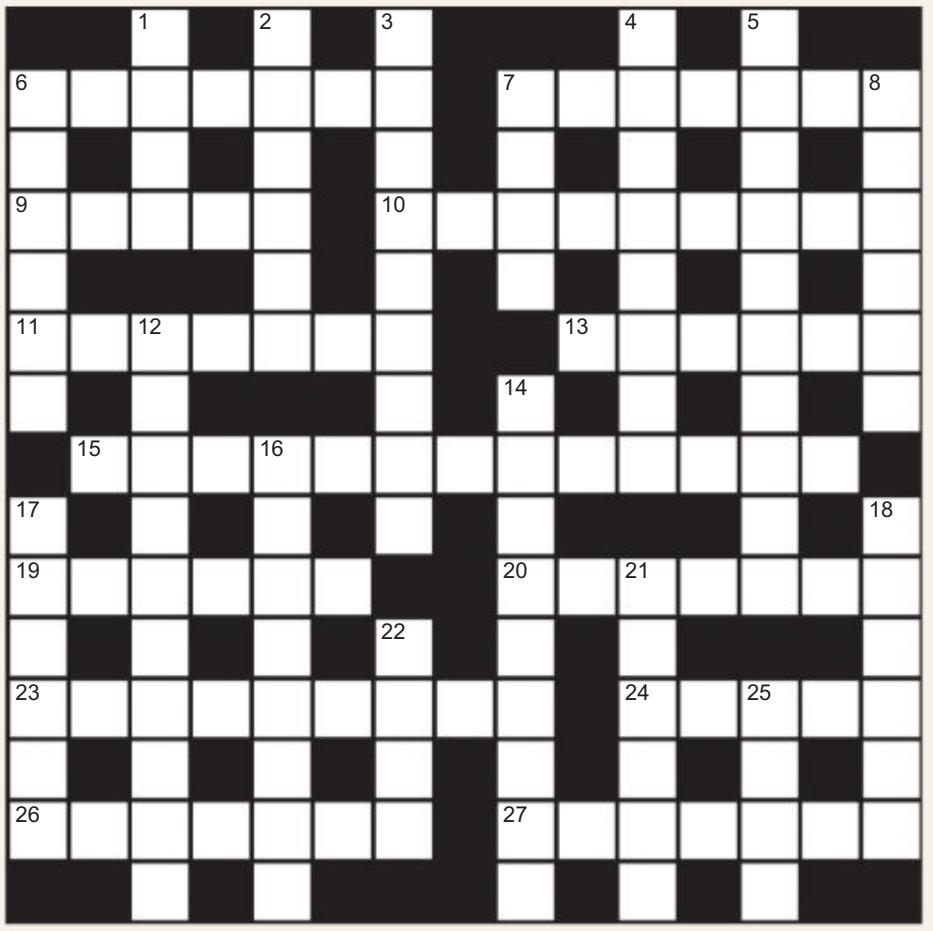
These articles are posted each week at newscientist.com/maker

Mathematics of life reveals the mathematical ideas and shortcuts behind everyday situations

Next week

Debunking gardening myths

Quick crossword #137 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

6 Blue copper mineral (7)
7 Conjunctivitis, informally (4,3)
9 Long-barrelled firearm (5)
10 *n*! (9)
11 Carlo ___, Italian physicist, author of *Seven Brief Lessons on Physics* (7)
13 Remove condensation (6)
15 Pachyderm, *Elephas maximus* (5,8)
19 4, 81 or 144, perhaps (6)
20 Obsolete form of chemistry (7)
23 Regulated outlet for irrigation (4,5)
24 Behaving memetically online (5)
26 Before (5,2)
27 Ag (7)

DOWN

1 Wading bird, *Calidris pugnax* (4)
2 ___ gland, source of melatonin in vertebrates (6)
3 Insect larva that lives and feeds within plant tissue (4,5)
4 Hardware, software, etc. (8)
5 Elasticity; bouncebackability (10)
6 The northern lights, perhaps (6)
7 Appetite for non-food substances (4)
8 Knapped flint nodule (6)
12 Inflammation of the blood vessels (10)
14 Emission of a β particle from an atomic nucleus (4,5)
16 Ant-eating African mammal (8)
17 Exhausted (4,2)
18 Axon insulator (6)
21 Hole; gap (6)
22 Prefix meaning mid-level (of clouds) (4)
25 Oil or gas platforms (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #210
set by Bethan Ackerley

1 The tongue-like structure used by molluscs for feeding is known as what?

2 Who was the first African-American person in space?

3 In what year was Concorde's maiden flight?

4 Name the polymath thought to have carved his surname into the prehistoric monument of Stonehenge in the UK.

5 Which kind of tissue does the pancreas contain more of: endocrine or exocrine?

Answers on page 47

Headscratcher
set by Daniel Griller
#230 Train of thought

She looked like a tourist – peaceful and observant as the train moved through the outskirts of the city – with an impressive-looking camera on her lap.

"May I ask what you are taking pictures of?" I inquired.

"The landscape; one at each station," she replied.

And yet she didn't move when the train pulled into a platform soon afterwards. She spoke before I could form my next question: "I'm travelling from one end of the line to the other and back again. I took a picture at this station on the way out."

She smiled, then returned her gaze to the woods beyond the window.

I knew this line well. Seven stations, one picture at each. And, as I whiled away my journey, I found myself wondering: across the entire day, in how many different orders could she take her photographs?

Solution next week

God of thunder

In the comics, Thor spins his hammer very fast and hurls it into the air, allowing him to be pulled into flight. Could you make a machine that "flew" using such a principle?

Alex McDowell
London, UK
When we jump, our legs propel our upper body upwards and it pulls our legs up with it. Hence our legs are, briefly, pulled into flight.

Cyrano de Bergerac proposed, in *A Voyage to the Moon* (published in 1656), sitting on an iron plate and repeatedly throwing magnets up, so they would pull the plate up, and then catching them.

Thor and Cyrano's methods would work, in principle, when on the ground. But, once airborne, the recoil from throwing the object would cancel out the "pull" from it (whether it were the hammer or the magnets). If Thor spun his hammer, he would spin the other way when he was airborne.

"The throws of shot put world-record holder Ryan Crouser bear an amazing resemblance to depictions of the Norse demigod Thor"

In space, you can, of course, propel yourself by throwing an object in the opposite direction of travel – but then that object is lost! In the *Doctor Who* television serial *Four to Doomsday* (1982), the Doctor is floating in space between a spaceship and the Tardis. To get to the Tardis, he throws a cricket ball at the spaceship and catches it when it bounces back.

Of course, the recoil alone would have propelled him to the Tardis, but the makers got it wrong and he didn't move until he caught the ball. Catching the ball would have got him there quicker and given him the chance to use the ball again to increase speed or for course correction.

Stephen Johnson
Eugene, Oregon, US
Yes, it is possible to make a flying machine based on the principles of Thor's hammer. In fact, three such machines already exist.

The first is the shot put. In order to make the shot put fly, the thrower spins in the ring for approximately 540 degrees to increase the acceleration of the ball prior to release. If you look at the throws of world-record holder Ryan Crouser, you will see that he bears an amazing resemblance to current romantic depictions of the Norse demigod Thor.

The second and even more impressive flying machine propelled by rotation is the discus. Because of its weight, its much better aerodynamics and the speed of rotation generated in its slightly bigger throwing circle, it really does look like it is heading for orbit when launched. For the most dynamic and elegant example of this technique, see the current women's Olympic champion Valarie Allman. If Thor had a sister, she would probably be stylised to look like Allman.

The third example is, of course, the hammer, which allows an even longer set of rotations before it takes flight. Since Thor is a demigod, and since the laws of physics might be different for someone from Asgard, he is able to go along for the ride and also ignore the effect of gravity.

Michael Horwood
Exeter, Devon, UK
Yes, but Thor would need to anchor himself to the ground while getting the hammer spinning before pulling the release at the critical moment.

Pat French
Telford, Shropshire, UK
We've already done it (a bit).

Of course, an immortal being just might be using effects that we mortals don't entirely understand. Thor apparently uses muscle power to build up angular momentum by swinging his hammer in a circle in the same way that the biblical David powered up his slingshot by twirling it around his head. David then released one of the restraining cords of his sling, thereby allowing centrifugal (a word that literally means "fleeing the centre") force to convert the angular (circular) momentum of his stone into the linear momentum of flight at the same time as releasing it.

Thor, however, appears to swing his hammer in a vertical plane in order to achieve take-off. Quite how he converts its angular momentum into the linear momentum of flight without letting go is unclear. He could jump at the right moment, freeing his boots from the friction that stopped him turning somersaults, but that would mean he had the stickiest soles imaginable. Also, he must have a hammer that is sufficiently dense that it would punch a hole in the pavement and then sink out of sight rather than take flight.

On the other hand, spaceships tend to take off in the direction of Earth's rotation, thereby tapping into the huge planetary momentum. They also sometimes accelerate during their journey by slingshotting around planets. They use the planets' gravity to develop added angular momentum. It "whips" them around a partial orbit. They then use their newly increased momentum to escape, but there

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This week's new questions

Bottoms up **Can all animals get drunk? If not, what enables this in those that can?** ***Chris Jack****, St Albans, Hertfordshire, UK*

Cooling off **Earth was a hothouse 201 million years ago, leading to the Triassic-Jurassic mass extinction event. How did it recover? Why was there no runaway greenhouse effect?** ***Ralf Ludwig****, Melbourne Beach, Florida, US*

If only a few animals can get drunk, what makes this possible in some but not others?

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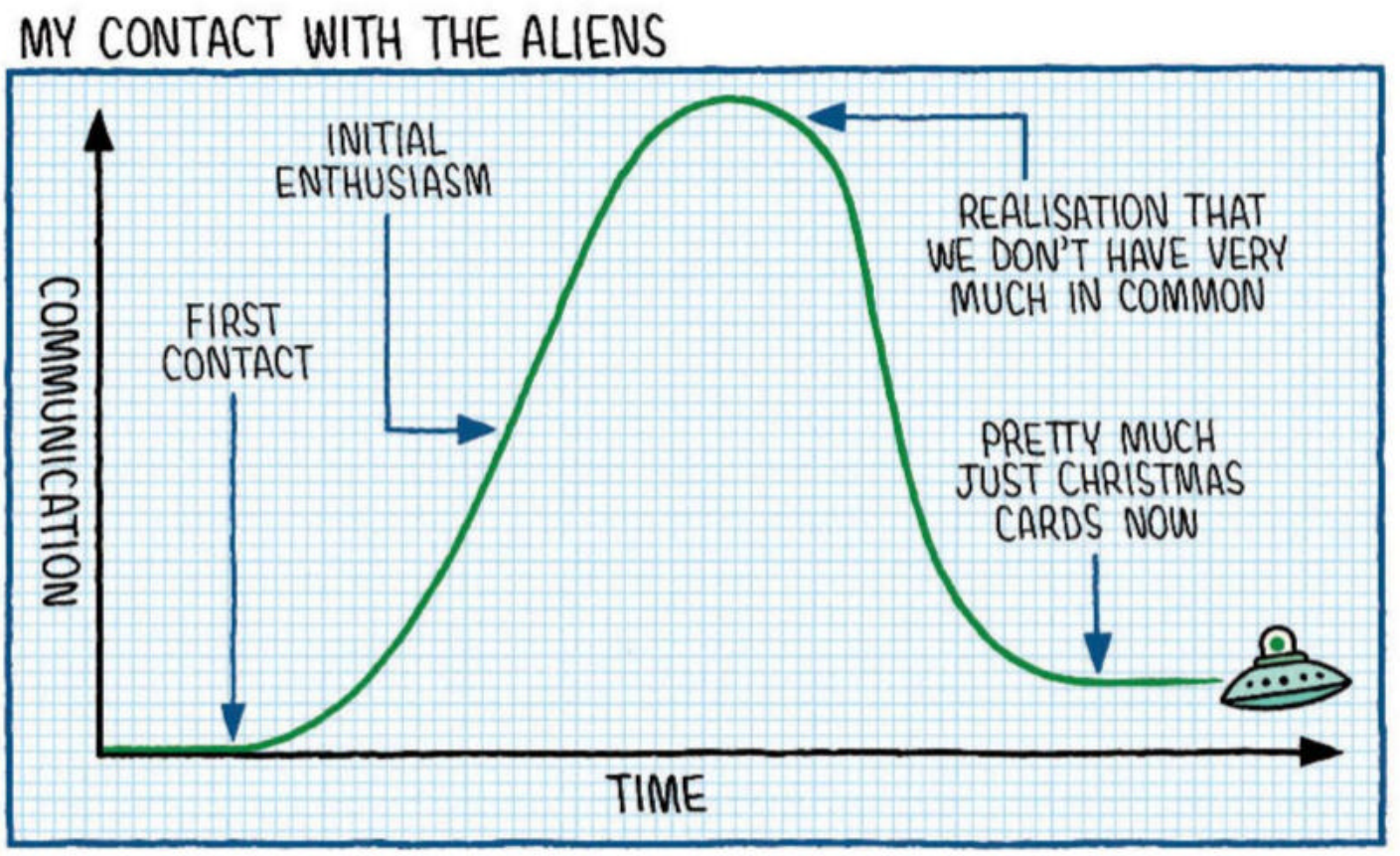

is a net overall gain. Theoretically, the planet or moon that gifted the craft extra energy would slow down imperceptibly.

Too much time

If humans colonised Mars, how would they calculate time, as a Martian day is longer than one on Earth? (continued)

Simon Dales
Oxford, UK
The Martian day is only about 40 minutes longer than the terrestrial one, so astronauts' body clocks should be happy, but their watches would drift from the local day.

History tells us that they should always use one measure, lest they get confused. In the UK, we used to have Bristol time and London time. That was fine until we wanted railway timetables.

Pope Gregory XIII's astronomers invented a better calendar to replace the Roman Julian one, so the Catholic world adopted it. England was strongly Protestant at the time, so resisted this "Papist plot". Over many decades, the two calendars drifted.

"We used to have Bristol time and London time. That was fine until we wanted railway timetables"

Confusing units like feet and metres can have dire consequences. Do that and spacecraft go splat, so day length becomes moot.

Charles Joynson
Rayleigh, Essex, UK
I researched this question during the writing of my book and found that Robert Zubrin, the founder and president of the Mars Society, has suggested that time on Mars could be measured in the same way that it is on Earth.

This would mean dividing a Martian day into 24 hours, each with 60 minutes. However, the seconds on Mars would be just a fraction longer than seconds on Earth.

Zubrin says we just need to divide each Martian day by 24 to get a Martian hour, and each Martian hour by 60 to get a Martian minute, and then divide that by 60 to get a Martian second. This would be equivalent to 1.0275 Earth seconds, which is a small enough difference not to be noticeable. Thus, 1 hour on Earth and Mars would equate to 15 angular degrees of surface rotational longitude, 1 minute would be 15 angular minutes of longitude and 1 second 15 angular seconds of longitude.

Additionally, Zubrin says that Martian seasons could be divided up into equal angles of travel around the sun, so each of the 12 months would represent 30 degrees of orbital travel. It may be confusing to use names from Earth. Signs of the zodiac may be a more acceptable alternative.

Harold Fuchs
London, UK
What makes you think humans would have a say in how Martians' clocks or calendars work? ▮

Answers

Quick quiz #210 *Answers*

1 The radula
2 Guion Bluford
3 1969
4 Christopher Wren
5 Exocrine

Cryptic crossword #113 *Answers*

ACROSS 6 Youth, **7** Wattage, **9** Treasure trove, **10** Nibbled, **12** Humid, **13** Stalk, **15** Arc lamp, **18** Triceratopses, **20** Augment, **21** April

DOWN 1 Ayrton, **2** Cube, **3** Chisel, **4** Stitch, **5** Legend, **7** Worlds apart, **8** Anosmia, **11** Blaring, **13** Satnav, **14** Keeper, **16** Choral, **17** Pestle, **19** Sere

#229 The greater gouda *Solution*

The best Madeline can do is six cuts.

Consider the cube in the centre that has six faces, all of which need to be separated from their neighbouring cheesy cubes. However, no straight slice can detach more than one of these faces from its neighbour, so she can't improve on her six-slice solution.

Catochromatograph

Laboratories looking to purchase a highly efficient coiled parallel gas chromatograph could save money by instead adopting and adapting a cat. Perhaps.

A study called "Domestic cat nose functions as a highly efficient coiled parallel gas chromatograph" in *PLoS Computational Biology* explains the capabilities of the cat.

The idea, composed and presented to you here, now, is speculative. One would need to do further assessment, both technical and legal. The researchers neither suggest nor advocate using a cat nose or an entire cat for this purpose. They present no information about the cost of converting a cat nose or an entire cat.

Headaches and nations

Italy is a country that openly, unembarrassedly, institutionally studies and tries to deal with headaches. Such efforts can take many forms. For example, the Italian Society for the Study of Headaches celebrated Cluster Headache Awareness Day in March – though the society did not use the word "celebrate".

Italy does not stand alone. At least 43 other nations have Headache Societies.

Four nations have a Headache Association, rather than a Headache Society: Guatemala, Iran, Mexico and the UK. The UK's is named the British Association for the Study of Headache; it goes by the acronym BASH.

Two nations, Kyrgyzstan and Turkey, each have a Headache Chapter. Another two each go their own way: Romania has a Headache Group, Colombia has a Headache Committee. (Feedback notes that the phrase "headache committee" has a painful ring to it. Almost every organisation, everywhere, has a headache committee.)

All these nations are famous for causing headaches, as well as trying to cure them. They also all have an affiliation with The International Headache Society, which is based in the UK.

The International Headache Society's headquarters hunker down high on the sixth floor of a building on London Wall Place, a short stroll from Lloyds Bank. Symbolically, this demonstrates that proximity to wealth doesn't eliminate all headaches.

Twisteddoodles *for New Scientist*

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Rosetta stone of plants

Plant nyctinasty (usually pronounced "NICK-ta-nasty") is one of the squat, ignoring-it-won't-make-it-go-away mysteries that most scientists ignore. Day after day, night after night, there it is: the rhythmic shape-sloshing of plants as their parts reconfigure in concert with the coming of light and/or darkness.

A century ago, the clever polymath Jagadish Chandra Bose rigged up some machinery to amplify and record the gymnastic movements of plants. Bose shared his findings in the 1927 book *Plant Autographs and Their Revelations*.

He sprinkled his pages with gripping phrases, such as "The Night Watch of Nymphea", "The Praying Palm of Faridpore" and "The Balanced Crescograph". (Of the latter, Bose wrote: "In the Balanced Crescograph, a train of revolving clockwork actuated by the fall of a weight, lowers the plant at the same rate at which it is growing".)

The why and, in many ways still, the how of plant nyctinasty was – and remains – elusive. Mystery pulses through the pages of recent papers such as Minoru Ueda and colleagues' "Plant Nyctinasty – Who Will Decode the 'Rosetta Stone'?" in *New Phytologist*.

Where there is mystery, there is wonder... once people have noticed what's happening. The day and night shape-shifting of werewolves and vampires inspires many sci-fi, fantasy and horror fiction writers. They know that animal nyctinasty intoxicates audiences.

Yet year after year, century after century, plant nyctinasty tempts relatively few fiction writers to put pen to paper, tongue to palate or fingertips to keyboard to create plant nyctinasty fiction. When, if ever, will that imbalance change, Feedback wonders.

Middle-ear superpower

Rob Holmes reports a trivial superpower that is both mild and hereditary, thus establishing a new category in Feedback's catalogue of trivial superpowers.

He says: "I was being put through a battery of hearing tests by an audiologist friend of mine. One of which was measurement of eardrum impedance. Seizing the opportunity, I commented that I could flex my middle-ear muscles. 'Oh yes?' he responded. 'Have a look,' I said, as we viewed the online display while I wiggled my middle ear muscles. 'Goodness!' he (politely) exclaimed. 'You have mild superpowers.' As I had never thought of mentioning it, I related the story to my younger daughter, now in middle age. 'Can't everyone do it?' she replied."

A man of letters

Andrea Sella tells Feedback how he discovered that a fellow scholar is an impressive man of letters.

Sella says: "Academics revel in their post-nominals, an alphabet soup thought to help establish one's dominance in a highly insecure world. I recently received an invitation to a conference in an exotic location. My host's signature read as follows: BSc (Honors), MASc, PhD, MTMS, MGDMB, MCIM, MSME, MAIST, MISIJ, MSigmaXi, MIFAC, MACS, MASM, MMRS, MACerS, MECS. Could this be a record? I think we should be told."

Marc Abrahams

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