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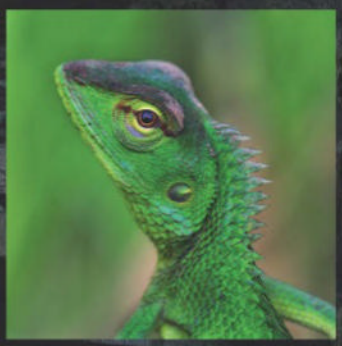

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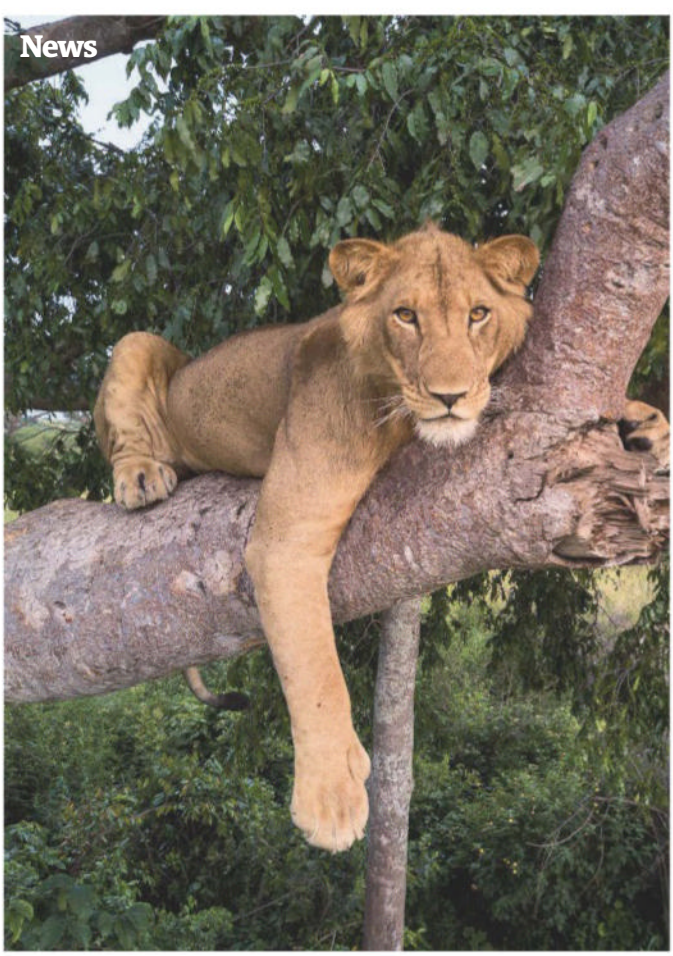

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Fairer sex research

Female biology is messy, but has much to tell us about human health

WOMEN aren't just "little men". And yet, it has long been convenient for medical science to act as if they are, focusing studies on male rodents and men because they lack the complicated hormone cycles of females, and then transferring any findings over onto women. Thankfully, in recent decades, there has been widespread acceptance that neglecting the study of female bodies in this way has harmed women's health, by producing treatments that don't work as well for them as for men.

Now, studying how sex chromosomes shape our immune systems has brought a further twist to the story – ignoring the complexity of female bodies hasn't just hurt women, but everyone (see page 34).

Much of the problem comes from the power of averages. Statistical tools give us the ability to smooth out variation and draw powerful discoveries from data. But when overused, they erase signals that have much to teach us. Women typically have stronger, more responsive immune systems than the

"Ignoring the complexity of female bodies hasn't just hurt women, but everyone"

average man, showing, for example, more durable responses to vaccines and lower rates of death from infectious diseases in older age.

But by lumping male and female participants together in medical research trials – admittedly better than not studying women at all – sex differences in response to antiviral drugs and new vaccines have been blended and lost. This can ultimately lead to the average woman receiving too high a dose of a drug, at the same time as the average man is given too little for optimum treatment. Research into how these differences might affect transgender people has received even less attention.

Finally though, researchers are unpicking how the X chromosome and hormones underpin these sex differences, and the insights from this work should enable us to better personalise treatments for everything from long covid to cancer – and for everyone. We all benefit from abandoning the concept of "little men". ▮

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Astronomy

A stellar surprise hiding in the dark

This twinkling tapestry of young stars being born amidst a swirling sea of gas and dust is part of a dark cloud named LDN 1641, around 1300 light years away from Earth. Dark clouds are so called because they block the visible light from stars behind them. It is only thanks to the infrared instruments aboard the European Space Agency's Euclid telescope that we have been able to capture this stunning image.

ESA/EUCLID/EUCL.ID CONSORTIUM/NASA, IMAGE PROCESSING BY M. SCHIRMER (MPIA, HEIDELBERG)

Archaeology

Strange holes may be Inca spreadsheet

Thousands of holes arranged in a snake-like pattern on Monte Sierpe in Peru could have been a massive accounting system for trade and tax, reports **Chris Simms**

A HILLSIDE in Peru covered by more than 5000 aligned holes may have been a giant Inca accounting device – a spreadsheet, but on an enormous scale.

Tracing across the slopes of Monte Sierpe (Serpent Mountain) in a snake-like shape, the "Band of Holes" has mystified archaeologists since an aerial photo of it was published in 1933. Various hypotheses have been put forward for the holes' purpose, including suggestions that they are graves or were used for gardening during the Inca Empire, which ran from 1438 to 1533.

"This 1.5-kilometre-long band of holes has baffled people for decades," says Jacob Bongers at the University of Sydney.

To find out more, Bongers and his colleagues analysed sediment samples from within 19 holes and used drones to provide the clearest aerial picture yet of the array of depressions, which are each about 1 to 2 metres across and between 50 centimetres and 1 metre deep.

The analysis revealed pollen from food crops, including maize, amaranth, chilli peppers and sweet potato, and from wild plants such as *Typha* (bulrush), which are traditionally used for constructing baskets and rafts (*Antiquity*, doi.org/qc4f).

The holes are too far from the fertile areas where the plants would grow for the pollen to have been delivered by wind, says Bongers. He suggests that local groups from the Chincha culture – which lasted from about AD 900 to 1450 – lined the holes with plant materials and deposited goods in them, brought up in woven baskets loaded onto llamas.

"The data support the idea that people brought goods to the site and deposited them in the holes," he says, and the use of baskets would also explain why there

C. STANISH

A group of mysterious holes atop Monte Sierpe in Peru

isn't much pottery at the site. "We think it was initially a barter marketplace. That was then turned into a sort of large-scale accounting device under the Inca."

Around 1480, the Chincha came under Inca rule, retaining their autonomy, but historical sources indicate they also paid levies, says Bongers. The accounting device idea comes from the aerial imagery, which allowed a more precise counting of the number of holes – revealing there are about 5200 of them – and of the variation in their layout.

The holes are organised into at least 60 sections or blocks. The researchers say their layout mirrors some Inca counting devices made from knotted strings, known as khipus, which have been compared to calculators or abacuses. But Bongers says a better analogy for the hole layout might be a spreadsheet to record the collection of tributes of food or goods from local communities.

"There are these interesting mathematical patterns. You have some [sections with] multiple rows of eight holes, and then you have other sections that have alternating counts. Eight holes, then seven, then eight and seven, then eight. It hints that there was some sort of intention behind it," says Bongers.

He thinks the different sections correspond to distinct groups of people from the heavily populated and productive agricultural region

"There are these interesting mathematical patterns. It hints that there was some sort of intention behind it"

around Monte Sierpe. Sources suggest some 100,000 people lived in the neighbouring Pisco and Chincha valleys, he says.

The particular khipu said to resemble the layout of the holes was found in the Pisco valley, and is divided into sections approximately similar to the holes at the site, but that khipu has 80 divisions overall.

"The 5200 holes are certainly big enough to put goods into, but they are not arranged in a clear-cut decimal pattern and the Inca had a decimal system, so I would expect things to be strongly organised in groups of 10," says Karenleigh Overmann at the University of Colorado, Colorado Springs. "The holes are organised into 60-some sections and the khipu is organised into 80, and that's a pretty big difference in numbers."

A monumental site

Bongers accepts that, but adds that we don't actually know over what period of time the site was built, and the layout or use of holes might have evolved, along with any matching khipus. "We're seeing the final form, but it could have started out as just a couple of sections and changed over time with the population," he says.

The goods might have been gathered here rather than in an urban area because it is near the intersection of a network of pre-Hispanic roads, and in between two major Inca administrative sites: Tambo Colorado and Lima La Vieja.

Overmann says the study does a good job of discounting alternative ideas for the purpose of the holes, but she says there might be a simpler explanation. "There is a lot of tradition in Peru of making giant petroglyphs that can be seen from a distance," she says. "Maybe they were just doing that."

That could indeed have been one purpose, says Bongers. "But two things can be true at the same time. It's a big, giant snake, but it served a functional purpose, so I see this site as a sort of social technology. They didn't have internet, they didn't have cell phones, so how are people figuring out when and where to meet? Let's build a giant site that you can see from kilometres away." ▮

Health

Covid raised risk of heart issues in children more than vaccination

Michael Le Page

THE evidence that children were better off being vaccinated against covid-19 than getting infected by it during the pandemic just got even stronger. The largest-ever study, involving nearly 14 million children, has found that the risk of serious – but very rare – side effects involving the heart and blood vessels was much higher after infection than vaccination.

For instance, among children aged between 5 and 18, there were more than 17 extra cases per 100,000 of inflammatory conditions such as Kawasaki disease in the six months after first getting infected with the SARS-CoV-2 coronavirus, compared with the expected baseline. Among those who got the Pfizer/BioNTech mRNA vaccine for the first time, there were nearly 2 fewer cases per 100,000 compared with the baseline.

With inflammation of the heart muscles, known as myocarditis, there were more than 2 extra cases per 100,000 in the six months after an infection. Among the vaccinated, there was less than 1 extra case (*The Lancet Child and Adolescent Health*, doi.org/g989rm). In other words, the risk of myocarditis was more than twice as high after infection than after vaccination.

Reports of covid-19 infections causing myocarditis were published as early as April 2020. This rare side effect got a lot of media attention – and was one of the reasons why the UK didn't routinely vaccinate young children until April 2022.

The latest findings confirm earlier studies suggesting children who were vaccinated had a lower risk of myocarditis than those who were unvaccinated. That's because most children got infected by the virus, and so were exposed to the higher risk from infection.

Getting vaccinated against covid was better for children than catching it

"I want to stress that these serious complications are really rare in children and young people overall," says Angela Wood at the Cambridge HDR UK Regional Network. "But we can see that the risk was generally higher after a covid-19 infection than after a vaccination."

NURPHOTO/SHUTTERSTOCK

Wood's team analysed data on nearly 14 million children aged under 18 from the National Health Service in England for the period from January 2020 to December 2021. During the latter half of this period, 3.9 million of the children were vaccinated with the Pfizer/BioNTech vaccine and 3.4 million were diagnosed with a covid-19 infection for the first time. The team couldn't look at later periods because not enough testing was done.

"The proviso is that what applied during the covid-19 strain circulating during the height of the pandemic might not apply to the current strain of the virus," says team member William Whiteley at the University of Edinburgh, UK.

The fact almost everyone apart from very young children now has some immunity to covid-19 also means the response to both additional booster shots and to reinfections with the virus will be different, says team member Pia Hardelid at University College London. "We need to keep doing these studies," she says. ▮

Solar system

Odds of asteroid hitting the moon could soon rise

ASTRONOMERS are running out of time to decide whether to prevent asteroid 2024 YR4 from hitting the moon in 2032. A small observing window with the James Webb Space Telescope will open in February, and could see the chance of an impact rise to more than 30 per cent.

2024 YR4 was discovered at the end of last year and was quickly assigned the highest probability of hitting Earth of all known asteroids. At its most perilous, it had a 1-in-32 chance of hitting Earth in 2032. Further observations reduced the probability of an Earth impact to effectively zero, but there remains a 4 per cent chance of the asteroid slamming into the moon, which could put thousands of critical satellites around the planet at risk from lunar shrapnel.

The asteroid has now flown out of view of Earth's telescopes, meaning astronomers thought there was no chance of learning more about its trajectory until it returns to view in 2028.

But now it seems the James Webb Space Telescope (JWST) will have a brief glimpse at 2024 YR4 in February 2026, which will represent the last good chance to decide on a deflection mission, says Andrew Rivkin at Johns Hopkins University in Maryland. "By 2028, it would be cutting things very, very close, and so getting it in early 2026 instead gives some extra time," says Rivkin.

It is JWST's unique orbit around Earth and vantage point that allows it to see 2024 YR4 where ground-based telescopes cannot.

30%

What the chances of asteroid 2024 YR4 hitting the moon could rise to

Rivkin and his colleagues have calculated how our understanding of the asteroid's position and speed could change based on these observations. They found there is an 80 per cent chance of a lunar collision dropping to below 1 per cent, and a 5 per cent chance of the risk increasing to more than 30 per cent. JWST will have another chance in 2027 to repeat these observations, but that will leave less time in which to make a decision, says Rivkin. ▮

Alex Wilkins

Environment

Toxic algae blighting South Australia could pose a global threat

James Woodford

OVER the past eight months, a vast and deadly algal bloom in South Australia has ravaged over 20,000 square kilometres of the marine environment, killed an estimated 1 million animals from more than 550 species and had widespread impacts on human health.

Now, researchers have identified the species behind the ecological disaster, and warn it represents an "emerging international threat with unknown consequences".

The culprit is an algal species named *Karenia cristata*, which has only previously been reported in two locations near South Africa, where it caused fish die-offs in 1989 and the mid-1990s, as well as near Newfoundland, Canada.

The team has also identified a new toxin produced by *K. cristata*, part of a class of compounds called brevetoxins (bioRxiv, doi.org/qb34). These can cause nerve damage to sea life and damage the gills of fish, killing animals from seadragons to dolphins. They are also harmful to humans when inhaled or ingested.

Team member Shauna Murray at the University of Technology Sydney, Australia, says the discovery has caused concern among her overseas colleagues about what it might mean to have a new toxin-producing species that "could pop up in their waters".

"We know that it can bloom in other countries in the world," she says. "What we didn't know is that *cristata* produced brevetoxins and that it could cause these harmful algal outbreaks that are so huge and so disruptive and last for eight months." As a result, "I do think that it is an international threat," she says.

Of nearly 850 deadly marine algal blooms reported worldwide between 1985 and 2025, this event in South Australia is "amongst the most destructive and widespread" ever reported globally, according to Murray and her colleagues.

The team isn't certain what caused such a massive and deadly bloom. Around the world, an increased frequency of harmful blooms has been linked to higher seawater temperatures, and the start of the bloom coincided with a severe marine heatwave that saw water temperatures up to 3°C higher than normal. But the bloom unexpectedly expanded after May 2025, when the sea had begun to cool.

AUSTRALIAN ASSOCIATED PRESS/ALAMY

Beachgoers in Adelaide have been warned about the algal bloom

K. cristata could potentially affect many countries with suitable conditions, so there is an urgent need to understand what could trigger a bloom, the researchers say.

Christopher Keneally at the University of Adelaide in Australia says the dominant *Karenia* species in the bloom was previously thought to be *Karenia mikimotoi*, which isn't known to produce brevetoxins. "There is a great deal unknown about how the specific toxins produced by [*K. cristata*] affect humans," he says.

He agrees that the discovery raises the prospect of an emerging threat beyond Australia. "Given the broad global distribution of this species, it is likely to already be present in low abundance in many coastal areas across the globe," he says. ▮

Health

Sleep doesn't come slowly, but rather all at once

THE brain doesn't gradually fall asleep. Instead, it reaches a tipping point at which it rapidly transitions from wakefulness to sleep – a discovery that could improve our treatment of sleep disorders.

"Although sleep is so fundamental to our life, how the brain falls asleep has been a mystery," says Nir Grossman at Imperial College London.

Grossman and his colleagues have devised a new framework for studying how the brain behaves while we fall asleep using electroencephalography (EEG) data.

This test, which records electrical activity in the brain, indicates sleep stages and wakefulness. The team modelled 47 EEG signals in an abstract mathematical space where each data point had coordinates as if it were a point on a map. This allowed the team to plot brain activity during wakefulness and track it as it moved towards what they call the sleep-onset zone, where brain activity corresponds to the second stage of non-rapid eye movement (NREM) sleep.

They applied this approach to EEG data collected from more than 1000 people as they fell asleep, measuring the distance between brain activity and sleep onset. On average, this distance remained largely unchanged until 10 minutes before sleep and then dropped abruptly in the last few minutes (*Nature Neuroscience*, doi.org/g979tf). This tipping point – which occurred an average of 4.5 minutes before sleep – is the exact moment when the brain switches between wakefulness and sleep, says Junheng Li, also at Imperial College London.

"Although sleep is so fundamental to our life, how the brain falls asleep has been a mystery"

This suggests the transition from wakefulness to sleep "is an abrupt, drastic change that occurs in the last few minutes", says Grossman.

By understanding the dynamics of this transition, we may be able to identify how they differ in those with insomnia, says Laura Lewis at the Massachusetts Institute of Technology, potentially leading to new treatments for the condition. ▮

Grace Wade

Ageing

Is reproduction the cause of ageing?

Pregnancy may divert energy away from DNA repair, which could drive ageing in some women – but perhaps only when environmental conditions are tough, finds **Manuela Callari**

FOR millennia, we have tried to understand why we age, with the ancient Greek philosopher Aristotle proposing it occurs alongside the gradual drying up of the internal moisture necessary for life.

In modern times, a leading idea known as the disposable soma hypothesis suggests that ageing is the price we pay for reproduction, with evolution prioritising the passing on of genes above all else. This creates a fundamental trade-off: the immense energy devoted to having and raising offspring comes at the cost of repairing DNA, fighting off illness and keeping organs in good shape.

This may particularly apply to women, who invest more in reproduction than men via pregnancy and breastfeeding. However, when scientists have tested this hypothesis by checking if women with more children live shorter lives, the results have been mixed: some studies support the idea, while others have found no effect.

"It is very difficult to disentangle what is just correlation [between having more children and a shorter life] and what is the underlying causation, unless you have a good, big dataset that covers several generations," says Elisabeth Bolund at the Swedish University of Agricultural Sciences, who wasn't involved in the study.

Euan Young at the University of Groningen in the Netherlands and his colleagues hypothesised that the inconsistency between studies exists because the cost of reproduction isn't fixed – it depends on a mother's environment. "In good times, this trade-off isn't really visible. The trade-off only becomes apparent when times are tough," says Young.

To investigate this idea, the researchers analysed the parish records of more than 4500 Finnish women, spanning 250 years. These included the period of the Great Finnish Famine from 1866 to 1868, providing a means to gauge how hard times affect reproduction and longevity, says Young.

"In good times this trade-off isn't visible. It only becomes apparent when times are tough"

They found that among the women who lived before or after the famine or who didn't have children during it, there was no significant association between the number of children they had and their lifespan. However, for the women who did have children during the famine, their life expectancy decreased by six months for every child they had (*Science Advances*, doi.org/g99kpz).

The study builds on research published last year that used a dataset from a pre-industrial population in Quebec, Canada, monitored over two centuries, which showed this trade-off in mothers who were probably in poor health or under great stress, but didn't explore how this was affected by specific environmental conditions.

In contrast, Young's team points to a specific, catastrophic event as the driver that exposes the trade-off for mothers. "This very large dataset makes it feasible to account for confounding factors [such as genetics and lifestyle factors]," says Bolund. "The study gets us as close as we can to identifying causation without running a controlled experiment in the lab."

The study also confirms the energetic demands of pregnancy and breastfeeding, which require hundreds of extra calories per day. During a famine, women can't get this energy from food, so their bodies pay the price, "lowering basal metabolism [the minimum number of calories your body needs to function at a basic level] and thus slowing or shutting down other important functions, resulting in a decline in health and shorter lifespans", says Young. It also explains why previous studies sometimes found the trade-off only in lower socioeconomic groups, which were effectively always living in relatively resource-scarce environments, he says.

The effects of having a child may depend on the mother's environment

THOMAS M BARWICK/GETTY IMAGES

The longevity gap

According to Bolund, the fact that this trade-off seems to occur in particularly tough circumstances, and when women typically had many children, may partly explain why women generally live longer than men today, with girls born between 2021 and 2023 in the UK expected to live four years longer than their male counterparts.

The costs of reproduction are now fairly low in Western societies, where the average number of children women give birth to has reduced considerably over the centuries, says Bolund. As a result, few women today will probably reach the threshold where the cost to their lifetime becomes obvious. Bolund and her colleagues' research on a historical population in Utah, for instance, found this only appeared when women had more than five children – well below the 1.6 births that the average woman in the US is expected to have in her lifetime.

Men tend to be more likely to smoke than women and also drink more alcohol, which affect lifespan, says Bolund. The current longevity gap between men and women is probably a combination of the latter's reduced reproductive costs compared with other times in history and lifestyle differences between the sexes.

Archaeology

DNA find may rewrite Iceland's history

Biochemical evidence suggests that the first people settled in Iceland many decades before the accepted arrival date – and didn't chop down the island's forests, explains **Chris Simms**

NORSE people may have lived in Iceland almost 70 years earlier than historians thought, and their arrival might not have been the environmental disaster it is often portrayed as.

Historical accounts suggest that people first settled in Iceland in the 870s. This early migration is often depicted as an ecological disaster driven by Viking raiders or Norse settlers as they cleared the island's forests for fuel, building material and fields. Forests now cover just 2 per cent of the country.

Firm evidence for when the first settlers arrived has been hard to come by. Archaeologists have unearthed an ancient wooden longhouse near the fjord of Stöðvarfjörður in the east of Iceland dating to around AD 874. Underneath it, there is an older longhouse thought to be a summer settlement built in the 800s, rather than a permanent home, but this finding hasn't yet been reported in a scientific paper.

Now, Eske Willerslev at the University of Copenhagen, Denmark, and his colleagues have examined environmental DNA (eDNA) extracted from two sediment cores drilled at Lake Tjörnin in central Reykjavík, one of Iceland's earliest and longest-occupied settlements, to see which species were present when. By examining layers of volcanic ash and using radiocarbon dating and plutonium isotope analysis, the researchers put together a timeline spanning from about AD 200 to the modern day, aligned with known historical events.

One key marker they used is known as the Landnám tephra layer, the ash and fragments left over from a volcanic eruption in about AD 877. Most evidence of human occupation in Iceland sits above this layer, so it was laid down after the eruption.

INGOLF P. RAADSIG 1850, PUBLIC DOMAIN

A painting depicting the first Norse settlers of Iceland

"Signs below the tephra are like the smoking gun that there was earlier human activity," says Chris Callow at the University of Birmingham, UK.

Willerslev and his colleagues suggest people arrived almost 70 years before that mark: about AD 810. That is because at this point, they saw an increase in a compound known as levoglucosan, an indicator of biomass burning, as well as a rise in viruses associated with sewage (bioRxiv, doi.org/qcv3).

AD 874
When historians thought people first arrived in Iceland

AD 810
New estimate for when Norse settlers might have arrived

AD 1200
New estimate for when tree coverage started to fall, due to climate cooling, not settlers

"If it had been 850, I wouldn't have been so surprised, but 810 is early for Viking expansion in the North Atlantic," says Callow. "Overall, this is a nice confirmation of what we might have suspected, but it's still quite controversial to have a date as early as 810."

Putting together this comprehensive environmental history of the region is phenomenal, but the evidence for such an early date isn't conclusive, says Kathryn Catlin at Jacksonville State University, Alabama. "When it comes to sewage biomarkers, there is a little bump around 800 and then nothing until 1900. Where are all the indicators of humans in sewage biomarkers and the intervening time period?" she says. And although biomass burning can indicate the presence of people, fires can also be caused by natural sources like lightning, she adds.

Willerslev and his colleagues, who declined to speak to *New Scientist*, also found that the arrival of settlers coincided with an increase in local biodiversity. The DNA record suggests they brought grazing livestock with them, grew hay meadows and practised small-scale barley cultivation for brewing beer.

Telling a different story

Contrary to the conventional view of rapid deforestation, eDNA from pollen revealed that birch and willow trees expanded during the settlement period. For example, birch pollen grains increased fivefold between AD 900 and 1200, which the researchers think could have been down to deliberate management, keeping livestock away from trees to ensure settlers continued to have easy access to wood for timber and fuel.

"This is the nail in the coffin for that old just-so story of the Vikings getting to Iceland and then, suddenly, 'oh no, the environment is destroyed'," says Catlin.

Noticeable numbers of sheep, cattle, pigs and horses don't appear until several decades after the initial settlement, which Willerslev and his colleagues suggest is because it would have taken about 20 years to build big enough herds to be detectable in the eDNA record.Callow suggests it could be that the first people didn't bring many animals with them because they were coming just for the summer season in search of walrus ivory.

The eDNA suggests that pronounced loss of biodiversity, including birch and willow trees, didn't occur until after 1200. Willerslev and his team suggest this was due to climate cooling related to the Little Ice Age – a period of colder conditions from about the mid-13th century to the mid-19th century – plus volcanic eruptions and storm surges. ▮

Solar system

Martian caves could be the result of ancient water flows

Alex Wilkins

CAVES carved by water that once flowed beneath Mars's surface could have been ideal for life to thrive, and might still preserve traces of it today.

Mars is dotted with holes that look like cave entrances, but these are usually near regions thought to have been volcanically active, suggesting they formed due to processes like underground lava flows.

On Earth, there are thousands of caves formed when water dissolves soluble rock, known as karstic caves. But scientists have yet to find signs of such caves on Mars, despite evidence the planet was covered in water billions of years ago.

Now, Chunyu Ding at Shenzhen University in China and his team say they have identified eight possible caves that look to have been produced by ancient water flows (*The Astrophysical Journal Letters*, doi.org/qc42). The caves are in the Hebrus Valles, a north-western region containing hundreds of kilometres of valleys and depressions that seem to have been carved out by ancient floods.

These caves have been mapped by previous Mars missions, such as NASA's Mars Global Surveyor, which orbited Mars from 1997 to 2006. Ding and his team used spectrometry data from that mission to analyse the material around the cave entrances. This shows they are high in carbonate and sulphate minerals, which typically form in the presence of water.

They also found evidence of ancient streams that end near the cave entrances. This is similar to what we see near karstic caves on Earth, says James Baldini at Durham University in the UK.

If these are water caves, they could be good places to look for life. "In order to have life, you need water and an environment that is sheltered from the intense radioactive bombardment on the surface of Mars," says Baldini. ▮

Analysis Green energy

Australia is getting free electricity – will other countries follow?

An attempt to change people's energy consumption habits might become an example for the rest of the world, says **James Woodford**

AUSTRALIANS received a welcome surprise last week with the news that every household will soon receive 3 hours of free electricity every day, as part of a world-first initiative to share the benefits of solar power. If successful, it could be a model for others to follow.

The Australian electricity grid is zinging with excess capacity during the day thanks to solar power, but it is strained at night when people return from work and use most of their appliances. To address this, the Australian government says its "Solar Sharer" scheme will be rolled out from July 2026 in three states – New South Wales, South Australia and the south-east corner of Queensland – with the rest of the country joining in 2027.

Australia already leads the world in solar deployment per capita, with the installation of 42 gigawatts of solar capacity, equivalent to more than 1500 watts per person or about five times the global average, says Bin Lu at the Australian National University in Canberra.

"As a result, there's abundant solar power injecting into the grid in the middle of the day," says Lu. "If it isn't effectively used, it'll simply be wasted."

But while 4 million Australian households have their own solar panels, the vast majority of which feed into the grid, people who live in apartments or can't afford an installation are locked out – something this new policy solves, says Marnie Shaw, also at the Australian National University.

"There's abundant solar power in the middle of the day. If it isn't used, it'll simply be wasted"

"It gives everybody access to solar power in a very simple way," she says. "You don't need to buy a share in a solar farm. You don't need a battery. You just use the solar power that's already being produced by others."

Several Australian power suppliers already have similar schemes that operate at certain times where there is excess renewable energy, as do many in European countries. What makes this scheme unprecedented is its scale and that it is led by a national government instead of industry.

Some wonder, however, if it could introduce perverse outcomes. For example, Dylan McConnell at the University of New South Wales says it may disincentivise new solar installations.

"You sharpen your pencil and start doing the calculations when you're thinking about putting solar on your house," says McConnell. "Then someone says 'hey its free power for 3 hours in the middle of the day', you might reconsider that decision."

Another unknown is what would happen if there is a lengthy run of bad weather, says Alexandr Akimov at Griffith University, Gold Coast, Australia. "There is a risk," he says, "that during rainy days, particularly when wide weather fronts cover the eastern states, that high daytime consumption combined with low solar generation could lead to spikes in daytime grid demand."

Because Australia is so advanced in its solar journey, its policies will be widely watched by other countries. Glenn Platt at the University of Sydney says that, as other nations get deeper into their solar rollout journeys, they will "definitely" have to confront some of the same issues.

The big question, he says, is whether householders will actually change their ways. Evidence from existing free schemes in Australia is that shifting behaviours can be very difficult, especially for energy intensive heating and cooling.

"It means huge change, and we're assuming that energy consumers will do certain things," says Platt. "It's less about the electrons and the dollars and more about the social experiment, much more about the behavioural change." ▮

Australia produces the most solar power per capita of any country

STEPHEN DWYER/ALAMY

Mathematics

Computer may solve maths debate

For over a decade, mathematicians have failed to agree whether a 500-page proof is correct. Now, there may finally be a way settle the matter, reports **Alex Wilkins**

ONE of the most controversial debates in mathematics could be settled with the aid of a computer, potentially ending a bitter argument that has raged for more than a decade.

The trouble began in 2012, when Shinichi Mochizuki at Kyoto University in Japan stunned the mathematical world with a sprawling 500-page proof for the ABC conjecture, an important unsolved problem that strikes at the very heart of what numbers are. The proof used a highly technical and abstruse framework invented by Mochizuki, called inter-universal Teichmüller (IUT) theory, which appeared impenetrable even to most expert mathematicians seeking to understand it.

The ABC conjecture, which is now more than 40 years old, involves a seemingly simple equation of three whole integers, $a + b = c$, and dictates how the prime numbers that make up these numbers must relate to one another. As well as giving deep insights into the fundamental nature of how addition and multiplication interact, the conjecture has implications for other famous mathematical conjectures, such as Fermat's Last Theorem.

These potential ramifications made mathematicians initially enthusiastic about verifying the proof, but early efforts faltered and Mochizuki bemoaned that more effort hadn't been made to digest the work. Then in 2018, two prominent German mathematicians, Peter Scholze at the University of Bonn and Jakob Stix at Goethe University Frankfurt, announced they had located a possible chink in the proof's armour.

But Mochizuki rejected their argument and, with no grand adjudicating body to rule on who was right or wrong, the validity of IUT theory froze into two camps: on one side, most of the mathematical community; on the other, a small group of researchers loosely affiliated with Mochizuki and the Research Institute for Mathematical Sciences in Kyoto, where he is a professor.

Breaking the stalemate

Now, Mochizuki has proposed a possible solution to the stalemate. He has suggested translating the proof from its current form, in a mathematical notation designed for humans, to a programming language called Lean, which could be automatically checked and verified by a computer.

This process, called formalisation, is an ongoing area of research that could completely change the way mathematics is done. Formalising Mochizuki's proof has been suggested before, but this is the first time he has indicated a desire to move forward with the project.

Mochizuki didn't respond to a request for comment, but in a recent report, he argued Lean would be well suited to untangling the sorts of disagreements between mathematicians that have prevented the widespread acceptance of his proof: "[Lean] is the best and perhaps the only technology... for achieving meaningful progress with regard to the fundamental goal of liberating mathematical truth from the yoke of social and political dynamics," writes Mochizuki.

According to Mochizuki, he was convinced of formalisation's merits after attending a recent conference on Lean in Tokyo in July, in particular after seeing its ability to handle the sorts of mathematical structures he says are essential for his IUT theory.

This is a potentially promising direction for helping to break the impasse, says Kevin Buzzard at Imperial College London. "If it's written down in Lean, then it's not crazy, right? A lot of the stuff in the papers is written in a very strange language, but if you can write it down in Lean, then it means that at least this strange language has become a completely well-defined thing," he says.

"We want to understand the why [of IUT], and we've been waiting for that for more than 10 years," says Johan Commelin at Utrecht University in the Netherlands. "Lean would be able to help us understand those answers."

However, both Buzzard and Commelin say that formalising IUT theory would be a mammoth undertaking and would involve translating reams of mathematical equations that currently only exist in human-readable form. This project would be on par with some of the largest formalisation efforts that have ever been completed, which often involve teams of expert mathematicians and Lean programmers, taking months or years.

"This process, called formalisation, could completely change the way mathematics is done"

This may be an unattractive proposition for the small handful of mathematicians qualified to take on the project.

But even if mathematicians do manage to complete the project, and the Lean code shows that Mochizuki's theorem has no contradictions, mathematicians including Mochizuki himself could still fight over its meaning, says Commelin.

However, Buzzard is hopeful that a successful formalisation might, at least, move the decade-long saga on, especially if Mochizuki succeeds. "You can't argue with the software," he says.

THE YOMIURI SHIMBUN/AP IMAGES/ALAMY

Shinichi Mochizuki delivering a lecture at Kyoto University in 2013

Archaeology

Skeleton with savage injuries belonged to assassinated royal

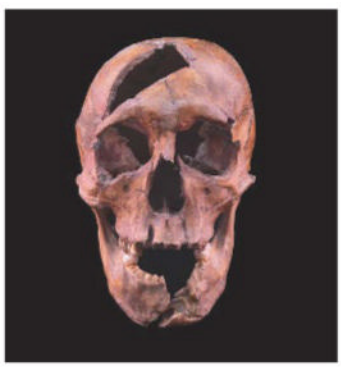
Christa Lesté-Lasserre

MORE than 700 years ago, a Hungarian duke was murdered in a brutal and bloody head-on attack in a convent. Now, researchers studying a skeleton excavated in Budapest have confirmed it belonged to the duke and revealed shocking details of his assassination.

"There were so many more serious injuries than would be necessary to kill somebody," says Martin Trautmann at the University of Helsinki in Finland.

Archaeologists uncovered the man's remains – which had been buried in dismembered pieces in the convent floor – during a 1915 excavation of a Dominican convent on Margaret Island, in the middle of the river Danube in Budapest. At the time, they suspected it might be the body of 29-year-old Béla of Macsó, the grandson of King Béla IV, who had built the convent.

Historical records from 13th-century Austria indicate the young duke was assassinated on



BORBÉLY NOÉMI/TAMÁS HAJDU ET AL. 2025

The cracked skull of Béla of Macsó, a Hungarian duke murdered in 1272

the island over a feud for the Hungarian throne in November 1272. The bones showed multiple signs of trauma, but the scientists lacked the tools and technology to confirm their suspicions.

The skeleton was apparently lost during the second world war, says Tamás Hajdu at Eötvös Loránd University in Hungary, but it resurfaced in 2018 in a wooden box at the Hungarian Museum of Natural History. Its rediscovery prompted investigations with modern techniques, including a facial reconstruction last year.

The skeleton had nine injuries to the head and face and another 17 to the rest of the body, all occurring at the time of death, says Hajdu. To determine how the attack unfolded, Hajdu, Trautmann and their colleagues marked an educational model skeleton with the same cuts and played out various scenarios. "It was step by step, injury by injury, like a stop-motion movie," says Trautmann.

The injuries suggested two or three people accosted the man from the front and the sides, and he used his arms to block the blows, says Trautmann.

Eventually he fell and cracked open his skull, but continued to fight with his left leg, lying on his side, until someone stabbed through his spinal column. His attackers then inflicted multiple injuries to the head and face.

Radiocarbon dating placed the death in the mid-13th century.

DNA analyses identified the man as a fourth-generation descendant of King Béla III of Hungary and an eighth-generation relative of a 13th-century regional Russian prince, Dmitry Alexandrovich – aligning with historical records about the duke's family history (*Forensic Science International: Genetics*, doi.org/g99dk3).

> **"There were so many more serious injuries than would be necessary to kill somebody"**

Additional genetic analyses were also consistent with historical knowledge of the duke's ancestry.

The study sheds "convincing" light on a poorly understood historical event that has few recorded details, says Tamás Kádár, an independent medieval historian in Budapest. ▮

Solar system

Chances of life in Enceladus's ocean are now even higher

THE liquid water ocean hidden underneath the icy crust of Enceladus has long made this moon of Saturn one of the best prospects in the hunt for extraterrestrial life – and it just got even more promising. The discovery of heat emanating from the frozen moon's north pole hints that the ocean is stable over geological timescales, giving life time to develop there.

"For the first time, we can say with certainty that Enceladus is in a stable state, and that has big implications for habitability," says Carly Howett at the University of Oxford.

Howett and her colleagues used data from NASA's Cassini spacecraft, which orbited Saturn from 2004 to 2017, to hunt for heat seeping out of Enceladus. Its interior is heated by tidal forces as it is stretched and crunched by Saturn's gravity, but, so far, this heat has only been caught leaking out of the south polar regions.

For life to have developed in Enceladus's ocean, it would require balance: the ocean should be putting out as much heat as is being put in. Measurements of the heat coming out of the south pole don't account for all of the heat input, but Howett and her team found that the

SCIENCE PHOTO LIBRARY/ALAMY

An artist's impression of water jets venting from Saturn's moon Enceladus

north pole is about 7°C warmer than we previously thought (*Science Advances*, doi.org/g99kp2). Combined with the heat radiating from the south pole, that matches the total almost exactly – the ice shell is thicker around the equator, so heat only escapes in significant amounts at the poles.

This means the ocean should be stable over long periods of time. "It's really hard to put a number on it, but we don't think it's going to freeze out anytime soon, or that it's been frozen out anytime recently," says Howett. "We know life needs time to evolve, and now we can say that it does have that stability." Actually finding that life, if it is there, is another story entirely. ▮

Leah Crane

Space

Cosmic rays destroy comet clues

Evidence of where interstellar visitor 3I/ATLAS came from may have been lost in space

Alex Wilkins

3I/ATLAS, the interstellar comet passing through our solar system, might have been radically transformed by cosmic rays over billions of years, changing its appearance so thoroughly that we may never be able to work out where it came from.

Since astronomers spotted 3I/ATLAS in July, they have detailed some puzzling properties. These include levels of carbon dioxide in its coma – a plume of gas and dust – that are at least 16 times higher than typical comets in our solar system, making it one of the most CO_2-rich comets ever seen.

Some hoped this might be an indication of the exotic star system 3I/ATLAS originated from (or, improbably, extraterrestrial involvement).

But Romain Maggiolo at the Royal Belgian Institute for Space Aeronomy in Uccle and his colleagues argue that the high CO_2 levels are best explained by the outer part of 3I/ATLAS having been radically altered by high-energy particles known as cosmic rays over billions of years.

"Somehow, this process has been a bit overlooked or taken as a secondary process, because it's very slow. But in the end, for objects like comets or interstellar objects, it has a strong effect," says Maggiolo.

The researchers compared the observations of 3I/ATLAS to laboratory studies where cosmic rays are fired at ice made of water and carbon monoxide, which is thought to be like the ice that forms on comets. These studies find that this process creates abundant CO_2, as well as leaving behind a red-looking residue that is high in carbon, which astronomers have also observed on the comet (arXiv, doi.org/qcwf).

"Very slowly, [cosmic rays] will break molecules and produce reactive radicals, fragments of molecules that will recombine, and so they will slowly change the chemical composition of the [comet's] ice," says Maggiolo.

This would be a significant blow to our hopes of understanding where these comets come from, he says, as the cosmic rays could have destroyed crucial evidence. Astronomers believed interstellar comets were extremely well preserved, acting as cold fossils that contain information about other star systems.

The possibility of visiting the comet with a satellite to sample material directly has been ruled out due to its high speed through our solar system. But there is one glimmer of hope for discerning 3I/ATLAS's true nature.

The comet is currently passing close to the sun, out of view from Earth, but is set to reappear in December. This close pass could melt enough ice in its outer layer to reveal material underneath that has been protected from cosmic rays, says Maggiolo.

Cyrielle Opitom at the University of Edinburgh, UK, says upcoming observations, both with the James Webb Space Telescope and ground-based telescopes, will be crucial to look for more pristine material below the comet's surface. "We have a very exciting few months coming," she says. ▮

This deep image of 3I/ATLAS shows the coma of dust and gas around the comet

INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA

Health

Enamel-boosting gel may remove the need for fillings

A GEL can repair and regenerate tooth enamel using chemicals found in saliva, which could prevent people from developing cavities that require fillings.

Enamel – the hard, shiny layer on the surface of teeth – shields the sensitive inner layers from wear and tear, acids and bacteria. "Enamel is the first line of defence. Once that line of defence starts to break down, tooth decay becomes accelerated," says Alvaro Mata at the University of Nottingham, UK. Enamel doesn't naturally regenerate, and treatments such as fluoride varnishes only stop the situation from worsening.

Looking for a solution, Mata and his colleagues have developed a gel containing a modified version of a protein that they manipulated to act like amelogenin, a protein that helps guide the growth of our enamel when we are infants.

Experiments that involved pasting the gel onto human teeth under a microscope in solutions containing calcium and phosphate – the primary building blocks of enamel – show that it creates a thin and robust layer that stays on teeth for a few weeks, even during brushing (*Nature Communications*, doi.org/g986fj).

The gel fills holes and cracks, creating a scaffold that uses the calcium and phosphate to promote the organised growth of new crystals in the enamel below the gel layer, even when the underlying dentine below was exposed.

"The gel was able to grow crystals epitaxially, which means it's in the same crystallographic orientation as existing enamel," says Mata.

"The gel creates a thin and robust layer that stays on teeth for a few weeks, even during brushing"

That orientation means the new growth – which reached up to 10 micrometres thick – is integrated into the underlying natural tissue, rebuilding the structure and properties of enamel. "The growth actually happens within a week," says Mata. The process also worked when using donated saliva, which also naturally contains calcium and phosphate.

Clinical trials in people are set for early next year. ▮

Chris Simms

Archaeology

Map reveals the Roman Empire's vast road network

Tom Leslie

A COMPREHENSIVE map of Roman roads has boosted the known size of the empire's land transport network by almost 60 per cent, and it is available for anyone to explore online.

The project, called Itiner-e, brings together topographic mapping, satellite imagery and historical records in what its creators say is the first open dataset of its kind.

"It emerged from enormous frustration," says Tom Brughmans at Aarhus University in Denmark. "It's like the most enigmatic topic in Roman archaeology. We even have proverbs that say, 'All roads lead to Rome'. So why on Earth can't I download all the Roman roads?"

Brughmans and his colleagues incorporated evidence from a large set of studies and traced more realistic paths for previously known routes to produce a map of the road network as it might have looked around AD 150. They also gave the placement of each stretch of road a confidence rating, based on the quality of the source.

According to their data, the total length of the road network at this time was around 299,171 kilometres – much more than the previous estimate of 188,555 km given by the *Barrington Atlas of the Greek and Roman World* (*Scientific Data*, doi.org/qcss).

They also found that, although we have strong evidence for the starts and ends of many roads, only 2.8 per cent of the network's length can be located precisely – within 50 metres in mountains and 200 metres on flat land.

Improved knowledge of the Roman road network could inform our understanding of many highly impactful events in European history. The emergence of early Christianity, mass migration and continent-wide pandemics were all influenced by the Roman road system, says Brughmans. ▮

Gene editing

Grafting technique could let us gene-edit a huge variety of plants

Michael Le Page

JAN SOCHOR/GETTY IMAGES

We can't gene edit avocados, but that may be about to change

THE ancient trick of grafting one plant onto another could enable gene editing of plants that are very difficult or impossible to edit by other means.

"It is still at the beginning stage, but this technique has great potential," says Ugo Rogo at the University of Pisa in Italy.

Making plants more productive and nutritious is vital for tackling the damage done by farming and limiting food price hikes as the world's population grows and climate change hits yields. The precise changes that can be made with CRISPR gene editing are the most powerful way of achieving this.

However, gene editing plants is tricky because they have rigid cell walls around them. Conventional approaches involve techniques such as firing DNA-impregnated pellets at plant cells – known as biolistics – or using a natural gene-engineering microbe known as *Agrobacterium*.

These approaches rely on generating entire plants from modified cells, and with many plants, especially trees, this cannot be done. For instance, it does not work with cocoa, sunflowers, or avocados.

Even for plants where it does work, there is another major issue. When gene editing is used to induce tiny mutations of the kind that are very common naturally, regulators in several countries see it as equivalent to standard plant breeding,

"Making plants more productive is vital as climate change hits yields"

meaning such plants can get approval without the long and expensive trials required for conventional genetically modified plants. But with biolistics and *Agrobacterium*, extra DNA is often inserted into plants' genomes, so they would have to go through the full regulatory process.

Scientists are trying to find ways of editing plants that work for more species and don't add any unwanted bits of DNA. One option is to use viruses to deliver RNA coding for parts of the CRISPR toolkit to plant cells. However, the Cas9 protein widely used for gene editing is very large, meaning the RNA coding for it can't fit into most viruses.

In 2023, Friedrich Kragler at the Max Planck Institute of Molecular Plant Physiology in Germany unveiled another approach. He knew plant roots produce a special type of RNA that can travel around plants and enter cells in the shoots and leaves.

So his team genetically engineered plants to produce such RNAs coding for two key CRISPR components: the Cas9 protein that does the editing and the guide RNA that tells it where to make the edit. They then grafted shoots of non-modified plants onto the roots of the modified plants, and this resulted in gene editing of some of the shoots and seeds.

Rogo and his colleagues think the approach is so promising that they have now written a paper encouraging others to help develop it (*International Journal of Molecular Sciences*, doi.org/qcrw).

The key thing about grafting is that relatively distantly related plants can be grafted onto each other – for instance, you can graft tomato shoots onto potato rootstocks.

Once there is a rootstock producing the necessary RNAs, it can be used to gene edit a wide variety of plants. "You can use the roots to deliver Cas9 and editing guides to all sorts of elite varieties," says Julian Hibberd at the University of Cambridge. ▮

Zoology

Three-legged lion hunts like a leopard

Adam Popescu

ALEX BRACZKOWSKI

Jacob, pictured here wearing a tracking collar, lost his left hind leg to a poacher's snare

A LION that lost one leg to a poacher's snare has defied conservation scientists' expectations by adopting an inventive new hunting strategy.

Jacob, an 11-year-old lion in Queen Elizabeth National Park, Uganda, made headlines last year when he and his brother swam 1.5 kilometres across a crocodile-filled river, the longest swim ever recorded for their species.

Wounded carnivores usually scavenge, take cattle or rely on others for food, but Jacob, who is also missing an eye after being gored by a water buffalo, has only his brother Tibu to support him.

Researchers were convinced that he would starve after he lost his left hind leg in 2020. "Instead, he refuses to quit," says Alexander Braczkowski at the Kyambura Lion Monitoring Project, which is supported by the Volcanoes Safari Partnership Trust, a Ugandan NGO focused on conservation and community development.

Now thermal drone footage has revealed his secret: this lion has learned to act like a leopard.

Since he can't overpower prey as lions typically do, Jacob sets close-range ambushes in dense thickets and scrub forests, lying in wait and pouncing, or digging his prey out.

He also targets prey lions normally don't hunt, Braczkowski says. Filming at night, cameraman Daniel Snyders and the Kyambura Lion Project captured Jacob hunting 200-kilogram forest hogs.

Losing limbs to snares is common for felines, says Andrew Loveridge at Panthera, a global wild cat conservation organisation.

So is adapting, says Craig Packer, at the University of Minnesota, who has studied lion behaviour for decades. "I'd expect to see similar behaviour in other groups of lions," he says, "all of which had four good legs, in the same area."

But Braczkowski says Queen Elizabeth's lions focus on large, fast-moving game like antelopes and water buffalo.

Jacob's novel hunting strategy may be teachable behaviour that could help reverse declining lion numbers in a region facing habitat loss, climate change and encroaching communities. That is why Jacob is important, "symbolically and genetically," says Braczkowski. ▮

Quantum computing

Have we built a prototype of the quantum internet?

Matthew Sparkes

ONE of the most complex quantum networks built to date would allow 18 people to communicate securely thanks to the power of quantum physics. The researchers say it offers a path to a global quantum internet, but others are sceptical.

The long-promised quantum internet would allow quantum computers to communicate at distance by exchanging particles of light – or photons – that have been linked together by quantum entanglement. But wiring together a quantum world isn't as simple as laying down cables, because ensuring that one node of the network can be entangled with another is a challenge.

Now, Xianfeng Chen at Shanghai Jiao Tong University, China, and his colleagues have shown how to link two quantum networks together. First, they built two networks, each with 10 nodes that all shared quantum entanglement – effectively making two tiny versions of a quantum internet. They then sacrificed one node from each network to fuse the two together into one larger, fully entangled network, in which every pair among the 18 remaining nodes could communicate (*Nature Photonics*, doi.org/qcpp).

> **"Our approach offers a crucial capability for quantum communication"**

Networking 18 classical computers would be a simple task, requiring only extremely cheap components, but in the quantum world, it involves sharing individual photons between multiple users with timing so precise that it demands cutting-edge technology and expertise. Even communication between a pair of devices is complex, but allowing any pair among 18 users to communicate is unprecedented.

"Our approach offers a crucial capability for quantum communication across different networks and is advantageous for building a large-scale quantum internet that enables communication among all users," write the researchers, who didn't respond to a request for comment, in a paper about their work.

This network fusion, as they describe it, requires a process called entanglement swapping. Photons can be made quantum entangled by carrying out a particular observation called a Bell measurement. Simultaneously measuring the state of one photon from each of two pairs of entangled photons effectively links the most distant two photons in the chain, but uses up the measured photons because any attempt to directly check their state destroys the fragile quantum equilibrium.

"This is not the first time entanglement swapping has been shown," says Siddarth Joshi at the University of Bristol, UK. "What they have done is they have created a scheme where you can do the swapping between the networks in a bit more of a convenient way."

But Robert Young at Lancaster University in the UK says that, while the result is a phenomenal technical achievement, the cost and complexity make it unlikely to act as a prototype for future, wide-scale quantum networks.

"It's just so far from practical, and it's so far from anything that could be implemented in the real world," he says. ▮

Health

Daily steps slow Alzheimer's decline

Walking just 3000 steps seems to prevent the build-up of misfolded proteins in the brain

Carissa Wong

OLDER people who are particularly at risk of Alzheimer's disease could slow their cognitive decline by walking just 3000 steps a day. Why this step count might have this effect is unclear, but it could be linked to the impact of regular exercise on inflammation or blood flow to the brain.

Prior studies that link regular exercise to reduced cognitive decline have mostly relied on people recalling their activity levels and have rarely explored why staying active may have this effect.

To address this, Wai-Ying Wendy Yau at Harvard University and her colleagues analysed the physical activity of 296 cognitively healthy people, aged between 50 and 90, who wore a step-tracking device for one week, to objectively measure their activity levels.

Most of the participants had their brain imaged to reveal their baseline levels of misfolded proteins called tau and beta-amyloid, clumps of which are thought to cause Alzheimer's. These levels were then measured every two to three years or so over a follow-up period of between three and 14 years. The participants also completed annual cognitive tests that assessed things like their memory and how quickly they processed information.

By feeding the step count, brain imaging and cognitive test data into a statistical model, the researchers estimated how exercise affects cognitive decline. They found that, among the participants with above-average levels of misfolded beta-amyloid in their brain at the start, taking between 3000 and 5000 steps per day seemed to substantially slow the accumulation of misfolded tau, but not beta-amyloid (*Nature Medicine*, doi.org/qcpn).

Regular exercise has benefits for the mind as well as the body

G. SCAMMELL/LOOP IMAGES/UNIVERSAL IMAGES GROUP VIA GETTY IMAGES

"[Exercise is] somehow slowing the spread of this tau protein, which is more strongly associated with people developing symptoms [of Alzheimer's disease] than amyloid-beta," says Charles Marshall at Queen Mary University of London.

This level of activity was also linked to a roughly 40 per cent slowing in the rate of cognitive decline over an average follow-up period of nine years compared with taking fewer than 3000 steps per day. The researchers lacked the data to assess whether any of the participants were diagnosed with Alzheimer's during the follow-up period.

Meanwhile, taking between 5000 and 7500 steps per day seemed to slow tau accumulation even further, leading to a 54 per cent slower rate of cognitive decline compared with being inactive. But taking more than 7500 steps per day wasn't linked to further cognitive benefits. "Those tau and cognitive benefits eventually plateau," says Yau.

The researchers didn't explore exactly how regular exercise may have these effects, but it could be due to physical activity reducing inflammation, which is thought to occur as a result of misfolded beta-amyloid and tau that disrupt neural connections and kill cells. Exercise may also boost blood flow or levels of a protective hormone to the brain. ▮

Space

Black hole rips star apart to produce brightest ever flare

ASTRONOMERS have spotted the brightest flare ever seen coming from a supermassive black hole. It was so powerful it can only have come from a huge star being torn apart at the centre of a distant galaxy in what is called a tidal disruption event (TDE).

The burst of energy came from an active galactic nucleus (AGN) – a supermassive black hole at the centre of a galaxy that is actively consuming matter – nearly 20 billion light years away, making it one of the most distant TDEs ever detected.

"We've known what AGNs are for about 60 years, and we knew that they were very variable, but we didn't understand the variability," says Matthew Graham at the California Institute of Technology. The event, nicknamed "Superman" for its incredible brightness, was first spotted in 2018, but it was assumed to be from a relatively nearby galaxy. In 2023, follow-up observations revealed it was much more distant, making its intrinsic brightness far higher than we initially thought (*The Astrophysical Journal Letters*, doi.org/qcpm).

The initial flare brightened the AGN by more than a factor of 40, making it 30 times as powerful as the previous strongest flare ever seen from an AGN. Graham and his colleagues found the most likely cause was a massive star being ripped apart: one at least 30 times the mass of the sun.

In the area around every active supermassive black hole is a ring of material in the process of falling in, called an accretion disc. The density of material in that area should produce huge stars, but we have never seen them directly. "If our interpretation is correct... then it is proving the existence of these massive stars in that environment," says Graham.

"We used to think an active supermassive black hole just sat there. But it's much more vibrant and dynamic"

"We used to think that an active supermassive black hole would just have its disc of gas and it would sit there and burble along. But it's a much more vibrant and dynamic environment," says Graham. ▮

Leah Crane

Environment

Antarctic glacier retreats at record rate

Jonathan Amos

SCIENTISTS have documented what they say is the quickest retreat of an Antarctic glacier in modern history.

Hektoria glacier on the Antarctic Peninsula shortened by 25 kilomeres in just 15 months, collapsing at speeds up to 10 times faster than current records.

Naomi Ochwat at the University of Colorado Boulder and her colleagues attribute the rapid shrinkage to a vulnerability in Hektoria's configuration, which saw its thinning trunk withdraw across a flat seabed area known as an ice plain (*Nature Geoscience*, doi.org/qcpk). This triggered a runaway surge in iceberg production.

The team warns that the collapse mechanism could threaten other Antarctic glaciers, with serious implications for sea level rise.

"The question is: was Hektoria an end-member case, where it was a perfect storm of events that caused this, or is there a recipe for disaster elsewhere?" says Ochwat.

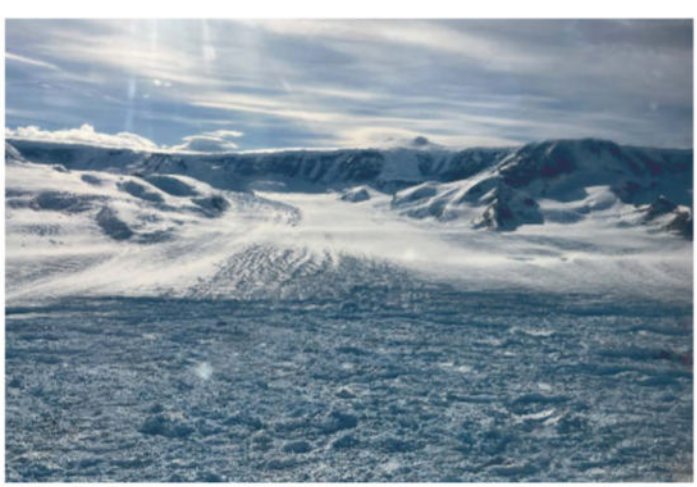
Hektoria's problems began in early 2022, when a mass of sea ice detached from the city-sized glacier's front and its floating ice tongue disintegrated. The removal of this stabilising ice exposed the glacier to new stresses, causing its flow and thinning rates to accelerate.

But the most dramatic change occurred over the ice plain, where Hektoria's trunk, previously grounded on flat bedrock, apparently thinned so much that its bulk was eventually resting only very lightly on the seabed.

According to the researchers, the entire section went afloat almost instantaneously, exposing weaknesses in the trunk and initiating its break-up. Buoyant forces ripped away icebergs, generating "glacial earthquakes" that were detected by seismic sensors. The glacier lost 8 km in length in November and December 2022.

The analysis has sparked controversy, however. Frazer Christie of Airbus Defence and Space says there is "significant disagreement" within the glaciological community about precisely where Hektoria had been fully grounded on bedrock due to a lack of high-accuracy satellite records.

Hektoria glacier shortened by 25 kilometres in just 15 months



NAOMI OCHWAT

Views

Comment

Supremely selfish

A study hammers home how the "survival of the nicest" view makes no sense when it comes to evolution, says **Jonathan R. Goodman**

SELFISHNESS is an uncomfortably common biological phenomenon. Recent research showing how genetic mutations accumulate in sperm in middle and older age highlights this. Stem cells that emerge over time make it much more likely that sperm will have disease-causing mutations in older fathers – possibly up to 5 per cent of gametes by age 70, according to the study.

This finding goes further than showing the benefits of having children when younger. The mutated stem cells don't care whether their deviations lead to problems in potential offspring, as long as their cellular progeny make it to the next generation. It is a great example of how the selfish gene remains the model of evolution we should collectively converge on. Genes don't act for the benefit of anything but themselves. And no matter how often some people try to defend a "survival of the nicest" view in biology, explanations always have to come back to genetic selection.

The broader debate is old and tired, and hinges on whether you want to believe that evolution via natural selection favours cooperation and friendliness or competitiveness and a cold, calculating organism designed to reproduce successfully at any cost. For the past century or so, many biologists have labelled these contrasting views of evolution group versus individual selection. The difference between them is fundamental to how we view the natural world – and each other.

ADRIÀ VOLTÀ

The split between the two views has always been across ideological lines. Early ethologists thought that organisms act for the good of the species. If I survive, according to this view, it is good for all people, because there will be another person who can at least potentially contribute to the perpetuation of *Homo sapiens*. Helping each other is an obvious route to achieving this shared goal.

The problem – as nearly every major biologist has pointed out, from Ronald Fisher, who combined Charles Darwin's theories with genetics, to modern writers like Richard Dawkins – is that organisms that accept help without providing it to others will always do better in the game of life. Individuals that subvert their groups are best-placed for success – assuming the damage they cause isn't so horrendous it kills off every other group member.

The individual's optimum, from an evolutionary point of view, is then to promote cooperation among others while withholding cooperation themselves – and ideally, without anyone knowing they are doing so. Cooperation, rather than leading to selection for nice, helpful qualities, just creates an environment where competing or exploiting is most effective when it is undetected.

The problem of subversion undermines groups, whether we are talking about gametes, bacteria, animals or people. The stem cell that reproduces at the expense of the organism's offspring is blind to whether its success harms future generations. The good of the host, let alone the host's species, is irrelevant.

The same holds true for human societies, ancient or modern. Those with power – globally, this is often older men – monopolise groups however they can, and often choose younger women for themselves. Given the negative consequences of older men remaining reproductively active, as evidenced by the new research on sperm, it is hard to understand how anyone can take the group selection model seriously.

Most importantly, though, is that these unpleasant truths about our biological heritage don't need to define how we behave today. Mutual aid is something we should aim for, not take for granted – and recognising our selfish heritage, at every biological stage down to our genes, is the first step towards overcoming it. ▮

Jonathan R. Goodman is author of *Invisible Rivals: How we evolved to compete in a cooperative world*

This changes everything

We don't need no education

New technologies and academic funding cuts are upending the ways we learn today. Newly enrolled student **Annalee Newitz** finds some silver linings

Annalee Newitz is a science journalist and author. Their latest book is *Automatic Noodle*. They are the co-host of the Hugo-winning podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is techsploitation.com

Annalee's week

What I'm reading
The Keeper of Magical Things *by Julie Leong, a cosy fantasy about archivist mages.*

What I'm watching
Frankenhooker, *the greatest adaptation of* Frankenstein *ever made.*

What I'm working on
Doing homework for Karen Attiah's class!

This column appears monthly. Up next week: Rowan Hooper

IN 1907, US historian Henry Adams first started circulating a memoir that would go on to be a smash hit in 1919: *The Education of Henry Adams*. Given Adams's illustrious family – both his grandfather and great-grandfather were presidents – you might expect it to be a self-congratulatory tale of the wonders of US education.

Instead, it galvanised audiences with the bold claim that everything Adams had been taught in 19th-century schools was useless. Immersed in religious studies and the classics, he was ill-equipped for a world of mass electrification and automobiles. If education was supposed to prepare him for the future, he argued, it had failed.

Nearly 120 years later, Adams's critique is once again relevant, especially in the US. New technologies are upending the traditional ways that students learn. The problem isn't just the rise of AI models, though. It is also ideological. The US government is depriving universities of billions in federal funding while it demands more control over curriculums and admissions. The future of education is in chaos, but it isn't dying; it is changing to meet the moment.

I was thinking about Adams as I sat down to take my first college course in over two decades. "Race, Media and International Affairs" is taught by journalist and international studies professor Karen Attiah. In 2024, Attiah covered politics at *The Washington Post* and taught international affairs at Columbia University in New York. But earlier this year, Columbia unceremoniously cancelled her courses. A few months later, Attiah says she was fired by the *Post* over social media posts regarding racism and right-wing activist Charlie Kirk. The newspaper declined to comment on Attiah's dismissal at that time.

But, in Attiah's words: "This is not the time for media literacy or historical knowledge to be held hostage by institutions bending the knee to authoritarianism and fear." So she converted her Columbia class into what she called "Resistance Summer School", which she would livestream to anyone who paid a tuition fee. Five hundred students enrolled within 48 hours, and the wait list was huge. Now, she is teaching two courses this fall, including mine.

In many ways, Attiah's class feels like a throwback to the courses I took in college over 25 years ago. Sitting at a desk, Attiah lectures on topics such as how colonial newspapers in the 1600s described wars with Indigenous nations in the colonies, and why the media failed to cover Japan's Racial Equality Proposal for the Treaty of Versailles in 1919. Weaving together the history of US media and international race relations, Attiah has taught me a lot that I never knew, despite working my whole adult life as a journalist and occasional media studies professor. I feel like I am back in college, in the best possible sense.

> **"I fear for academic institutions, but not for the future of education. The quest for knowledge can never be stopped"**

Attiah's no-nonsense approach stands in stark contrast to other professors who have taken their work online. Philosophy Tube, a long-running series of lectures delivered by philosopher Abigail Thorn on YouTube, teaches modern philosophy with effects, costumes and witty scripting. But Thorn's aim is the same as Attiah's: she wants to make education as publicly accessible as possible, and to question authority without academic constraints.

Attiah and Thorn are following in the footsteps of the scholar and activist Stuart Hall. After teaching cultural studies at the University of Birmingham, UK, in the 1960s and 70s, he wanted to break out of his ivory tower and teach the British public about racism in the media. So he co-wrote and co-hosted a documentary for the BBC in 1979 called *It Ain't Half-Racist, Mum*, about racial bias in news reports and TV shows about Black immigrants.

When the public can't gain access to higher education, Hall suggested, then higher education should come to the public. And that is exactly what educators are doing now. Some are teaching for free, relying on crowdfunding; others, like Attiah, are using a subscription model. Either way, they are finding ways to educate.

But what about students who don't want to stare at a screen for hours? There is a new movement afoot to reach these learners too. Hacker and maker spaces – community centres for learning about science and engineering – are springing up all over the world. Members can take classes in everything from electronics to 3D printing and welding.

As Adams argued, education should prepare us for what is coming next. And what is coming, I believe, is a world where academic freedom exists only outside academia. I fear for the future of academic institutions, but not for the future of education. As long as we support our renegade professors and hacker space tutors, the quest for knowledge will never be stopped. ▮

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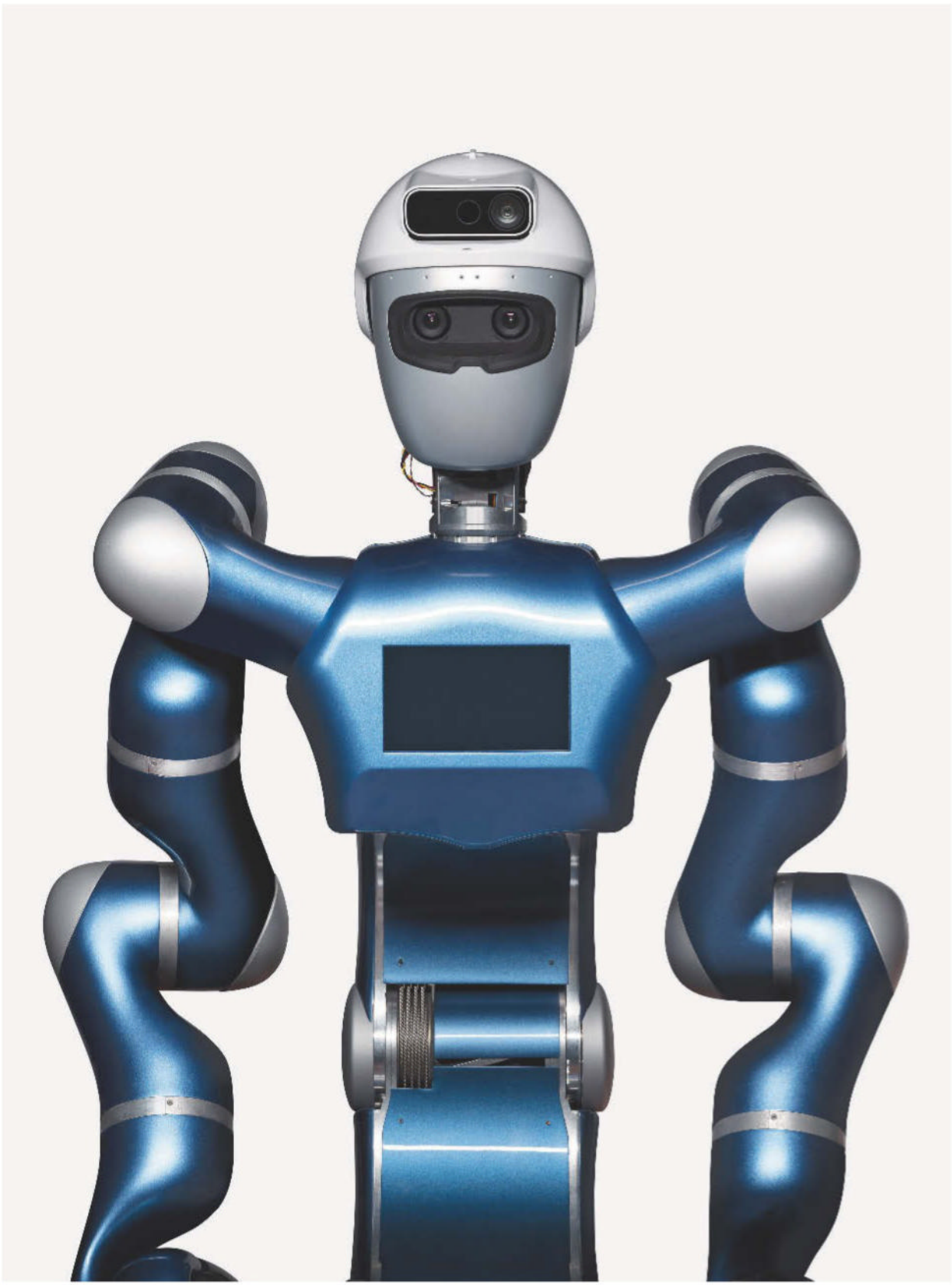
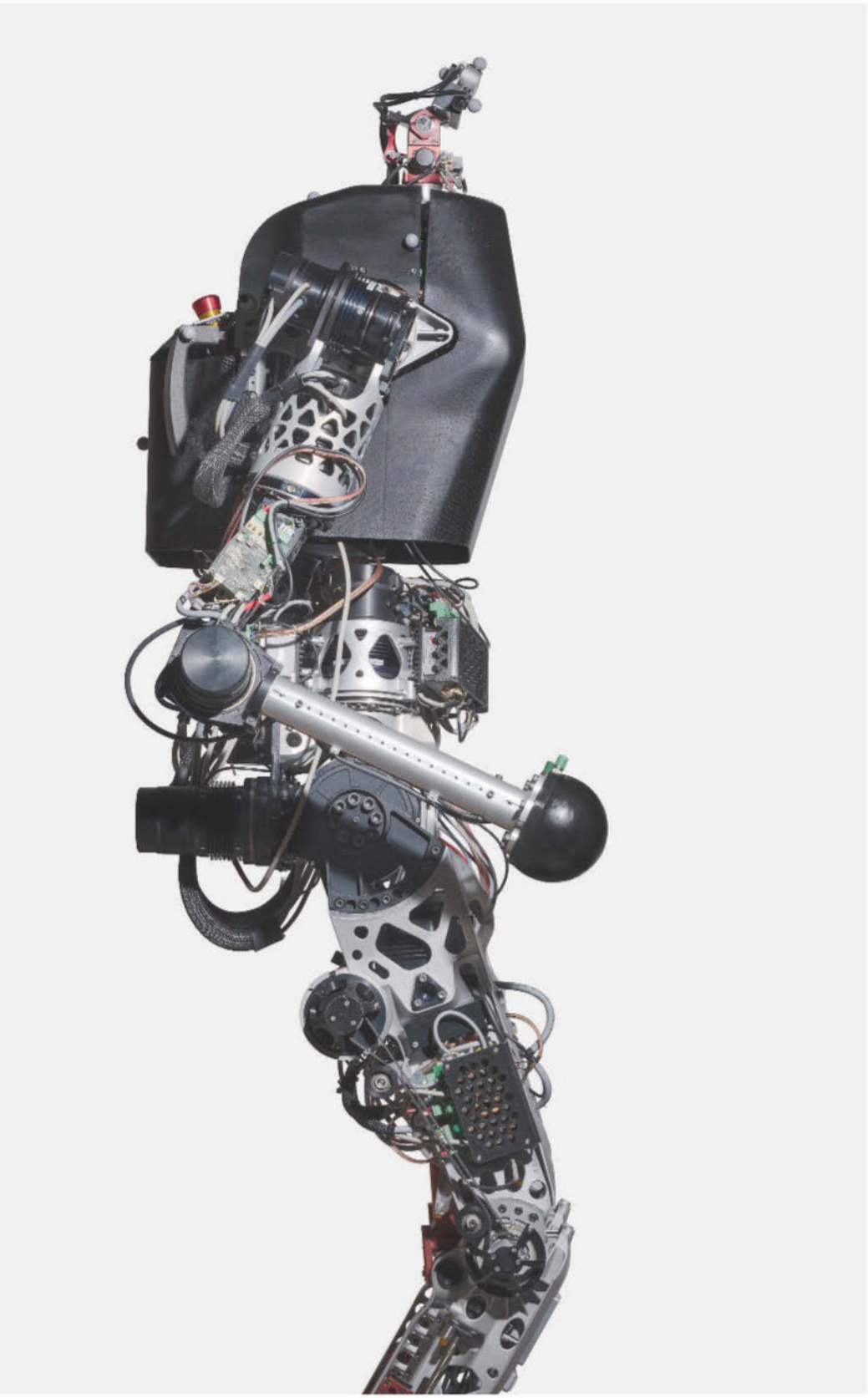




Robotic realms

Henrik Spohler/laif/CameraPress
Tomorrow Is the Question

WE HAVE long been fascinated with our own image. In the 1920s play *Rossum's Universal Robots*, Czech writer Karel Čapek coined the term robot to describe human-looking creatures forced to work in factories. Since then, we have built many humanoid robots that can move and interact with the world in anthropomorphic ways.

Award-winning photographer Henrik Spohler at photo agency laif explores such endeavours in his project *Tomorrow Is the Question*. The far-left image shows a metallic creation by the German Aerospace Center's Institute of Robotics and Mechatronics in Oberpfaffenhofen.

The 200-kilogram robot, called Rollin' Justin, can travel long distances on wheels. Using cameras to take in its surroundings, it can avoid obstacles and carry out tasks such as serving drinks. It could potentially be developed to assist astronauts or people with disabilities.

The other image is a side profile of Lola, a robot built by the Technical University of Munich, in Germany. Standing nearly 1.8 metres tall, it can walk in unfamiliar environments and navigate unstable ground.

Carissa Wong

Unravelling the DNA story

Fascinated by DNA? Then this biography of Francis Crick, who co-discovered its structure, is for you. **Michael Le Page** finds plenty of surprises

Book

Crick: A mind in motion – from DNA to the brain

Matthew Cobb

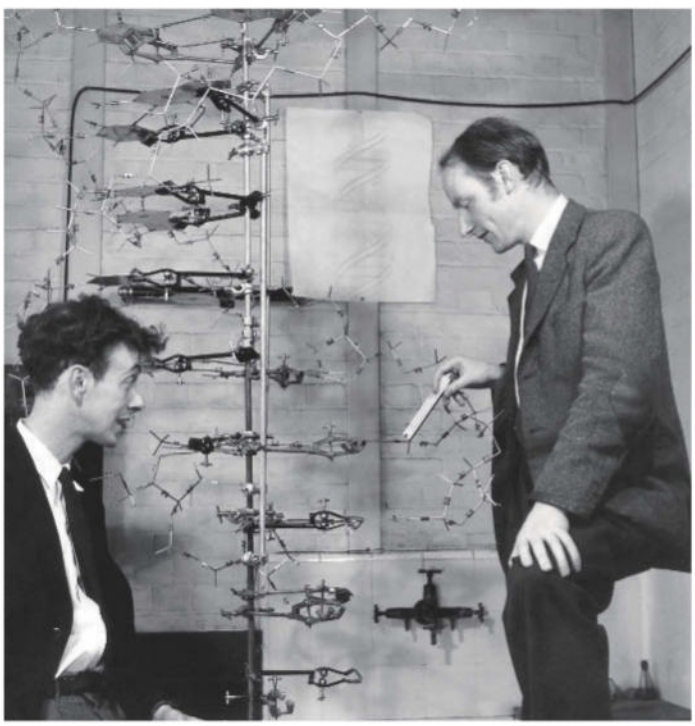
Profile Books, UK; Basic Books, US

FRANCIS CRICK missed a crucial seminar in 1951, probably because he was seeing a lover. James Watson did go, failed to take notes and misremembered key details. As a result, their first model of DNA was embarrassingly bad.

This is one of many fascinating details in *Crick: A mind in motion – from DNA to the brain,* a biography by zoologist and writer Matthew Cobb. If you are interested in how DNA's structure was discovered and what happened next, this is the book to read.

A son of shopkeepers, Crick didn't do well enough at school to get into Oxbridge, got a second-class degree and was doing a very dull PhD on water's viscosity until he was sent to work on sea mines during the second world war. By 1947, he was a civil servant with a failed marriage and his son was living with his grandparents. But Crick's reading had left him fascinated by the molecular underpinnings of life and of consciousness. He went back into research, initially working at an independent lab in Cambridge, UK.

In 1949, he began studying the structure of biological molecules by looking at how they diffract X-rays. His notebooks catalogue his blunders: spillages, misloaded films, wrongly placed samples and more. Crick twice flooded the corridor outside his boss's office, and annoyed his colleagues by talking endlessly to Watson. The pair were banished to a remote room.



A. BARRINGTON BROWN, © GONVILLE & CAIUS COLLEGE/SCIENCE PHOTO LIBRARY

Francis Crick (right) and James Watson in 1953 as they modelled DNA

By 1952, Crick had a new family, but was broke and at risk of being sacked by his boss, Lawrence Bragg. Then Bragg's rival, biochemist Linus Pauling, claimed he had worked out DNA's structure. He was wrong, but Bragg didn't want Pauling to get there first, so he gave Crick

"Crick succeeded in part because he was willing to fail, proposing many ideas that turned out to be wrong"

and Watson the go-ahead to work on DNA. By March 1953, they had solved it.

Yes, chemist Rosalind Franklin's data was vital – but Crick and Watson didn't steal it, writes Cobb. He has also found papers suggesting Crick, Watson, Franklin and her colleague Maurice Wilkins were all more collaborative than anyone knew.

Many forget that Crick and Watson cited Franklin and Wilkins in their famous *Nature* paper and that papers by Franklin and Wilkins appeared alongside it. Franklin also became a friend of Crick and Odile, his second wife, often staying with them while recovering from operations for the cancer that killed her. This early death is why she didn't share their 1962 Nobel prize.

Crick went on to play a major part in uncovering how DNA coded for proteins, having many important insights about the process. The biography is a gripping read up to this point, but here it fades a bit, reflecting Crick's life rather than Cobb's writing. After the genetic code was cracked in the 1960s, Crick published a series of bad papers, and in 1971 he experienced what was probably depression.

He moved to California in 1977, shifting his attention to consciousness. Cobb argues that his contributions there were as important as his work in molecular biology, in that he proposed or popularised approaches that are now mainstream, such as figuring out the brain's "connectome".

This book is also about Crick the man, and he was a curious mix. Anti-religious and anti-monarchy, the book details how he had an open second marriage, supported the legalisation of cannabis, took acid and held wild parties at which pornography was sometimes screened. It also notes that he made unwanted sexual advances to several women.

What's more, he corresponded with racists about IQ and genetics, then came to believe this issue was more complex than he first assumed, writes Cobb. Crick never mentioned it after the 1970s – in stark contrast to Watson, who died last week at the age of 97.

It is clear Crick succeeded in part because he was willing to fail; many of his ideas turned out to be wrong. That said, he was also brilliant. For instance, one Saturday morning, he read a paper outlining the X-ray results for a protein. By noon, he had solved its structure, with help from a visiting friend.

As I read, it struck me that Crick probably lacked the credentials to make it as a scientist now. Researchers today will be astounded to discover that he did no formal teaching and only ever wrote one grant application. There may never be any more Cricks, because we have created a system that doesn't nurture his kind of genius. ▮

A bad case of superiority

The myth of human exceptionalism needs a final demolition job, argues a provocative, moving book. **Elle Hunt** explores

Book

The Arrogant Ape

Christine Webb

Abacus, UK; Avery, US

IN THE beginning, God made man in his image, granting him dominion over every living thing that moves upon the earth. Most people don't look to the Bible to understand the world and our place in it, yet this view of humans as superior to nature and non-human life is sneakily persistent.

The characteristics said to distinguish humans and justify our dominance – including the ability to reason, use tools, feel pain, act morally – aren't exclusively human, it seems. Chimps, crows and others show nuanced intelligence, have complex social bonds and use tools; fish and crustaceans feel pain; bees are cultural beings; even plants may have senses akin to ours.

The concept that *Homo sapiens* is supreme in a natural hierarchy may be best ascribed to a "human superiority complex", argues primatologist Christine Webb in *The Arrogant Ape: And a new way to see humanity*. In this deeply felt, searching but rigorous work, based on a seminar she taught at Harvard University, Webb sets out to dismantle this perceived exceptionalism. In so doing, she shows it to be rooted in religious tradition, among other distinctly human constructs, and reveals how it distorts scientific understanding and hastens ecological breakdown.

The belief that humans are special "flies in the face of Darwinian notions of continuity between species", which emphasise differences "that are a matter of *degree* rather than *kind*", Webb writes. Yet, she argues, it is a hidden undercurrent in research.

This is evident in our interest in other primates and "charismatic" mammals, favoured as "like us", she writes, while we overlook plants, fish and the majority of Earth's life. It is also seen in how we hold animals to unequal or arbitrary standards. Take comparisons of intelligence between humans and other apes, most of which contrast captive chimps with autonomous Western humans, despite the lab constraints affecting chimps' behaviour, development and functioning.

Tests of chimps' intelligence often take place in labs, not in the wild or in sanctuaries like this one

PATRICK MEINHARDT/AFP VIA GETTY IMAGES

Troubled by the ethics of captivity as well as the potential limitations of the resulting research, Webb only works with apes in the wild and in sanctuaries. Those intimate, often profound encounters inform her belief that more non-human beings are likely to possess some kind of consciousness, or "minded life".

Webb expects critics to see this as anthropomorphism, a "cardinal scientific sin". She counters that the strenuous resistance to observing similarities between humans and other species can unduly complicate the scientific process and undermine conclusions. The insistence on certainty about animal cognition or experience is also a double standard, Webb argues: can we really ever be sure about any other consciousness than our own?

Dismantling this isn't just essential for understanding the world in all its magnificence and diversity, Webb writes, it is the first step to "a radically humbler approach". Only by accepting ourselves as animals no better than others, and as much a part of nature, can we counter the destructive capitalistic forces driving outbreaks of zoonotic diseases, mass extinctions, the climate crisis and ecological breakdown.

Webb proposes we expand "good science" to include insights and knowledge from Indigenous cultures on how all life is unique, irreducible and entwined. She acknowledges the challenge, declaring human exceptionalism "the most powerful unspoken belief of our time", but argues the process of unlearning it can reawaken a connection with nature and inspire awe – even advocacy for animal welfare and the environment. In *The Arrogant Ape*, she highlights this "stubborn ideology" and its harms, and models the humility, curiosity and compassion that may undo it. ▮

Elle Hunt is a writer based in Norwich, UK

New Scientist *recommends*

Timothy Revell
Executive editor
London

"This here would be my older brother Quentin. And last year, he was diagnosed with a rare and aggressive form of early-onset birdwatcher."

This is Owen, talking in **Listers: A glimpse into extreme birdwatching** – and it may just be my favourite documentary of the year. It was made by Quentin (pictured), most often appearing on camera, and Owen, most often narrating behind it.

In 2024, the pair set out to spot as many bird species as possble – known by birders as a "big year". It isn't clear why they did so, and yet the whole thing never feels like a joke as the pair throw themselves into the culture of competitive birdwatching.

The documentary is often hilarious, but also profound, exploring the relationships we form with nature, competition and tech. It is wonderfully shot and edited, mixing a home-movie style with crisp shots out of the David Attenborough playbook.

Amazingly, *Listers* is free on YouTube. Whether you've caught the bug or not, it's well worth a watch.

OWEN REISER

The TV column

One among many From the showrunner behind *Breaking Bad* comes *Pluribus*. It is a smart sci-fi series with a deceptively rich premise about happiness – and Carol, the most miserable person on Earth, as its foil, finds **Bethan Ackerley**

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

APPLE TV+

Carol (Rhea Seehorn, left) struggles to grasp the outbreak of happiness

IF I asked you to name the best episode of a TV show (as I often ask my patient friends), you could do worse than pick "Ozymandias". One of the final episodes of *Breaking Bad*, an extraordinary drama about a chemistry teacher who starts cooking meth after being diagnosed with cancer, it is a total and unimpeachable triumph of writing, acting and directing.

Being part of a single, perfect episode of a TV show is a fine legacy. Creating two fantastic series – *Breaking Bad* and its sister show *Better Call Saul*, which changed the landscape of the medium – is something else entirely. Which is to say that Vince Gilligan, showrunner par excellence, has little to prove with *Pluribus*, his new sci-fi series for Apple TV.

Having seen the first six episodes of the nine-part season, I can say that it has been made with the utmost confidence, and doesn't hold your hand through the twists and turns of its deceptively rich premise.

Carol (Rhea Seehorn, a veteran of *Better Call Saul*) is the author of *Winds of Wycaro*, a popular book series of pirate-themed bodice-rippers. Writing about sinewy forearms and stiff mizzenmasts has bought her a comfortable life, but she is unfulfilled. There are, however, worse things than creative malaise, as she is about to discover.

One night during a book tour with her agent and partner Helen (Miriam Shor), everyone around Carol stops dead in their tracks, then breaks into spasms. When their seizures end, they are very different. Carol, it transpires, is one of the vanishingly few people who are unaffected. It isn't clear what happened, but it probably has something to do with a mysterious radio signal first detected 439 days earlier. The base-four pattern in the signal is repeating every 78 seconds and is broadcast from 600 light years away.

"Can a society become a utopia without the consent of its citizens? Is it still a utopia if one person feels trapped?"

Carol isn't aware of this, only that practically everyone on the planet is elated, free from the petty gripes of humanity. What's more, they will move heaven and Earth to get her to join them.

I understand why they are so obsessed with Carol. She's glorious in her grumpiness, even before she becomes the most miserable person on the planet. Indeed, she reminded me of Paul Sheldon in *Misery*, held prisoner by an apparently benevolent fan – but in Carol's case, she is monitored by billions. Her fellow humans will serve her unflinchingly until they figure out why she is different and how to fix that. Soon, Carol starts to learn the rules of her new reality, realising she isn't quite as powerless as she might seem.

There are many satisfying ideas in *Pluribus*. Can a society become a utopia without the consent of its citizens? Is it still a utopia if even one person feels trapped? The most promising thing, beyond Seehorn's powerhouse performance, is that it is unapologetically character-driven, the kind of show that devotes half an episode to someone trying to bury a body. Nothing is rushed, but nor is anything superfluous. It is building to something, and when you expect it to zig, it zags.

It says a lot that, despite seeing most of the first season, I have no idea where *Pluribus* is heading. I imagine many viewers will be put off by such uncertainty, and the show's leisurely pacing could also be divisive. But I found it thrilling that *Pluribus* hits none of the obvious notes of a big-budget sci-fi series.

With a guaranteed second season, I have every faith it will produce its own "Ozymandias", once it gathers steam. ▮

TV

Pluribus

Vince Gilligan

Apple TV

Bethan also recommends...

TV

Breaking Bad

Vince Gilligan

If you need convincing of Vince Gilligan's credentials, watch his first masterpiece. The story of a chemistry teacher who turns to cooking meth, it's a five-act tragedy and a character study of one of TV's greatest antiheroes.

Outlander

Adapted by Ronald D. Moore

There's a great moment in Pluribus *where a character rearranges a bookstore so her partner's books are more visible. Diana Gabaldon's* Outlander *series ends up on a bottom shelf. I can't speak for the books, but the TV adaptation is swoon-worthy.*

Editor's pick

Space, time and sleeping non-quantum cats

1 November, p 30

From Robin Asby,
Porthmadog, Gwynedd, UK

The problem for me with Vlatko Vedral's beautiful new vision of reality is that all theories about the world in which we find ourselves are created by observers proposing ideas. Examination of those ideas by other observers (i.e. the use of the scientific method) winnows them to those that pass the tests.

The trouble with quantum mechanics is that Western scientists are trained to think in terms of objects and their categorisation, so that, somehow, there is a divide between the world of the very small and our everyday world. But let us consider the cat. When I return home, my cat could be sleeping in a number of different places, to which I can assign probabilities. These, of course, "collapse" as soon as I arrive and observe my cat in just one of them. This is a collapse of probabilities, just as in the quantum case. Is that a problem?

From Tony Watkins,
Oldbury, West Midlands, UK

I agree with Vedral that space and time don't exist, but I don't believe we can explain reality in any meaningful way without particles because, for any sentient organism, reality is its understanding of itself and anything outside itself as perceived by its senses. It may be argued that atoms and subatomic particles are minute bundles of energy, but I see and feel solids, liquids, gases etc., not quantum fields or tables of "q-numbers".

The debate regarding consciousness rumbles on

25 October, p 36

From Andy McGee,
Adelaide, South Australia

Further to your exploration of the wide variety of ideas about consciousness, biological consciousness is the only one we know exists. It is most likely to have come from an evolutionary process that involves reaction to stimuli, which allows entities to find energy sources. As such, levels of awareness in the biological world range from basic heat and light sensing to complex, abstract thought. Ice senses heat and reacts by melting, but it is probably not considered conscious by most.

From Lyn Williams,
Cilffriw, Neath, UK

I cannot believe we are still debating consciousness. For self-preservation, we must be conscious of where we are and what's happening around us. Our sense of sight, hearing, smell, taste, touch etc. all help us survive any danger that might threaten us. We must be conscious, therefore, when we use these senses. It seems to me that "experts" are dragging this subject out. Why make simple things complicated?

Here's one solution for satellite pollution

25 October, p 32

From Jim McHardy, Clydebank,
West Dunbartonshire, UK

To reduce the problem of old satellites releasing pollution when they burn up in the atmosphere, it should be internationally mandated that every satellite keeps enough reserve fuel to move it into a designated "capture orbit". Small rocket drones could refuel still functioning satellites if needed using universal connectors or collect them for delivery to a large cargo rocket ready for return to Earth. Having separate spaces on this rocket for different countries and companies would provide security.

Does the punishment really fit the crime?

Letters, 1 November

From Hillary Shaw,
Newport, Shropshire, UK

David Aldred's suggestion to burn the money gained by criminal means could lead to unpleasant socioeconomic consequences. Money isn't an asset per se. It is more like a share certificate that entitles you to a fraction of society's actual assets (like food, houses or magazines). Just as the value of a share certificate can be diluted by issuing more shares, burning money does the reverse: increasing the entitlement value of everyone else's £10 notes. This could lead to populist demands for more punishment (and money destruction), so more offences would be created. Not a nice society to live in.

The hottest peppers make the strongest deterrent

18 October, p 44

From John Benham, Uxbridge,
Massachusetts, US

I read James Wong's article on the use of capsaicin to deter mammals from damaging gardens with great interest. Recent development where I live has resulted in an overpopulation of eastern meadow voles.

I noticed that these voles have been happy to eat the accessible parts of jalapeño peppers in the raised vegetable beds in my garden, while the equally accessible habanero peppers have remained untouched. From painful experience, I have found that these habanero peppers are sufficiently high on the Scoville spiciness scale that gloves and a face mask are necessary when preparing them for dehydration.

The biologists versus the engineers

25 October, p 25

From Bill Tango,
Sydney, Australia

In 1965, I started postgraduate studies at the Massachusetts Institute of Technology. During a presentation on a new degree programme in bioengineering, the speaker apologised that a short course in biology would be required, saying that it was trivial for engineers to pick up the biology basics, but, of course, you couldn't expect a biologist to master all the necessary engineering principles. I thought at the time that it was staggeringly condescending, but it may have been an early shoot of what Aleks Krotoski describes as "engineer's syndrome" in her book on the "tech bros" aiming to cheat death.

Beware the relentless spread of bamboo

18 October, p 15

From Robert Checchio,
Dunellen, New Jersey, US

While bamboo might be a possible candidate as a renewable source of plastic, I hope no one decides to start growing bamboo on their own in the hope of starting a lucrative business.

Its rapid growth rate, while adding to its attractiveness as a renewable source, is accompanied by a virtually unstoppable capability to spread via underground rhizomes, which can result in neighbouring property owners spending what seems like an eternity cutting the invading bamboo shoots. Sadly, I have learned this from personal experience. ▮

For the record

▮ The nanodiscs in a new kind of e-paper reflect light and each one's brightness can be varied by a brief electrical pulse that places ions inside the disc (1 November, p 12).

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05:00

Knowing when to quit

We admire perseverance, but giving up on ambitions the right way can improve our health, finds **David Robson**

ARON LEAH OF FRIED CACTUS

THIS was meant to be a big year for me. I planned to run a marathon in 2025, gain a diploma in Spanish and begin work on my next book – all while growing my social media following to promote my journalism. Even when I have felt frustrated or stressed, I have tried to keep slogging on. Our culture, after all, is steeped in the idea that determination is a virtue. When the going gets tough, the tough get going; winners never quit, and quitters never win; if at first you don't succeed...

"We really value people who have goals, and we don't like people who give up on goals," says Kentaro Fujita at The Ohio State University. "Our heroes are never the ones who gave up and did something else. It's always the people who tenaciously persist."

Yet there seems to be increasing cynicism towards excessive self-improvement. It became apparent during the early years of the covid-19 pandemic, when critics rallied against the "hustle mentality" that was leading us to view a global disaster as an opportunity to set new targets. More recently, there has been a proliferation of social media posts lamenting the "grindset", a term that entered Merriam-Webster's online dictionary earlier this year. Now, a growing body of research is highlighting the serious advantages of knowing when to quit, including better physical and mental health.

The challenge is choosing which goals to keep and which to ditch. We could call this process "productive quitting" – as opposed to the unintentional slippage that often leads us to abandon objectives against our will – and the research can equip us with some mental tools to help.

Our obsession with self-discipline can be traced to the writer and political reformer Samuel Smiles. In 1859, he published an influential polemic on middle-class improvement through self-discipline. He called it *Self-Help*, launching a whole genre of manuals on perseverance and productivity that continue to line our bookshelves.

Until recently, the psychological literature appeared to side with Smiles, with a huge body of research demonstrating the benefits of determination and the best ways to cultivate it. "The central focus has been on how to keep people sticking to their goals," says Fujita.

The concept of grit, defined as a combination of passion and perseverance, offers a case in point. People with grit tend to agree strongly with statements such as "I finish whatever I begin" and to disagree with statements such as "I often set a goal but later choose to pursue a different one". Such attitudes can be enormously beneficial when we have the time, resources and talent to succeed, with abundant research showing that grit correlates with greater achievement in many different domains.

Often, however, our circumstances severely limit our chances of realising our dreams. This has led some researchers to question ›

JAMIE SCHWABERO/NCAA PHOTOS VIA GETTY IMAGES

Team sports are very social, but if you don't have time to play there are other ways to get that connection

whether dogged persistence can sometimes have a dark side. Psychologist Carsten Wrosch at Concordia University in Montreal, Canada, was one of the first to explore this possibility. He was inspired by his earlier research on people whose romantic relationships ended later in life, he says. As you might expect, many people had hoped they would find lifelong love and felt enormous disappointment at the dissolution of their partnerships. While some kept on yearning for another long-term relationship, many focused on alternative life goals, such as building stronger friendships – and they were far happier because of it.

Wrosch wondered whether this flexible attitude would be relevant for other ambitions, so he designed the Goal Adjustment Scale (GAS). It invites you to imagine that you are forced to stop pursuing an important goal, then asks you to rate your agreement with statements such as "it's easy for me to stop thinking about the goal and let it go" (see "Are you a good quitter?", right).

The best outcomes are seen in people who find it easy to both quit goals that are no longer working and to find new objectives that give their life meaning. For example, in one early study, Wrosch and his colleagues found that students who readily disengaged with their old projects and re-engaged with new ones scored far better on many measures of well-being, including their sense of purpose and overall life satisfaction. Those who stubbornly stuck to their initial goals, in contrast, tended to be less content with their lives – as were those who weren't at all inclined to try something new.

Multiple studies have since extended these results. For instance, a study published in 2024 showed that people who score highly on both elements of the GAS are significantly less likely to experience anxiety than people who don't.

Some of the most surprising discoveries concern our physical health. Wrosch and his colleagues have shown that a greater tendency for goal disengagement is associated with a lower risk of complaints such as headaches, constipation and eczema. Accepting defeat may even protect you from infection. Wrosch and his colleague, Joelle Jobin, analysed six years of data from the Montreal Aging and Health Study. During the study, 131 participants, all older adults, reported how often they had had the common cold.

"Those who stubbornly stuck to their initial goals tended to be less content"

When the pair compared this with their GAS scores, they found a clear correlation between the two, with greater goal disengagement predicting a lower rate of infection. The link appeared to be emotional distress: the quitters were less likely to feel depressed, which in turn predicted a smaller chance of catching the virus.

Persistence's dark side

This may seem remarkable, but our state of mind can powerfully influence our physiology through many well-accepted mechanisms. Testing people on four separate days, Wrosch and his colleague Michael Scheier at Carnegie Mellon University in Pennsylvania found that those who struggled to disengage from unfulfilling goals had higher levels of the stress hormone cortisol, for instance, which is known to suppress the immune system. They also had higher levels of inflammatory molecules such as C-reactive protein, which are known to cause wear and tear on our tissues. The result could be a heightened susceptibility to all kinds of conditions, including cardiovascular disease and Alzheimer's. "That doesn't mean that they will have a heart attack anytime soon," says Wrosch. "But if those levels of inflammation remain elevated over years and decades, [that person] might be at a much higher risk in midlife or old age."

At first, Wrosch's work raised some eyebrows among other psychologists, though much of what it shows is highly intuitive. "We've never

Are you a good quitter?

The Goal Adjustment Scale (GAS) is a way for people to measure whether they have a good balance of grit and flexible attitudes to their goals. Imagine that you are forced to stop pursuing an important goal in your life and then rate your agreement with the following statements from 1 (strongly disagree) to 5 (strongly agree):

- **IT IS EASY FOR ME TO STOP THINKING ABOUT THE GOAL AND LET IT GO**
- **IT IS EASY FOR ME TO REDUCE MY EFFORT TOWARDS THE GOAL**
- **I SEEK OTHER MEANINGFUL GOALS**
- **I START WORKING ON OTHER NEW GOALS**

The first two of these statements measure goal disengagement, which is your capacity to set aside your objectives when they are no longer serving you; the last two examine your capacity to re-engage with another goal.

It is the balance between these two "subscales" that appears to have the greatest impact. The higher your score, the more able you are to take a flexible attitude to your goals, which is associated with increased physical well-being and mental health.

ERDARK/GETTY IMAGES

Birthdays are a good time to reassess your goals

said that persistence is not important," he says. "But there are circumstances in life when we can't achieve what we want, and persistence then leads to accumulated failure. There's an emotional outfall that comes with this, which can have adverse consequences on our biology." The tide is now turning, as many other researchers rethink their understanding of self-control and what it means to successfully manage our motivation and willpower.

Take Fujita. Like many psychologists, his research has tended to focus on the value of persistence, but he now accepts that it can have a downside. Indeed, he recently explored the value of goal disengagement for the journal *Nature Reviews Psychology*. He points out that it isn't just major events like an athlete's injury that may lead us to give up. We all have multiple competing goals in life, with limited resources to devote to each one – and this necessarily involves some sacrifices. In this view, quitting doesn't demonstrate a lack of character; it is simply a recognition that we need to focus our energy carefully. "I think it [often] takes as much self-control to give up as it does to stick to a goal," says Fujita.

He admits that making these tough decisions can test our mettle. One major barrier to goal disengagement is the sunk cost bias – our reluctance to cut our losses on a project we have invested in. The result may be an "inaction crisis", during which we dither in a period of conflict and doubt, neither fully committing to the goal nor fully disengaging.

However, this is less likely to happen if you feel a sense of autonomy over your decision to quit, as Anne Holding at New York University and her colleagues have demonstrated. They found that students who abandoned a goal – such as to lose weight or compete in university sports – were less likely to experience an "inaction crisis" if their reason to quit had been under their control, for example, if they felt the goal no longer aligned with their values or reflected who they were.

The key, then, is knowing your priorities and recognising your personal responsibility for planning your time. For many of us, however, it can be difficult to determine which goals to abandon, which to shelve and which to pursue. "It takes a lot of self-reflection," says Fujita. For this, he recommends using what psychologists call "construal-level theory" – although you might think of it as putting on your perspective goggles. If a particular situation feels extremely personal – the emotions it invokes are raw and you find yourself focusing on the fine details – then try to zoom out to see the bigger, more objective picture. This raises the construal level, which is known to help clarify people's thinking about many life decisions.

There are various ways to put this into practice when deciding whether or not to abandon a goal. You may find that a temporary change of location helps. "When I'm on a plane and I'm literally 30,000 feet away from real daily life, that often helps me think about my values," says Fujita. ›

Another option is to imagine yourself in the future. What would you think of your current goals in 10 or even 50 years? Fujita even suggests that you write your own obituary. Would the goal that you are agonising over now even come into it? If not, then you can probably afford to lose it. If that sounds too involved, simply listing the values that matter most to you, then ranking them from most to least important, might be a good way to start gaining some perspective.

Putting it into perspective

Once you have identified a project that is no longer working, you can start to think about the purpose it served and whether you can get the same satisfaction elsewhere. If you are giving up a team sport, for example, you might try to get the same sense of social connection without the same time commitment. This strategy is sometimes called "goal shifting". And if you are dropping one project to devote more resources to another, you can bolster your sense of autonomy by telling yourself that the sacrifice is for a good cause. This is called "goal shielding". Evidence suggests people who do this have more success in their selected pursuit, compared with those who carry on struggling with their juggling act.

In some cases, you may need only a temporary break. "You can press pause for now but hope to re-engage with the goal in the future," says psychologist Zita Mayer at the University of Zurich, Switzerland. This is known as "goal shelving", and Mayer's research conducted with Alexandra Freund, also at the University of Zurich, suggests it can help reduce people's sense of burden without the lingering regret that can occur when we abandon our goals completely.

"Accepting defeat on goals may even protect you from infection"

JEFF J MITCHELL/GETTY IMAGES

Making more time to devote to your passions can bolster your sense of autonomy

It may work by preserving a sense of identity attached to the goal, she says. She gives a personal example: as a child, she put a lot of time and effort into playing the violin. For now, Mayer is focusing on her scientific career, but she hopes to return to her instrument in the future. "Shelving that goal allows me to continue to identify as a musician, which is a social identity that I value a lot," she says.

This comes with a risk, though. New research by Mayer and Freund suggests that shelved goals can lose some of their shine over time, which may be a source of regret in the future. However, there is a way to ensure that they don't gather dust in perpetuity. It involves setting a specific if-then rule for the future called an implementation intention. Imagine you move to a new city and decide to shelve a sport you enjoy. Your implementation intention may be to revisit the decision in six months' time – and then, if you have settled into your new home well, resume playing. And Mayer suggests choosing a significant date to revisit your decision that can signal a new chapter in your life, like your birthday.

Even with these pointers, knowing when, how and what to quit isn't easy. "It can take a lot of trial and error to find the right constellation of activities," says Fujita. Nevertheless, speaking to these scientists has helped me to apply Marie Kondo's primary query for organising – what sparks joy? – to my life. By writing a fake obituary, I realised that certain goals, such as building my social media following, sparked very little joy. They were easy to ditch, with zero regrets. Others, including my hopes to run a marathon, hold more importance for me, but have been too difficult to fit around family commitments. Before writing this, I felt guilty for letting them slide. Now, I realise that shelving them is quite a relief.

I won't achieve everything I had hoped to in 2025, but I have at least learned the value of productive quitting – and I may be happier and healthier as a result. ▮

David Robson is a science writer specialising in the human brain, body and behaviour. His latest book is *The Laws of Connection*.

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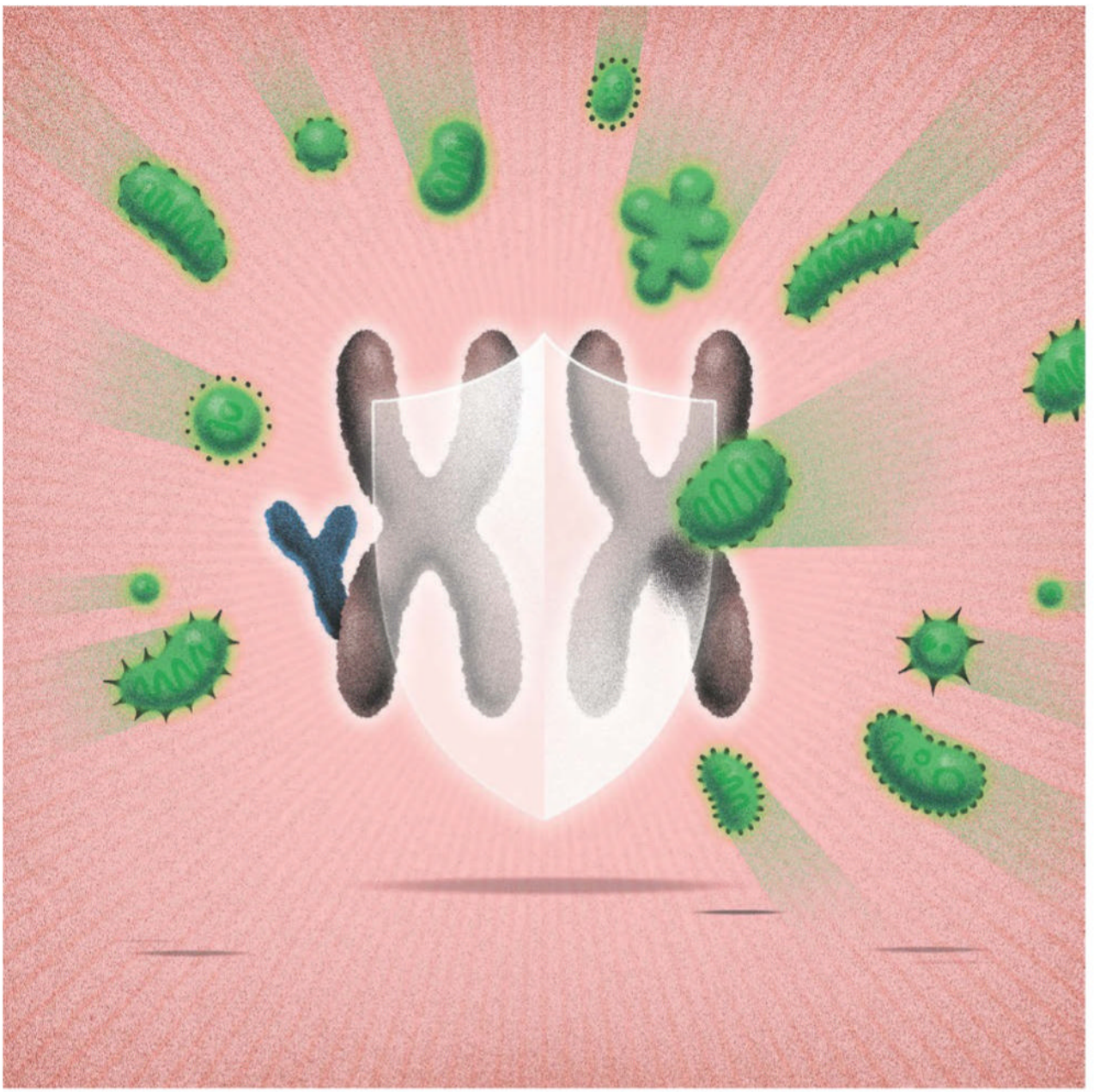

LUCA D'URBINO

The XX factor

Having two X chromosomes sets most women up for a lifetime of stronger immune health, and unpicking could improve treatments for everyone, discovers **Starre Vartan**

THE women in my family are hardy, to put it lightly. They have shaken off countless illnesses and powered through pregnancies. They've managed this in spite of questionable lifestyle choices (let's just say a taste for gin and Virginia Slims didn't stop my grandmother from hitting her 90s before she slowed down). For at least five generations, the women in my lineage have cruised into old age seemingly unfazed by what life – or their own predilections – threw at them.

As fun and fabulous as my female relatives were and are, my family isn't unique. It is possible that yours tells a similar story. Statistically, women don't just outlive men, but they are also better at fighting off almost every challenge to their health. They even get more benefit from vaccination. And there's a reason for that. Their immune systems are superior – faster, stronger and more durable than men's. This advantage is seen across continents, historical periods and illnesses. It is recognised by traditional medical systems such as Ayurveda.

Now, research by immunologists, virologists and geneticists is finally exposing why, illuminating the reasons for women's long-known yet under-examined immune strength. It reveals the roles that hormones and sex chromosomes play in supercharging women's immune cells to detect, fight and remember intruders, and in keeping their immune systems more youthful for longer than men's.

This knowledge can be harnessed to design more precise, sex-specific health interventions. It already informs cancer therapies, and it could result in differing vaccine protocols and treatments for a variety of infections. It's not only women who stand to benefit. In an age of global pandemics and vaccine uncertainty, understanding the female immune advantage will improve the health of everyone.

The historical lack of research into female bodies throughout medical science extends to immunology. To date, it has favoured a "one-size-fits-all approach skewed toward male biology", says Caroline Duncombe at Stanford University in California, whose research explores the ways that sex-based differences influence immune response. The fact that immunology research is still underpinned by foundational knowledge based largely on studies of men is a problem for women. "Biological sex is one of the most important factors affecting health and disease across the lifespan," she says, "because it affects environment and lifestyle, as well as genetics and hormones – all of which are important when you're evaluating immune response."

But the male bias in research is also a problem for men. "[Women] have an immunity advantage that could have offered insights had it not been neglected for so long," she says.

What has become apparent from research on immunity in female bodies is that a significant part of this advantage lies in the sex chromosomes. The usual female complement is two X chromosomes, one from each parent, both packed with genes related to immune function. Those who are male usually inherit one X chromosome from their mother and a diminutive Y chromosome with fewer genes on it from their father. "The X chromosome has the greatest number of immune-related genes, so having two copies gives women a genetic advantage," says immunologist Duygu Ucar at the Jackson Laboratory in Connecticut.

Although one copy is usually inactivated to ensure the correct amount of protein is produced, between about 15 and 25 per cent of genes escape this silencing. And these escapees often have a role in immunity. As a result, female bodies have more options when faced with threats. "This stronger gene expression leads to a more potent immune system," says immunologist Petter Brodin at the Karolinska Institute in Stockholm, Sweden.

Such strength in diversity is obvious when you look at the first line of defence against intruders, known as innate immunity. It consists of cells bristling with a range of receptors, including killer-activated receptors, pattern-recognition receptors and toll-like receptors, which detect the presence of pathogens, then initiate a response involving a slew of other immune cells to fight off intruders and heal the body.

With greater variability and redundancy in the genes coding for them, female receptors can respond to a wider range of pathogens faster and more reliably. The result? Infections are caught earlier, giving female bodies a head start in eliminating them – often before symptoms even appear.

The stronger sex

Escapee genes may also help explain why women are around 20 per cent less likely to develop most types of cancer than men. Cancer cells often contain mutations in genes that help suppress tumours. Some of these genes are on the X chromosome, and when things go awry, escapee genes provide women with a backup copy that can override the error. Not so for men. Indeed, new research by Margaret Gadek at the University of California, San Francisco, and her colleagues indicates that the same system of redundancy provided by two X chromosomes could also help explain why female brains show greater resilience in ageing.

Meanwhile, the Y chromosome, once considered a genetic wasteland that is set to disappear from the human genome with time, is now known to influence immunity too – but not always in a good way. In particular, a lineage of the Y chromosome common in men of European descent leaves them with an elevated risk of coronary artery disease due to increased inflammation and a suppressed immune response. Separately, a gene called *UTY* seems to underpin an immunity-driven susceptibility to complex diseases in some men. ›

One way we know that some of the female immune advantage lies in fundamental genetics is that it lasts a lifetime. Research shows that women of all ages are less likely to get hospital-acquired infections than men. "If you trigger a female immune system with a virus, it is more likely to respond more strongly than a male, and it doesn't matter when in life you do this," says Brodin.

Hormones have an impact too. Oestrogen enhances both arms of the immune system: innate immunity – those first responders – and adaptive immunity, which develops over time. It does this by modulating the activity of immune cells, which helps them to coordinate a faster, more precise attack.

We already saw that having two X chromosomes gives the innate immune system a more diverse range of receptors on its cells. And it turns out that oestrogen can also boost the power of some of these cells, including neutrophils, the white blood cells that engulf and destroy intruders. Immunologists knew that women have more neutrophils than men. More recently, they have found that oestrogen helps activate these cells, making them more sensitive to invaders and increasing the efficiency of their pattern-recognition receptors. Research by Sarthak Gupta at the US National Institutes of Health and his colleagues revealed that this is what makes neutrophils in women better equipped to detect and destroy pathogens, particularly in those aged between 20 and 30.

Oestrogen also influences the development of B-cells, the elite task force of the adaptive immune system that produces antibodies to lock onto and neutralise invaders. In a process called somatic hypermutation, B-cells mutate up to a million times faster than other cells to fine-tune their antibody output, and women's immune systems run more cycles of this refinement. This means tighter-fitting antibodies and more effective immune responses.

As well as producing antibodies, B-cells create the body's memory of pathogens encountered in the past. Once formed, memory B-cells can last for decades or even a lifetime. And across a wide range of species, females retain these cells for longer than males, suggesting it evolved as an adaptive advantage, probably so mothers can transfer protective antibodies to their offspring. It may also explain why girls and women tend to have stronger, more durable responses to vaccines. If their bodies already have a memory of a virus, the challenge from a vaccine will provide a bigger uplift in immunity.

"The X chromosome has the greatest number of immune-related genes"

Hormones are involved here too, but they can't be the whole story because postmenopausal women retain their superior B-cell function. What's more, this seems to be a key factor when it comes to keeping the immune system stronger for longer. Research by Ucar and her colleagues found that both men and women lose immune capacity, starting in their 40s. However, men hit a second decline in their early 60s, whereas this comes about five years later in women – "which could be linked to differences in lifespan", says Ucar. The biggest difference was after the age of 65, when women's B-cells (and T-cells, the other major component of the adaptive immune system) were more active than men's. This, she suggests, might explain why older men are more prone to infectious diseases than older women.

Double-edged sword

The downside for women of all ages is that a more reactive immune system can sometimes overcorrect and attack the body it is supposed to defend. Women account for between 70 and 80 per cent of people with autoimmune diseases and, although the exact mechanisms aren't known, there is no doubt that this is underpinned by both genes and hormones. "Women have a greater resistance to infectious diseases and cancer, but greater susceptibility to all kinds of unpleasant autoimmune

A supercharged immune system helps women better detect and fight infection

LINN HEIDI STOKKEDAL/MILLENNIUMIMAGES, UK

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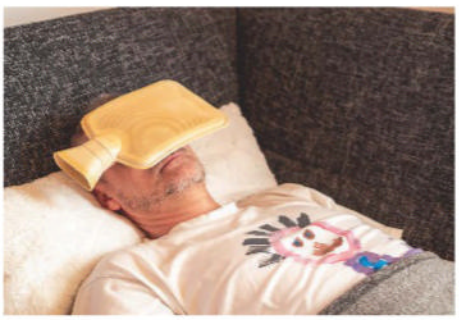


SONJA RACHBAUER/GETTY IMAGES

Women have a strong immune system throughout their lives, while men's declines with age

diseases," says Mark Davis at Stanford University. "It's a double-edged sword."

There is still much to be discovered about the immunological differences between the sexes, but what we know already exposes the inadequacy of the one-size-fits-all approach to the science of immunity. For a start, it means we are missing the nuanced picture when it comes to women. "People have hormones in different amounts throughout life, so understanding and taking into account that impact is really important," says Duncombe.

It also has big implications for medical research. In trials for new antivirals and vaccines, if data from male and female participants is lumped together, sex-specific reactions get averaged out, potentially leading to men getting too low a dose and women being given too much, or providing the wrong treatment entirely. That's not to mention how treatments might be tailored for transgender people, where there has been even less research.

Cancer treatment is another area where a person's sex really matters. "Sex hormones influence your response to different types of cancer therapies, by both influencing tumour growth directly and the immune response trying to fight it off," says Duncombe. Here, however, researchers are beginning to recognise that they can use this knowledge to their advantage. "Understanding how you can leverage different hormones to maximise or minimise your immune response to different cancer therapies is being actively researched for this reason," she says. For example, researchers know that oestrogen acts as a catalyst for breast cancer growth, and they are designing therapies that could prevent activation by blocking that hormone's receptors.

Others who could benefit from this approach are people with long covid or myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS). New research by Davis and his colleagues has found that both men and women with these conditions have high levels of reactive oxygen species (ROS), chemically reactive molecules that are a normal by-product of energy production in cells and play a critical role in immunity. "You have to elevate ROS to activate B-cells and T-cells to do their job," says Davis.

ROS levels in these women are especially high, which may help them fight off infections, but this comes at a cost: an even higher risk of autoimmune diseases than usual. This is useful knowledge because preliminary studies suggest that a common diabetes drug called metformin can lower ROS levels, offering a promising treatment for people with long covid and ME/CFS – especially women.

If medicine had paid closer attention to the ways female bodies fight illness, heal and adapt to health challenges, we might already have better vaccines, fewer autoimmune flare-ups and more targeted treatments for conditions like long covid and cancer. So, it is good news that researchers are finally looking at women's immune systems on their own terms, not just as quirky deviations from a male baseline. What they are discovering is something those hardy women in our family trees seemed to know intuitively: strength isn't just about brute force. It is about endurance, adaptability and outsmarting pretty much everything.

Just ask my grandma. ▮

Starre Vartan is the author of *The Stronger Sex: What science tells us about the power of the female body*

The testosterone trade-off

Although oestrogen boosts many aspects of female immune function (see main story), testosterone appears to do the opposite – and not just in humans and other mammals. In lizards, for example, it blunts immune cell activity. And among birds, females mount stronger defences against infection than males do – especially during the mating season, when male testosterone peaks.

You might think that evolution would have weeded out males with the highest levels of the hormone. But testosterone does other things very well. It raises sperm production, increases competitiveness and promotes those showy traits – from muscle mass to deep voices – that are culturally or biologically appealing to partners. According to the immunocompetence handicap hypothesis, high testosterone is a kind of evolutionary gamble. Only the fittest males can survive its drag on their immune system while still thriving. This "honest signal" of resilience makes them more sexually attractive. And, across the animal kingdom, more testosterone often equals more mating success.

Not everyone buys this idea, however. Some researchers argue that things might work the other way around – that illness suppresses testosterone. Others suggest that testosterone doesn't reduce immunity outright, but modulates it instead. And stress hormones like cortisol, which rise during infection, add another layer of complexity to the hormone-immunity dance. Still, the bottom line holds: in males, more testosterone often means less immune firepower. It is a trade-off: strength and status versus susceptibility to disease.

In today's world of novel pathogens, that trade-off may be costing men more than it used to. Research published more than a decade ago found that those with the highest testosterone levels show some of the weakest responses to vaccines. Medicine has tended to overlook the immunological differences between men and women. However, with a better understanding of how testosterone shapes immunity, we could tailor vaccine dosing and other medical treatments to better support both men's and women's needs.

"We don't want to keep an asteroid secret, because then no one ever trusts you"

When an asteroid threatens Earth, the Torino scale helps us make sense of the risk. Astronomer **Richard Binzel** tells Alex Wilkins why he created it, why we shouldn't worry about an imminent collision and what the future of asteroid tracking looks like

RICHARD BINZEL has been watching the skies for hazardous asteroids for more than 50 years. In 1995, he proposed the Near-Earth Object Hazard Index, later renamed the Torino scale, which rates asteroids from 0 to 10 based on how certain we are that they could hit Earth – and the potential devastation such an impact might cause.

Earlier this year, Binzel's scale got a high-profile outing when asteroid 2024 YR4 briefly reached level 3 on the scale – the first space rock to get this high in two decades. While the risk has since faded, it won't be the last time we need to fire up the Torino scale. But Binzel, who is at the Massachusetts Institute of Technology, says we can probably rest assured that we won't see the very highest levels of the scale reached in our lifetimes, or even those of our grandchildren. He spoke to *New Scientist* about the chances of a devastating asteroid impact and the future of planetary defence.

Alex Wilkins: When you started your career, how did people view the threat of an asteroid impact?
Richard Binzel: I published my first paper in the 1970s, when I worked for [the geologist] Eugene Shoemaker, who understood that craters we see on the Earth are impact craters, so I grew up with the awareness of asteroid impacts as a natural process that still occurs in the solar system today.

In the public, it was a giggle factor. Shoemaker was just doing serious science, not paying too much attention to the public side of things, but people like [astronomers] Clark Chapman, David Morrison and Don Yeomans were beginning to see it was important to talk about this. There was a book called *Cosmic Catastrophes* that Chapman and Morrison wrote [in 1989], which was the first real treatment for the public. The Alvarez discovery of the K-T boundary layer [the geologic record of the Chicxulub asteroid thought to have wiped out the dinosaurs] was probably the wake-up call to greater scientific awareness that impacts can happen in modern geologic history.

Why did you come up with the Near-Earth Object Hazard Index?
There was an object named 1997 XF11, which had a non-zero impact probability based on its initial orbit. Email had just become a thing. I was in a small email list with people like Brian Marsden, Yeomans, Chapman, Morrison, and we were debating what to do with this information. We wanted to release it publicly, but we wanted to make sure [of the risk]. ›

RYAN WILLS; BARRY HETHERINGTON; ESA; NASA; ADOBESTOCK

"We may see a few objects that get numbers like 4 on the Torino scale, but never in the red zone"

We thought maybe we should just get a little more data, because with longer measurements of that orbit, [the probability of collision] would probably go away. Why cry wolf if this object is going to go away in a few days?

Marsden decided to write a press release, and just as he was sending it out, we found some earlier observations that gave a sufficient orbit to say [the probability of impact was] zero. I remember an email from Yeomans, who did the analysis, and the email basically said, "That's zero, folks." Brian went ahead with his press release, because he thought it was important to get the issue out into the public. Most of us disagreed, that that was crying wolf.

This set into my mind the need for some means of communicating when you discover an asteroid that has a non-zero impact probability, however small. Just be a little patient, and we'll get enough data to make it go away. That if we discovered another object like that, we don't want to keep it secret. That's the worst thing we could do, because then no one ever trusts you, because they never know what you're not telling them.

So, we collectively decided that we needed to tell people what we know as soon as we can, when we know it. Then later, when it goes away, it's not that anyone made a mistake or made an error, it's just that we now have better information to know it goes away. That was the genesis of what was first called a Near-Earth Object Hazard Index.

How was it received at the time?

There happened to be a United Nations conference on near-Earth asteroids, where I first presented the idea, and it was not well-received. There were people who said we don't need that, because we can explain the longitude and latitude and the ascending node of the orbit, and we can explain this all perfectly well. We don't need some simple thing like a small, 0-10 scale. So, the initial response was arrogance by some astronomers that they didn't need this, because we are smart enough and capable enough to communicate all these three-dimensional orbital characteristics that most people wouldn't know.

But I persisted. I brought it forward again to a conference in Torino, and I had the idea that we should call it the Torino scale, because it was presented at the conference. I didn't want to put my name on it because it would look egotistic. But if we called it the Torino scale, everyone had ownership of it and everyone would feel it useful to use, anyway.

Has it worked as you thought it would?

I thought it would be called into play a bit more than it has, but I think it's because discoverers have done a good job of following up objects right away, and so if they have a non-zero probability, they go away pretty quickly.

There have been a dozen or so objects that have reached 1 on the Torino scale without much news, which is perfect. That's exactly the intent. It's like the Richter scale, where if you tell someone in California there's going to be a magnitude-1 or magnitude-2 earthquake tomorrow, they go on with their day and think nothing of it.

What will future asteroid tracking look like?

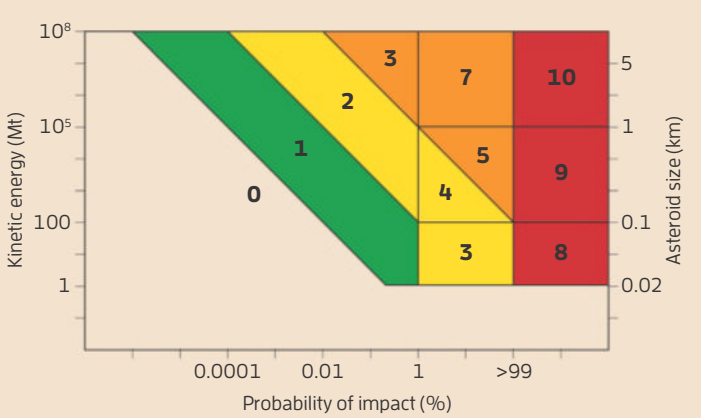
The discovery rate of near-Earth asteroids is going to improve or accelerate dramatically as the Vera C. Rubin telescope and Near-Earth Object (NEO) survey telescope come online. We will discover near-Earth objects at an incredibly fast rate. Some of them will have very uncertain initial orbits that we will want to extrapolate forward for decades, so that means it's a non-zero impact probability. It will simply take time to get enough orbital data for a long enough period that we can say more precisely where it's going to be many decades from now, and entirely rule out an Earth impact.

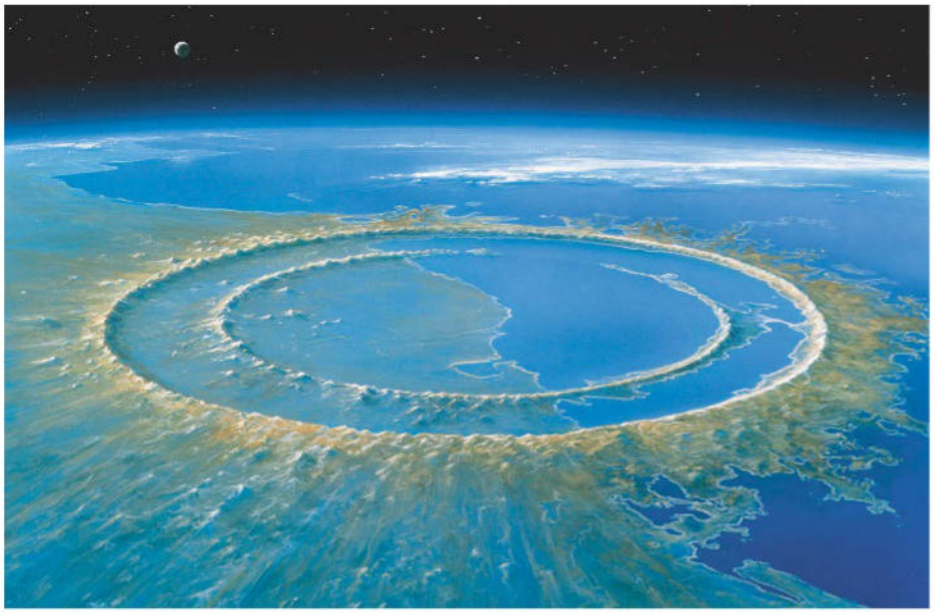
We may see a few objects that get numbers like 4 or maybe 5 on the Torino scale, but never in the red zone (see "Collision course?", below). I don't expect we'll see that in anyone's current lifetime, or even in our great-grandchildren's. It's just incredibly, incredibly rare. But if we do, we have a method for people to immediately know, should I pay attention, or should I not?

The low end of the Torino scale will become

Collision course?

The Torino scale assigns asteroids a score of 0 to 10 based on their size, energy and probability of hitting Earth, with 10 being the most devastating





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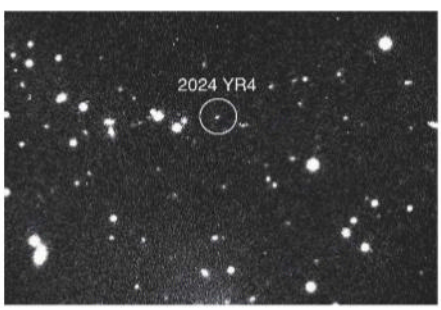
How the Chicxulub crater may have looked shortly after it hit Earth, possibly killing the dinosaurs



NASA/MAGDALENA RIDGE 2.4M TELESCOPE/NMT

The asteroid 2024 YR4 reached level 3 on the Torino scale, but quickly dropped to 0

so routine that we won't need to pay attention, or the public won't need to pay attention. They can rest assured that, for interesting objects like that, the astronomers are going to do their job and follow them up and make sure they go away. The Torino scale did its job.

When we saw asteroid 2024 YR4 reach Torino level 3, did the system work as intended?
My colleagues did an excellent job, clearly and consistently saying over and over again: "We expect, when we get more data, this object will go away." That was always the message. If you read the description in each Torino scale category, especially on the lower end, it says this is of interest to astronomers, and we fully expect additional data will rule out any possibility of it intersecting the Earth.

I think what was confusing to most of the media and to the public was the impact probabilities. They were always low. (At its peak, 2024 YR4's probability of impact reached 3.1 per cent.) The impact probabilities started going up, but that's a natural consequence of what happens when you get more data. When you first discover an asteroid, you have watched it over a very short track, and now you want to extrapolate that track forward decades and decades into the future. Sometimes the probability number can go up, but it's really just a function of the process of refining the orbit and shrinking the window to make sure that the Earth isn't in it at all.

What about Apophis, a 340-metre asteroid that will pass very close to Earth in 2029, but ultimately miss. How can we be so confident?
When asked about Apophis, I give three answers. Apophis will safely pass Earth. Apophis will safely pass Earth. Apophis will safely pass Earth. How do we know that? This is an asteroid we've been tracking for more than 20 years, and that tracking includes pinging radar waves off this asteroid, which pins down its position to metres in space. The overall uncertainty for this asteroid passing safely by Earth is that it will be 38,000 kilometres away from Earth, plus or minus 3 kilometres.

Astronomers have taken this object very seriously for the past 20 years. In fact, when it was first discovered, it was a 4 on the Torino scale, the only object that ever reached 4. It didn't stay there very long, maybe a week, but this object got astronomers' attention back in 2004, right around Christmas time. I wanted to call it Grinch, because I was working late into Christmas Eve on different aspects of the asteroid's orbit until my family yanked me downstairs from my office.

The DART mission, which saw NASA fly a spacecraft into an asteroid to try to change its orbit, felt like a new direction for planetary defence. How significant was this mission?
DART was a step forward in our maturity as a species, where we are no longer at the complete mercy of whatever space wants to throw at us. DART was simply a demonstration that we could target an object and have a consequential effect on its orbit. I think it's a pivotal moment for humanity. It's saying: "Wait a minute, folks, if we ever need to do something to mitigate an incoming asteroid, with enough time, we have the capability to do so."

You often hear people still talk about the risk that a massive asteroid will be discovered that will wipe out humanity. How has this risk changed from when you started to now?
We are on the job. This isn't a major problem. It isn't a major threat, but it's one that we now have the capability to understand. Speaking very personally, as a scientist who's been in the field for 50 years, who has largely been supported by public funds, I feel a moral responsibility to push forward the idea that, because we now have the capability to find any serious asteroid threat, we have a moral obligation to do it. Otherwise, we are not doing our job as scientists.

Putting it another way, if we were to be taken by surprise tomorrow by an object that we could have discovered if only we had built that telescope 10 years ago, that would be an epic failure in the history of science. That's the only thing that keeps me awake about asteroids: that somehow we haven't done our job yet.

It's tremendous progress to see Vera Rubin and the NEO surveyor coming online, and it's finally about time that we get a thorough survey done and make sure that there is no imminent asteroid threat in the coming decades or centuries. Because we now have the capability to get the answer. It's our responsibility to see that we go out and get the answer. ▮

Alex Wilkins is a news reporter at *New Scientist* specialising in physics, astronomy and technology

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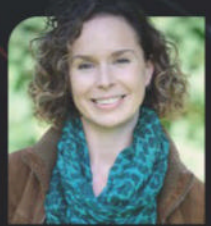

Kate Shaw, experimental particle physicist, working on the ATLAS experiment at CERN and the Deep Underground Neutrino Experiment (DUNE) at Fermilab

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Mathematics of life

Taking turns

How should we deal with badly brewed coffee, or allocate teams? A piece of 19th-century maths has the answer, says **Katie Steckles**

Katie Steckles is a mathematician, lecturer, YouTuber and author based in Manchester, UK. She is also adviser for *New Scientist*'s puzzle column, BrainTwister. Follow her @stecks

IMAGINE you have a pot of coffee that amounts to two cups' worth. It has been brewed badly, so it is much stronger at the bottom than at the top. If coffee is poured out of the pot into two cups, the first one you pour will be significantly weaker than the second one.

While this is a slightly contrived situation, there are other occasions when this kind of "first is worse" (or "first is better") setup creates unfairness.

Say we are picking teams for a football game and everyone knows roughly which players are better than others. If you allowed one team captain to pick all of their players first, leaving the other captain with whoever remains, there would be a serious imbalance in how good the teams are.

Even just taking turns at picking doesn't make this fair: if there were players whose skills could be roughly ranked from 1 to 10, then captain A, picking first, would choose 10, then captain B would pick 9, then captain A would choose 8, and so on. Overall, the team picking first would have 10+8+6+4+2, giving a total of 30, while the other would have 9+7+5+3+1, which totals 25.

So, how can we fairly allocate players? A 19th-century maths sequence has the answer. Originally studied by Eugène Prouhet in the 1850s, but then written about more extensively by Axel Thue and Marston Morse in the early 20th century, the Thue-Morse sequence requires that you don't just take turns: you take turns at taking turns.

ALEXANDER SPATARI/GETTY IMAGES

Let's say the two team-pickers are called A and B. The sequence would then be: ABBA. The first pair are in one order, but then the second pair are in reverse order. If we want to continue the sequence, we can repeat the same set again, but flipping As and Bs: ABBA BAAB. This can be continued (taking turns at taking turns at taking turns), giving ABBA BAAB BAAB ABBA, and so on.

This ordering makes things fairer. In our team-picking example, instead of 30 vs 25, the teams are now 10+7+5+4+1 and 9+8+6+3+2, totalling 27 and 28.

Versions of this sequence are often used in real sporting competitions. Tie-breaks in tennis involve one player serving the first point, then the players take turns to serve two consecutive points – giving the pattern ABBA ABBA ABBA. This simplified version of Thue-Morse is widely considered fairer than just taking turns. A similar ordering has been trialled by FIFA and UEFA for penalty shoot-outs in football, where the second shot of each pair is higher pressure for the shooter.

For our coffee pot, the solution is perfect: pouring half a cup of coffee into cup A, then two half-cups into B, then the final half-cup back into A, will give two cups of exactly equal strength. If you prefer, you can just use a spoon to stir the coffee. But won't it taste more satisfying if you have used maths to solve the problem? ▮

Mathematics of life appears monthly

Next week
Debunking gardening myths

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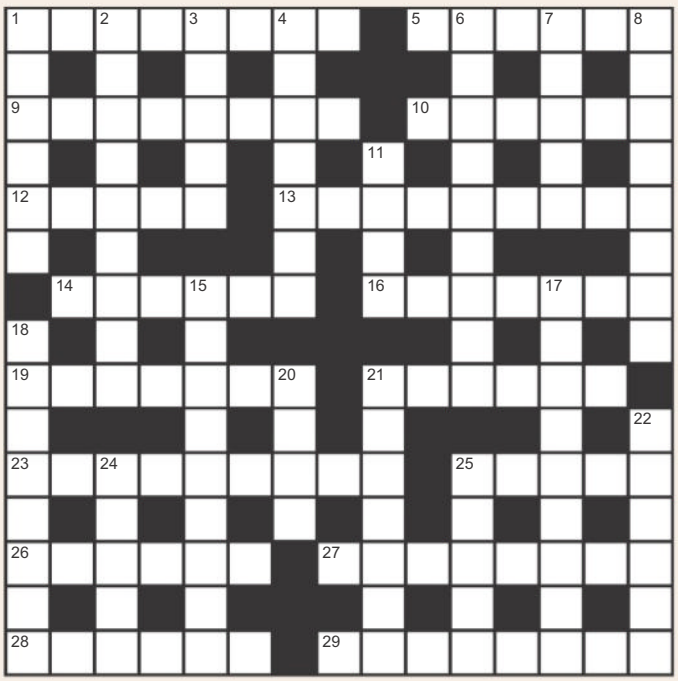
Quick crossword #196 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Indoor space for crafting, engineering, etc. (8)
5 Protective car feature (6)
9 Installation of new tech in old systems (8)
10 Soft tissue injury (6)
12 George ___, *Star Wars* creator (5)
13 Artillery soldier; aerospace engineer; comic book hero (9)
14 Alkene (6)
16 Vitamin B1 (7)
19 Impersonation (7)
21 Scarab or ladybird, say (6)
23 Nearest major galaxy to the Milky Way (9)
25 Sonic navigation and ranging (5)
26 Split into three (6)
27 Limited bodily movement (8)
28 Luminous; hi-visibility (3-3)
29 Unbelievers (8)

DOWN

1 Word game invented by Josh Wardle (6)
2 Compartment of the ruminant stomach (9)
3 See 7
4 o (7)
6 Not highly accurate (9)
7/3 Car components (5,5)
8 Tissue death (8)
11 Tail of a deer or rabbit (4)
15 n! (9)
17 Hyperpigmentation (9)
18 Of wisdom teeth, prevented from erupting (8)
20 State of matter hypothesised by George Gamow (4)
21 [, say (7)
22 Heart, liver and lungs, perhaps (6)
24 Yellow-and-white lawn flower, *Bellis perennis* (5)
25 Taste, for example (5)

Our games are now solvable online
newscientist.com/games

Quick quiz #328
set by Tom Leslie

1 Researchers want to invent an artificial process that replicates the taste of kopi luwak coffee beans. How are these coffee beans usually produced?

2 The lymphatic system is named for the Roman deity Lympha, who presides over what?

3 Physicists recently discovered a new way to search for dark matter using which kitchen staple?

4 Last month saw a 16-year-old boy in the news for a robotics innovation. What did he make?

5 Tim Berners-Lee's computer at CERN, which hosted the world's first website, had a sign on it that said what?

Answers on page 47

BrainTwister
set by Christopher Dearlove

#99 Hat trick

Balls numbered 1 to 9 are secretly placed in three hats, with three balls in each. The total of the numbers in the first hat is 15, and in the second hat it is 7. What is the total of the numbers in the third hat?

One ball is randomly taken from each hat, and without showing the balls, their sum is announced as 15. Then, without replacing the first balls, three more balls are taken in the same way, and their sum is announced as 10. Which three balls are left in the hats?

What would the initial arrangement of balls be if the totals were 22 and 8 in the first two hats, and 16 and 20 as the sums of two sets, taking one ball from each hat?

What would the initial arrangement of balls be if those four numbers were 20 and 10, and 6 and 21?

Solution next week

Push it to the limit

Can eagles have sharper eyes? Or cheetahs run even faster? Or must the evolution of any adapted trait in nature reach a limit?

James V. Stone
Buxton, Derbyshire, UK
Yes, the evolution of any adapted trait in nature must reach a limit. In principle, this limit is defined by the laws of physics, but, in practice, it may also be defined by the constraints of biology.

Physics dictates there must be a fundamental limit to the resolution of any eye. The eye's lens forms an image on the retina, which is densely packed with photoreceptors. These act like optic fibres, guiding light to light-sensitive photopigments. But a photoreceptor with a diameter less than half the wavelength of visible light (0.5 micrometres) becomes increasingly "leaky", so can't guide light efficiently. A diameter of 1.5 µm is required for reasonably efficient transmission. This sets a limit on the smallest useful diameter of photoreceptors, which constrains the maximum useful photoreceptor packing density (photoreceptors per square millimetre).

"Given the constraints on eye design, it seems likely that evolution has crafted the eye of an eagle for optimum performance"

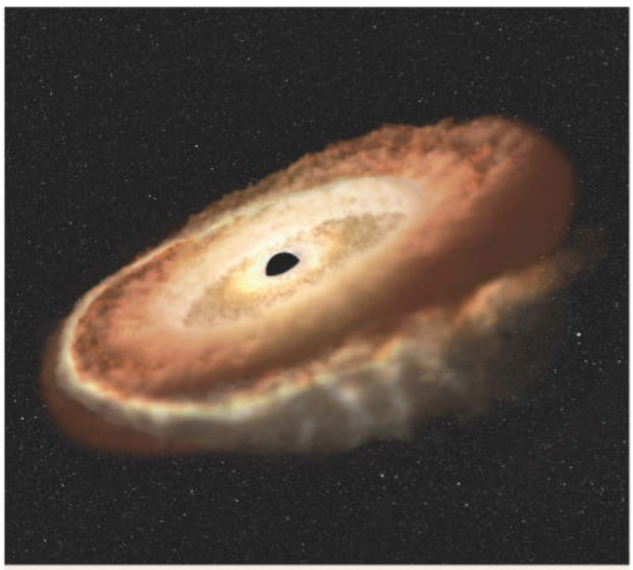
In practice, the smallest diameter of a photoreceptor is limited by the size of an essential component of all cells: the mitochondrion, which supplies cells with energy in the form of adenosine triphosphate. A mitochondrion is an ellipsoidal structure with a width of about 1 µm. By contrast, the diameter of each photoreceptor is 1.6 µm in an eagle, so this is probably the lower limit dictated by the width of a mitochondrion (a photoreceptor must contain many mitochondria).

The lens of a wedge-tailed eagle (*Aquila audax*) eye has a focal length of 22 millimetres, so if the retinal image "matches" the packing density implied by a photoreceptor diameter of 1.6 µm, then this predicts a lens diameter of 8.4 mm (assuming a visible light wavelength of 0.5 µm). In fact, the lens diameter is 10.5 mm, so the retinal image resolution is higher than required by the photoreceptor packing density.

However, because the brightness of an object's image decreases inversely with the object's distance squared, photoreceptors are starved of light from distant objects, especially in dim conditions. This is particularly relevant for eagles, which search for distant prey under variable light conditions.

Given the demands and various constraints on eye design, it seems likely that evolution has crafted the eye of an eagle for optimum performance in the real-world conditions of a predator.

John Davies
Lancaster, UK
Of course, but at what cost? Evolution is all about survival of the fittest. An eagle has retinal cells at five times the density of a human, plus two foveas, the retinal area where the cells are concentrated, and their eyes are much larger in proportion to their skulls than ours are. More cells and foveas would necessitate even bigger eyes. But would those make the super-eagle even more successful? If so, then fine. If not, it is down among the dinosaurs!



NASA

This week's new questions

Doughnut holes **Black holes are depicted as having doughnut-shaped discs around them, and space telescope images seem to support this. Do they somehow have this shape when viewed in all directions?** ***Peter Leach****, Mold, Flintshire, UK*

Tyre change **What are the pros and cons of using carbon dioxide in tyres?** ***Roger Everest****, Masterton, New Zealand*

Do black holes look like doughnuts from every direction?

Averell Kingston
Banbury, Oxfordshire, UK
Why would cheetahs need to run faster? If they can run fast enough to catch adequate amounts of food to enable them to breed and have babies, that is fast enough. However, if their prey evolved to run faster than at present, then those cheetahs that could run fastest would be the most successful at hunting, so would leave the most offspring in the next generation. This could lead to faster cheetahs. In order for evolutionary change (faster cheetahs) to happen, there needs to be selection pressure, in this case faster prey.

As for eagles' eyesight, a possible selection pressure could be something that reduces visibility, for example mist, increased vegetation on the ground or, in the case of sea eagles, cloudier water.

What's the matter?

If an antimatter comet or meteor came into our solar system, how would we know? What if it hit Earth?

Hillary Shaw
Newport, Shropshire, UK
I am not sure how a lump of antimatter as big as a meteor would form or survive in interstellar space, but suppose one did. Say it is 10 × 10 × 10 metres, and let's give it similar properties to rock, specifically a heat capacity of 2000 joules per kilogram, and a density of 2.5 grams per cubic centimetre. The solar system has about 10^6 hydrogen atoms per cubic metre at its outer edges, rising to 10^7 in the vicinity of Earth.

The distance from a little beyond Pluto's orbit to the sun is about 10^{13} metres, so along this path this antimatter "meteor" would encounter, and annihilate to energy, some 10^{22} hydrogen atoms, total mass 10^{-2} kg. That produces about 10^{15} J of energy.

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Tom Gauld
for New Scientist

Based on these figures, it would take around 10^{10} J to heat this antimeteor by 1°C, so, neglecting energy losses by radiation, it should heat up to a toasty 10^5°C. Even at 10^4°C, it would glow white, and at 10^5°C it would be blue-white, emitting mainly UV and X-rays. We would probably spot that.

If it hit the sun, the resulting explosion as it all annihilated would probably destroy all life on Earth. Any planet it hit, including Jupiter, would be instantly destroyed. If it hit Neptune, we might survive for a while, with spectacular night shows, but the gravitational disturbances might change our orbit and kill us all later via heat, cold or meteorite strikes.

Wrapping up

Should the bubbles on bubble wrap face the inside or outside of the object? (continued)

Robert R. J. Maier
Penicuik, Midlothian, UK
This depends in part on the shape of the object. If it is something with a smooth surface, such as a book or bottle, I would wrap it with the bubbles facing outwards on the first layer, followed by a second layer of bubbles facing inwards. For any other object, it is bubbles facing inwards on all layers.

"If an antimatter meteor hit the sun, the resulting explosion would probably destroy all life on Earth"

Tim McCulloch
Sydney, Australia
My guess is the bubbles should face the object being wrapped. That way, the flat plastic between the bubbles is held away from the surface of the object, which might help if something with an acute corner happens to hit between the bubbles. Besides, I just feel like it would be more comforting to be wrapped in the bubbly surface than the flat one. The question is moot, of course, if you choose cornstarch packing and eschew the plastic bubble wrap.

Mike Follows
Sutton Coldfield, West Midlands, UK
My hunch is that having the smooth side on the outside would make it easier to slide a bubble-wrapped object into a packet, since bubbles on the outside might snag. But I seriously doubt that whether the bubbles are on the inside or outside makes a significant difference to the level of protection.

If the bubble wrap had no outer covering, however, having the bubbles on the inside might provide slightly better thermal insulation, as air would be trapped both inside the bubbles and between the wrap and the object.

In the absence of an experiment worthy of consideration by the Ig Nobel prize committee, this might simply join the list of "binary preferences", alongside Marmite, crunchy versus smooth peanut butter, and whether the loose end of a toilet roll should hang closer to or further from the wall. ▮

Answers

Quick quiz #328 *Answer*

1 They are harvested from civet faeces
2 Fresh water
3 Table sugar
4 A robotic hand out of Lego pieces
5 Do not power it down!!

Cryptic crossword #174 *Answers*

ACROSS 1 Planck, **4** Niacin, **9** Warpage, **10** Kites, **11** Exams, **12** Radicle, **13** Phosphorous, **18** Forward, **20** Bumph, **22** Ruing, **23** Oviduct, **24** Eaglet, **25** Astern

DOWN 1 Powder, **2** Aorta, **3** Chassis, **5** Inked, **6** Catechu, **7** Nosier, **8** Tetrahedron, **14** Herring, **15** Rabbits, **16** G-force, **17** Chitin, **19** Argue, **21** Mouse

#98 S · P numbers *Solution*

The smallest super-S · P number is 6. (1 + 2) × (1 × 2) = 6, and 12 is a multiple of 6.

The two-digit sub-S · P number whose digits sum to 12 is 48. (4 + 8) × (4 × 8) = 384, and 48 is a divisor of 384.

The three-digit super-S · P number whose digits sum to 4 is 112. (1 + 1 + 2) × (1 × 1 × 2) = 8, and 112 is a multiple of 8.

Mooning NASA

There are some stories Feedback doesn't bother with. There are more than 8 billion humans, many of them believe silly things, and many of them have access to the internet, a phone or a letterbox. There just isn't enough time to deal with the resulting slew of mulched half-thoughts. Feedback doesn't want to be that guy in the xkcd cartoon who can't go to bed because "someone is wrong on the internet".

So we almost didn't mention the fact that Kim Kardashian apparently believes that NASA faked the 1969 moon landing. She said as much on *The Kardashians*, the long-running reality television show in which she stars with her mother and sisters.

Kardashian seems to have misunderstood an interview with Buzz Aldrin, the second person on the moon. At one point, Aldrin says "it didn't happen", meaning that a potentially scary incident during the trip didn't take place. However, Kardashian evidently decided that he meant the whole trip didn't happen. This is an extremely bold claim, not least because Aldrin has previously punched a moon landing conspiracy theorist.

But we aren't going to waste time teasing about Kardashian's lack of understanding. Instead, we are preoccupied with what followed. According to the BBC, NASA's acting administrator, Sean Duffy, "invited Kardashian to the Kennedy Space Center for the launch of the Artemis mission to the moon".

Duffy may go on to regret this precedent: if you spout a foolish conspiracy theory via a prominent outlet, it seems you get a guided tour of NASA HQ. Well, Feedback has long wanted to visit Mission Control, and we think we can come up with some better ideas than "moon landing faked".

Do you know why the New Horizons probe took so long (nine years) to get to Pluto? It's because NASA secretly moved the planet further away from Earth to make it look smaller. This enabled them to downgrade it from a planet to a dwarf planet.

Likewise, have you ever wondered why *The Martian* was so true to life? Deep NASA (which is like the deep state, but more so) wants you to think it's just because author Andy Weir did his research. Actually, it's because NASA secretly had an astronaut stranded on Mars for several years in the 1990s. The story is based on the video diaries he recorded before being killed by a robot armed with a heat ray.

We expect our NASA invite in the post.

Twisteddoodles *for New Scientist*

Got a story for Feedback?
Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

The middle of Saturday

We've previously exhausted the topic of the Scunthorpe problem: innocuous words and phrases can contain letter strings that may be seen as offensive by automated moderation systems that don't understand context (11 October). At least, we thought we had exhausted it. But Peter Lloyd tells us of an early progenitor of the issue.

On a Saturday afternoon in the 1970s, he writes, "I had tuned in to BBC1 and was waiting for *Grandstand* to start." For younger readers and those outside the UK: *Grandstand* was a sports programme that aired all Saturday afternoon. Depending on your attitude to televised sport, it was either a blessing or, in those days of hardly any channels, a curse.

"Suddenly the screen showed a single word filling the whole screen," writes Peter. "I was shocked! Why would the BBC want my TV to display TURD? After a short but discernible delay the image zoomed out to show 'SATURDAY ON BBC1' ".

Imagine that!

In case you weren't already in the know, you have until Friday 5 December to submit your work for the next issue of the *Journal of Imaginary Research*.

Feedback was previously unaware of this publication, and we have spent some time trying to figure out what it is. "We publish *imaginary* research abstracts," the editors write. "We mean short works of fiction, that take a format that is familiar to us as researchers and academics. An abstract is the summary of an academic paper, that gives us a succinct overview of the research that has been done."

If Feedback is reading this correctly, the idea is to write pieces of short fiction, presented in the form of fake abstracts of research papers. We had a look at volume 10, the most recent instalment, and some of the abstracts/stories are rather fun, because they're such good parodies of academic writing.

We particularly liked Edward Loveman's "Being in-between: A sensory autoethnography of otherworldly life", about "academics who have been able to achieve the ability to move in-between dimensions (transdimensionality)". Alas, Loveman reports, "such work has been met with scepticism, cruelty, and belittlement – both within the academy and wider public".

However, he argues that it actually represents "a unique, ever-evolving, fluid connection with existence that transcends temporalities".

Likewise, Soyon Park's offering is called "Can research flourish without a research question?" In this, a "group of doctoral students" engage in an "in-depth venting session over coffee", revealing that "their struggle was not with the question itself but with the act of questioning—a process that inherently implies and necessitates seeking an answer".

Feedback suspects the *Journal of Imaginary Research* might become a regular in these pages. It's just a pity it only comes out once a year.

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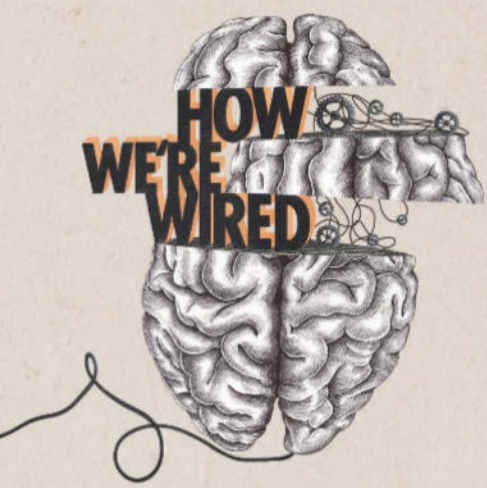

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