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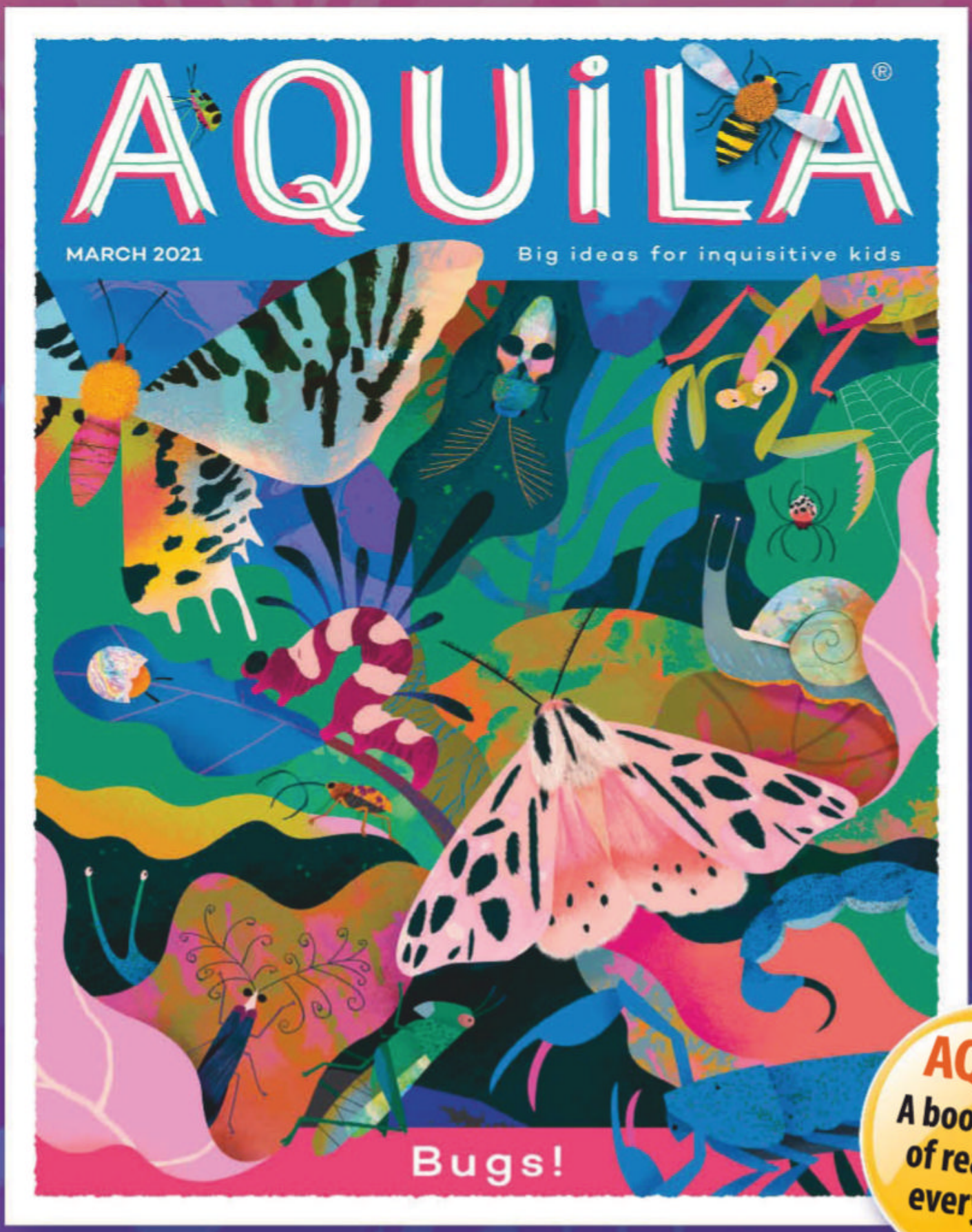

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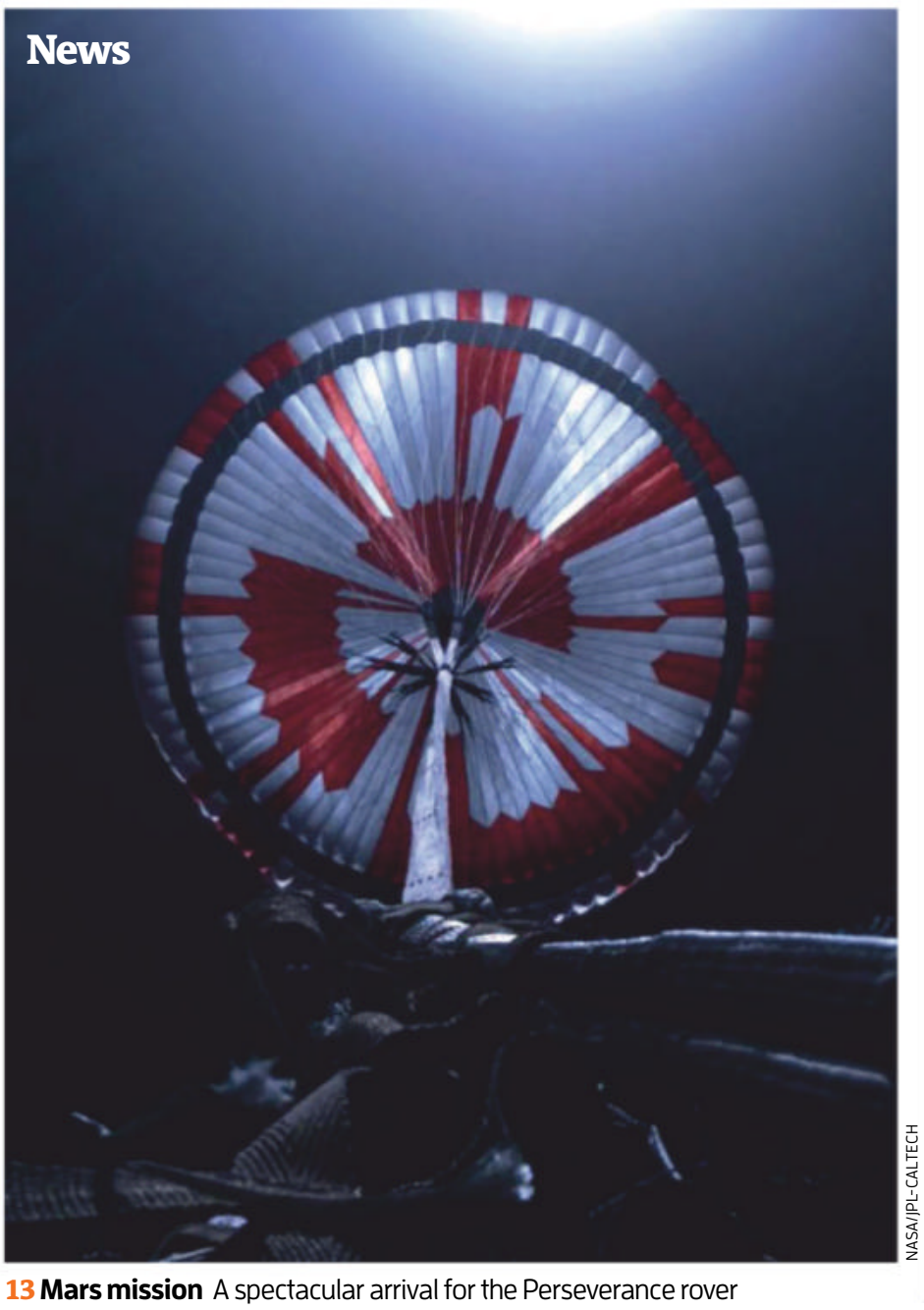

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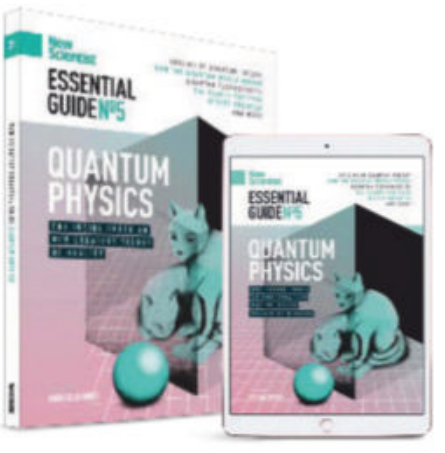

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Signal Boost

Welcome to our Signal Boost project – a page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from **STEM In Africa**

STEM in Africa (SIA) is a non profit organization based in Nigeria which aims to raise awareness and galvanise more youth to get involved in STEM in the continent of Africa. Our slogan is identifying and breaking barriers.

Due to its demographic asset, Africa has immense potential to improve its local and global economies, if it can produce a generation of young professionals that can take charge of the development of their countries. This is why it is critical for education in Africa to reach new levels, particularly with skills that can promote more STEM jobs. Africa has the potential to contain some of the world's fastest-growing economies, but it can only compete with the rest of the world if it invests in STEM education for young people. Supporting education and innovation is SIA's main priority.

OUR MISSION

With the continuous expansion of STEM in the 21st century, SIA's stated mission is majorly to help and empower young people on the continent and build the next generation of leaders,innovators and creative thinkers; science and technology plays a key role in sustaining growth and stability of all economies. As we enter this fourth industrial revolution, SIA's aim is to keep Africa up to speed and leave no one behind. SIA is envisioned to create more opportunities in STEM and serve as a boost to the innovation ecosystem.

Improving STEM education in Africa and resources in African schools will require the collaborative work of governments, organisations, communities, businesses and individuals. Although it currently falls behind other regions in STEM, Africa's demographic makeup and untapped potential give it an advantage moving forward. SIA is looking to achieve this through our events, programmes and partnerships.

OUR PROGRAMMES

SIA Mentorship Programme is a mentorship programme that pairs people from around the world with children from local elementary, secondary and universities from Nigeria. Mentors can be 14+ and the mentors do not have to study a STEM subject. The aim of the mentorship programme is to expose less privileged children in Nigeria to a plethora of higher education, research and opportunities. Mentors and mentees have to meet at least once a month but you are free to put in as much or as little devotion to the programme as you would like but, the more the better. Mentors and mentees can discuss personal background, aspirations and any academic troubles.

SIA SCIENCE HUB

By 2023 we aim to build a Science Hub in Lagos from plastic water bottles, to promote sustainability and to provide a space for students to tap into their innovative and creative minds. This climate-friendly project aims to tackle educational inequalities through a community-based approach and it directly tackles plastic-waste pollution whilst bettering the community it serves. The hub will be a space for our students to develop their soft and hard skills through research, 3D printing and laboratory experiments that they can utilise in the outside world. The potential of young African students is unlimited, SIA is one of the organisations within Africa that aims to unveil this potential.

In order for SIA to further our mission of sustainable learning, we believe that it is necessary to provide environments that can cultivate and nourish interest and engagement in STEM for children who do not normally have access to quality STEM education. Therefore, we are currently collaborating with DoGood Africa Foundation and Livingstones Initiative to build a Science Hub learning centre out of repurposed plastic bottles.

Want to help?

Support us in building our science hub in Nigeria by 2023 by donating on our website steminafrica.com. Instagram handle: @steminafrica Email: steminafrica@gmail.com

Investing in the future

How far would $1 trillion go towards improving public health or the climate?

SOME readers might remember the 1985 movie *Brewster's Millions*. Richard Pryor's character has to spend $30 million in 30 days in order to inherit a $300 million fortune. This week, we update the conceit, inflating the sum to a cool $1 trillion, and set a few ground rules: the money has to be spent on projects to improve human welfare, to restore the environment and to advance science (see page 38).

It is the premise of *How to Spend a Trillion Dollars*, a new book by *New Scientist*'s podcast editor Rowan Hooper that takes 10 megaprojects and costs them out. It is a timely exercise, with US president Joe Biden pushing a $1.9 trillion coronavirus stimulus package through Congress, with a $2 trillion climate plan waiting in the wings. What could be achieved, if money were no object?

To take the examples we focus on this week – solving world poverty, improving public health across the globe and preventing catastrophic climate change – the answer is quite a lot. So much could be achieved for what is, globally speaking, a small sum, that you have to wonder why we don't just get on with it.

"Solving the world's biggest problems is limited mainly by a lack of cash and political will"

One reason, of course, is that there is no "we" endowed to act internationally with this level of investment. Maybe there should be. It would be no bad thing if this book encourages greater public pressure for action on many issues, and if it helps to show that even big problems are soluble.

Sadly, Hooper doesn't tell us how to get our hands on a trillion dollars. But by assessing what it would take to tackle the world's biggest problems, he finds that solving them is limited not by technology, but by the availability of cash, and most of all by a lack of political will. So much might already be obvious, but the situation makes little sense: again and again financial analyses find that even huge investments pay for themselves many times over.

In that sense, it really is like a new version of *Brewster's Millions*: spend now, win later, with more jobs, better health and, crucially, a better functioning biosphere. Spending imaginary money is one thing, however. Now comes the task of getting politicians and the ultra-rich to make it happen. ▮

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Staff administer vaccine at a drive-through centre in Musselburgh, Scotland

Vaccination

Vaccine data 'spectacular'

The first real-world covid-19 vaccine studies are showing impressive results, report **Graham Lawton** and **Adam Vaughan**

FINALLY, some good news. The first real-world studies on the effectiveness of two coronavirus vaccines have shown they are performing "spectacularly well".

In the first of two results announced this week, one dose of vaccine cut hospitalisations due to covid-19 in Scotland by more than 85 per cent.

The research, led by five Scottish universities and Public Health Scotland, involved 99 per cent of Scotland's 5.4 million people, 1.1 million of whom received a vaccine between 8 December and 15 February.

By the fifth week after getting their first dose, those who received the Oxford/AstraZeneca jab had reduced their risk of hospitalisation by 94 per cent, and those who received the Pfizer/BioNTech vaccine by 85 per cent.

Aziz Sheikh at the University of Edinburgh says this is probably the first national report of its kind. "We are very impressed with both these vaccines," says Sheikh. "Both are working spectacularly well."

Among people over 80, who are most at risk from covid-19, hospitalisations were reduced by 81 per cent when results from both vaccines were combined. There isn't enough data yet to separate out the effects of the two different vaccines in this age group.

The results also showed that the jabs offer some protection seven days after vaccination, and that this increases over time. Peak protection appeared in the sixth week, though at this point the data becomes unreliable because few people had been vaccinated for longer than this when the analysis was carried out.

Meanwhile, an analysis from Public Health England (PHE) showed that the Pfizer/BioNTech vaccine prevented 70 per cent of asymptomatic and symptomatic infections in people under 65 after one dose. The protection appeared to take effect around 14 days after vaccination.

The analysis used data from a study that included 23,500 health workers in England, 89 per cent of whom were vaccinated. All were routinely tested for the SARS-CoV-2 virus between 7 December and 5 February. "This is the first time this [type of study] has been done in a systematic way for the Pfizer/BioNTech vaccine," said Susan Hopkins of PHE at a press briefing on 22 February.

Further research from PHE looked at 12,000 people aged 80 and over in England, who are less likely to get effective protection from the vaccine than younger people, and found a single dose of

"Not only is the vaccine reducing the risk of getting covid-19, it's reducing the risk of dying from it"

the Pfizer/BioNTech vaccine was 57 per cent effective at stopping symptomatic infections 28 days later. Protection against severe disease was found to be at least 75 per cent, said Mary Ramsay of PHE at the press briefing, and the risk of death from covid-19 in this age group was 57 per cent lower in those who had received the jab.

"Not only is the vaccine reducing the risk of someone becoming a case, on top of that, it's reducing the risk of them becoming hospitalised or dying," said Ramsay. She added that the study also shows the vaccine offers protection against the variant of the virus first identified in Kent, which is more transmissible and potentially more deadly.

The studies come as UK prime minister Boris Johnson this week revealed his four-stage lockdown exit plan for England, promising the summer would be "incomparably better" than life in lockdown.

However, while results like those we have seen this week offer hope for the future, UK chief scientific adviser Patrick Vallance emphasises caution, saying that England's road map out of lockdown should proceed slowly to avoid the risk of a resurgence in covid-19 cases. In a press conference, he warned that coronavirus will be a problem for the next few winters. ▮

Daily coronavirus news round-up
Online every weekday at 6pm GMT
newscientist.com/coronavirus-latest

Immunisation

Sights set on universal vaccine

Scientists have begun the race to create a single vaccine that protects us from all future coronaviruses, with human trials starting soon, finds **Graham Lawton**

THE coronavirus sweeping around the world isn't the first to make the leap into humans and it won't be the last. Vaccines against SARS-CoV-2 were developed in record time and are performing well. But now we urgently need a different kind of vaccine, say scientists: one that will protect us against other coronaviruses, even those we haven't met yet.

It is a daunting challenge, yet work has already begun on creating such a universal vaccine, with the first human trials of potential candidates planned to start later this year.

In the past 20 years, humanity has endured three outbreaks of disease caused by novel coronaviruses: SARS, MERS and now covid-19. The first two are very deadly – up to 35 per cent of people who catch MERS, and 10 per cent of those with SARS, die – but they aren't very transmissible. Covid-19 is highly transmissible, but not as deadly: so far, up to about 1 per cent of people who have caught it have died.

With a number of other coronaviruses out there poised to make the leap from animals into humans, there will almost certainly be a fourth. And as Wayne Koff, CEO of global consortium the Human Vaccines Project, points out, if the next coronavirus is as transmissible as SARS-CoV-2 and as deadly as the viruses that cause SARS or MERS, "within a year we could have 100 million dead".

"If the next coronavirus is as transmissible as this one and as deadly as the MERS one, 100 million could die"

The solution to this threat is obvious, says Anthony Fauci, director of the US National Institute of Allergy and Infectious Diseases (NIAID). "We would like to develop a universal coronavirus vaccine for all coronaviruses," he said at an online meeting run by the New York Academy of Sciences this month.

This is easier said than done. A universal coronavirus vaccine would need to identify a region of the virus that is so integral to its survival that it is conserved across all coronaviruses, and doesn't change as viruses mutate.

Scientists believe such highly conserved regions could be universal epitopes – immune system-stimulating regions of the virus – that could be used to make a vaccine that is effective against multiple coronaviruses.

So far, it isn't even clear that we can make a vaccine that protects against all variants of SARS-CoV-2, let alone coronaviruses in general. But there are signs that a universal vaccine may be on the cards.

Calls to create one began in 2014, when Abul Islam and Refat Sharmin at the University of Dhaka in Bangladesh discovered an epitope within an enzyme that was universal across all known human coronaviruses, and suggested it as a target for a universal vaccine. It was published in *BMC Bioinformatics*, but wasn't followed up.

According to Luca Giurgea at NIAID, scientists now accept the need to at least try. In May 2020, he and two colleagues published an opinion piece in the journal *NPJ Vaccines* entitled "Universal coronavirus vaccines: the time to start is now". They urged the world not to just focus on vaccines for SARS-CoV-2, but to think bigger.

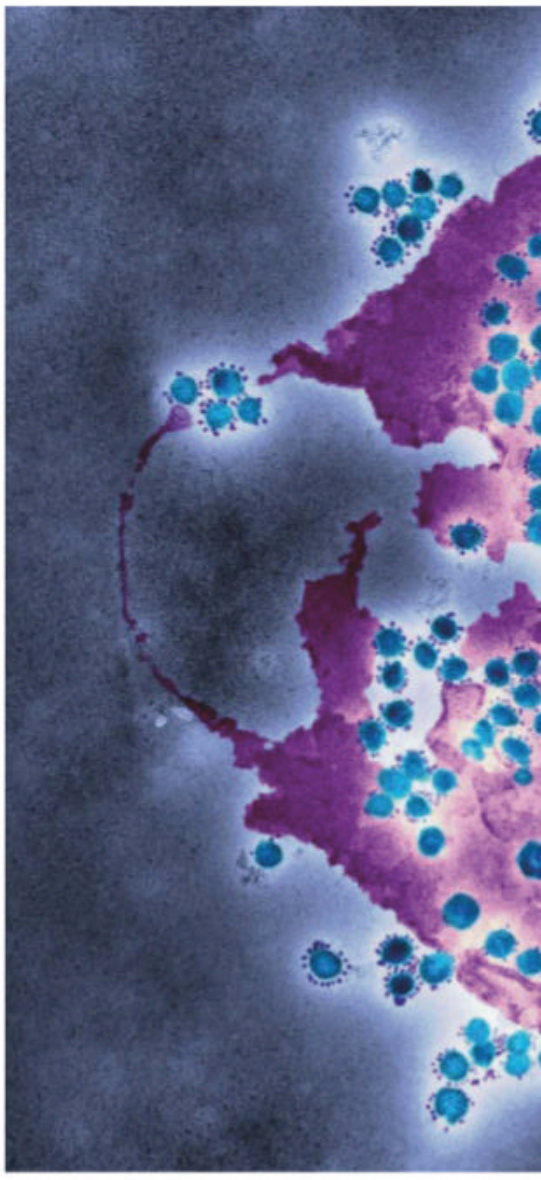
"We were confronted with some scepticism," says Giurgea. "Now that we are starting to get data suggesting some of the vaccines have lower efficacy against the new variants, we are finally seeing a considerable shift in attention towards more broadly protective vaccines."

Hidden targets

The good news is that present and future coronaviruses are likely to have common features that a universal vaccine could exploit. As well as the epitope discovered by Islam and Sharmin in 2014, there are also spike proteins that coronaviruses use to enter our cells. Those of SARS-CoV, the virus that causes SARS, and SARS-CoV-2 are about 78 per cent identical in terms of the sequence of their component amino acids.

Such highly conserved regions must be biologically important and so present a tempting target for vaccines because coronaviruses are unlikely to be able to escape them by mutating, given such changes would probably render the virus inactive.

Immunological evidence also suggests that there are conserved aspects of several coronaviruses, given that antibodies against one can protect against another. For instance, antibodies from people who have recovered from SARS are



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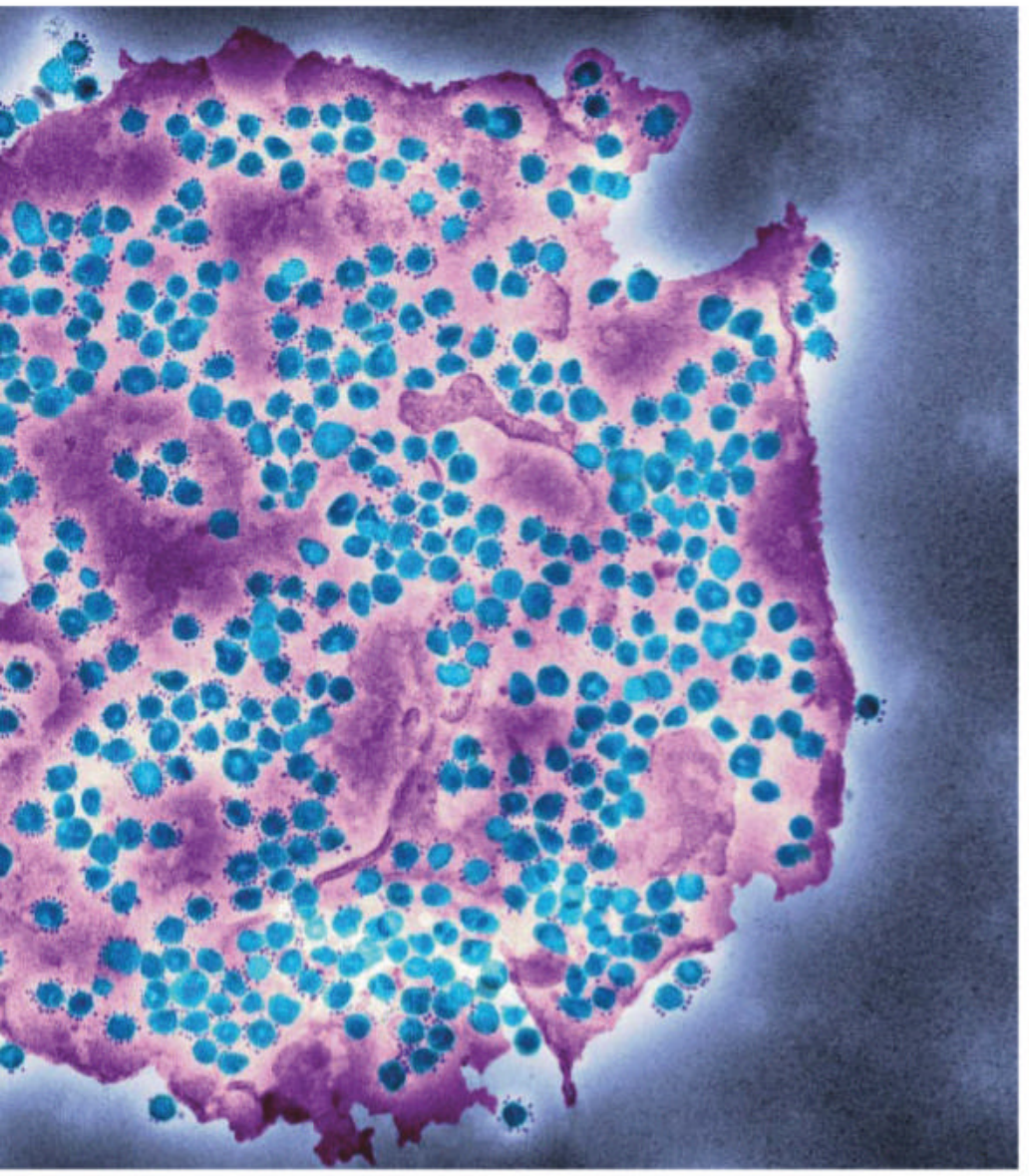
Samples are prepared in order to test them for the SARS-CoV-2 virus



SARS-CoV-2 viral particles (blue) penetrate a human cell

sometimes protective against SARS-CoV-2, and vice versa.

It is also possible to generate antibodies in mice that are effective against SARS, MERS and covid-19. Likewise, animals immunised against SARS-CoV gained resistance to SARS-CoV-2, as well as a SARS-like bat coronavirus that has previously been identified as a potential threat to humans.

The discovery of these broadly neutralising antibodies, which can recognise epitopes from several different coronaviruses, strongly suggests that a universal vaccine is possible, says vaccinologist Dennis Burton at the Scripps Research Institute in La Jolla, California.

"There's some serious threat out there and we really, really need to pay attention to it"

The difficult part is working out exactly which bits of the virus stimulate the production of these broadly neutralising antibodies in order to design a vaccine based on them. But several research teams are attempting to do just that.

Human trials

For example, Ralph Baric at the University of North Carolina School of Medicine and his colleagues isolated antibodies from a person who had been infected with SARS-CoV and identified those that were broadly neutralising against other coronaviruses, including SARS-CoV-2. They then tweaked the antibodies using genetic engineering to make them even more potent. Finally, they analysed these supercharged antibodies to work out which region of the spike protein they bound to as this must be highly conserved, and could be the Achilles heel of the virus.

"There are clearly major cross-neutralising epitopes that exist and if we're going to develop broad-based vaccines, we need to identify where those epitopes are," says Baric.

Another approach is to make artificial proteins bearing features of spike proteins from several human and animal coronaviruses. An experimental vaccine based on this approach has already been shown to induce broad immunity against multiple coronaviruses in a mouse model. This result is "rather promising", says Giurgea.

Researchers at Los Alamos National Laboratory in New Mexico also have a universal vaccine in their sights. Bette Korber, who leads its universal coronavirus vaccine research, says there are a number of highly conserved regions across the whole group of coronaviruses that include SARS-CoV, SARS-CoV-2, MERS-CoV (the virus responsible for MERS) and some viruses that cause the common cold.

Studies show that these regions can be used to provoke a T-cell immune response in mice. T-cells kill infected cells and aren't normally the primary goal of a vaccine. However, it might be useful to add these highly conserved epitopes to existing vaccines to get a broader immune response.

Finally, there are a handful of biotech companies that are taking steps towards a commercial universal vaccine. ConserV Bioscience in the UK says it is developing an mRNA vaccine that covers the full spectrum of coronaviruses, including those that cause the common cold, although it hasn't revealed exactly how its vaccine works.

The goal is to develop a vaccine that could be given to people every few years to head off a future pandemic, says CEO Kimbell Duncan. The vaccine is in preclinical testing and could enter early human trials this year, he adds.

Another company, VBI Vaccines in Massachusetts, says it is planning to begin human trials later this year of a universal vaccine that targets SARS-CoV, SARS-CoV-2 and MERS-CoV spike proteins.

The race to create a vaccine for SARS-CoV-2 was won in record time, but the next race is just starting, and not a moment too soon. "It's very easy to imagine highly pathogenic coronavirus strains with 10 to 15 per cent mortality rate that are nearly as transmissible as covid-19," says Baric. "There's some serious threat out there and we really, really need to pay attention to it." ▮

Long-term effects

Children with long covid

Almost half of children who contract covid-19 may have lasting symptoms, which should factor into decisions on reopening schools, reports **Helen Thomson**

A SERIOUS picture is emerging about the long-term health effects of covid-19 in some children, with UK politicians calling the lack of acknowledgment of the problem a "national scandal".

Children seem to be fairly well-protected from the most severe symptoms of covid-19. According to the European Centre for Disease Prevention and Control, the majority of children don't develop symptoms when infected with the coronavirus, or their symptoms are very mild.

However, it is becoming increasingly apparent that a large number of children with symptomatic and asymptomatic covid-19 are experiencing long-term effects, many months after the initial infection.

SCOTT OLSON/GETTY IMAGES

A man helps his daughter with a covid-19 test in Chicago, Illinois

Long-term symptoms

Symptoms of "long covid" were first thought to include fatigue, muscle and joint pain, headache, insomnia, respiratory problems and heart palpitations. Now, support groups and researchers say there may be up to 100 other symptoms, including gastrointestinal problems, nausea, dizziness, seizures, hallucinations and testicular pain.

Most long covid research is based on adults. There is less information about under-18s, in part because it takes longer to get ethical approval to study children, says Natalie Lambert at Indiana University School of Medicine.

A recent study found that 13.3 per cent of adults with symptomatic covid-19 have symptoms lasting more than 28 days (medRxiv, doi.org/ghgdsv). Long-lasting symptoms were more likely to occur with increasing age and BMI, and were more likely in women than men, although it isn't clear why.

Experiencing more than five symptoms in the first week post-infection was associated with a greater likelihood of having symptoms further down the line.

Evidence from the first study of long covid in children suggests that more than half of children aged between 6 and 16 years old who contract the virus have at least one symptom lasting more than 120 days, with 42.6 per cent impaired by these symptoms during daily activities. These interim results are based on periodic assessments of 129 children in Italy who were diagnosed with covid-19 between March and November 2020 at the Gemelli University Hospital in Rome (medRxiv, doi.org/fv9t).

The UK Office for National Statistics's latest report estimates that 12.9 per cent of UK children aged 2 to 11, and 14.5 per cent of children aged 12 to 16, still have symptoms five weeks after their first infection. Almost 500,000 UK children have tested positive for covid-19 since March 2020.

Most medical bodies say it normally takes a few days or weeks to recover from covid-19, and that most will make a full recovery within 12 weeks.

UK advocacy group Long Covid Kids says that it currently has details of 1200 children with long covid from 890 families in England. "And that number has been rising quickly," says founder Sammie Mcfarland. "Not one has returned to their previous health, and most are unable to do their normal activities."

The consequences of long covid in children can be debilitating. At a UK parliamentary briefing on 26 January, Mcfarland described how her 14-year-old daughter started to become vacant, weak and unresponsive after catching covid-19 in March 2020. After three weeks in bed, she did some gentle exercise in the garden and clutched her chest, complaining of heart pain. "She went very floppy and almost couldn't make it back into the house to bed," says Mcfarland. "And she pretty much stayed there [in bed] for the next seven months."

> **"She went very floppy and almost couldn't make it back to bed. She stayed there for seven months"**

Since August 2020, Mcfarland says there have been times where her daughter would feel better and they would go out of the house for a picnic, but they soon realised that every trip out triggered a long period of relapse, an issue that seems to be common in adults with long covid too.

Other cases seem to present very differently. Charlie Mountford-Hill has five children, all of whom have long covid after contracting the virus in the early stages of the pandemic. Almost a year after catching covid-19, her 4-year-old still has a sore neck, lethargy, stomach problems and headaches. Her 10-year-old has fatigue and gastric problems with pain around his heart. "Although they have bad periods and better periods, they are never well," says Mountford-Hill.

Seeking long-covid care

A common frustration among parents is the lack of support from doctors. Mcfarland says they can dismiss the symptoms as not being related to covid-19 because they are so varied. Often, blood tests and scans also fail to supply any answers. "The majority of people known to Long Covid Kids have been unable to get support," she says. The group is now working with NHS England to try to get access to care.

Several parents gave evidence at the parliamentary briefing on long covid in children, run by MP Layla Moran. She told *New Scientist* that the "lack of support, acknowledgement and treatment of long covid in children is a national scandal". In a letter to the Prime Minister that was shown to *New Scientist*, several MPs refer to the situation as a crisis that needs to be taken more seriously.

The lack of information on long covid in children is especially pertinent to decisions around schools reopening, as they are due to do in parts of the UK and the US in the coming weeks.

"We certainly don't have enough data on the long-term impacts of covid in children to make good policy decisions right now," says Lambert, who is director of research for Survivor Corps, the largest covid-19 advocacy group in the world. On 18 February, the UK's National Institute for Health Research awarded £1.4 million for a study to assess risk factors and prevalence of long covid in children.

Nurseries have been allowed to stay open in England while primary and secondary schools have remained shut since 5 January. When asked on 5 February whether the impact of long covid in children has been considered in relation to the reopening of schools, the UK Department for Education gave no reply.

Sending thousands of children back to school is "insane", says McFarland. "Sending children back to school seems to be inviting the possibility of giving a whole generation long-term chronic health issues. Why take the risk of opening schools before children have been vaccinated?"

500,000
Children in the UK who have tested positive for covid-19

12.9%
Percentage of UK children aged 2 to 11 who still have covid-19 symptoms five weeks after initial infection

14.5%
Percentage of UK children aged 12 to 16 who still have covid-19 symptoms five weeks after initial infection

Students in Glasgow, UK, returned to schools on 22 February

ANDY BUCHANAN/AFP VIA GETTY IMAGES

So far, no coronavirus vaccines have been approved for use in children, although CanSino Biologics in China is testing one in 6 to 12-year-olds, according to data revealed at a recent New York Academy of Science meeting. CEO Xuefeng Yu says that preliminary data will be analysed soon. US company Codagenix is also planning to test a nasal vaccine in children.

The good news is that evidence suggests children don't easily pass covid-19 to each other in the classroom. In one study, a 9-year-old in France with flu and covid-19 was found to have exposed more than 80 other children at three different schools. However, no one became infected with covid-19 as a result, despite numerous flu infections within the schools, suggesting that although the environment was conducive to transmitting respiratory viruses, covid-19 wasn't passed on as easily.

More recently, a study of children between 5 months and 4 years old in nurseries in France has shown low levels of infection and transmission of covid-19. The study also shows that staff weren't at greater risk of infection than a control group of adults. The results suggest that children are more likely to get covid-19 from family members than from their peers or teachers at nursery, although more evidence is needed, say the study's authors, because the study happened when strict measures were in place to control the virus, and before fast-spreading variants appeared.

Until now, the focus of the pandemic has been on preventing severe disease and deaths in the older generations, but Mcfarland says thoughts need to turn to the legacy the virus is leaving on children.

Military technology

US Army laser weapon to be most powerful ever

David Hambling

THE US Army is building a laser weapon over a million times more powerful than any used before – although because it delivers short pulses, the overall energy hitting the target is low.

Existing laser weapons produce a continuous beam that is held on a target, such as a drone or missile, until it melts. The first was deployed by the US Navy in 2014. The new weapon, known as the

1

Power of a laser pulse from the new weapon, in terawatts

Tactical Ultrashort Pulsed Laser for Army Platforms, would be more like science-fiction movie lasers, firing bullet-like pulses of light.

Such ultrashort laser pulses carry extreme power over vanishingly short lengths of time: the project is aiming for a terawatt pulse lasting just 200 femtoseconds (2×10^{-13} s), compared with a maximum of 150 kilowatts for previous systems.

The laser would produce between 20 and 50 pulses per second, for an overall power rating of 20 to 50 watts, about 10 times more than an LED light bulb.

Ultrashort lasers this powerful are already used in laboratories and factories, but the US Army wants a compact, rugged version that can be aimed at distant targets.

Normal lasers are ineffective over long distances because the beam spreads out, but ultrashort pulses can be shaped into self-focusing light pulses called solitons that turn the air itself into a lens, continually refocusing the pulse.

Such a weapon would produce dramatic effects. The rapid temperature rise from the ultrashort pulse would vaporise the surface of a target rather than melting it, a technique used industrially to cut precise holes through metal. The resulting rapid expansion of gas can also produce a powerful blast wave.

In addition, the US Army hopes the laser will create an electromagnetic pulse (EMP) effect. On striking a metal target, the laser pulse rapidly accelerates electrons, and the moving charges produce a burst of radio-frequency energy powerful enough to disturb nearby electronics. This is a known problem in lab settings, where EMPs can affect measuring instruments. A sufficiently powerful EMP could bring down drones or missiles by disrupting their control systems.

Contractor Aqwest in Larkspur, Colorado, is developing a ceramic disc laser for the project. The design is a variation of the thin-disc laser invented in Germany in 1992.

The US Navy has previously deployed laser weapons

JOHN F. WILLIAMS/U.S. NAVY

The original lasing disc was just 0.1 millimetres thick and was attached to a heat sink to disperse waste heat. Aqwest's version is thicker and can deliver proportionately more energy in each pulse. The firm declined to comment on the work.

Building this kind of laser weapon is possible with current technology, says Derryck Reid at Heriot-Watt University in Edinburgh, UK. "This is not science fiction."

Reid sees the self-focusing effect as the key benefit of the new laser. Although the amount of energy is low compared with a continuous beam laser, delivering it rapidly to a small enough area could be effective. "You could certainly do some damage with these power levels," he says.

Laser weapons are generally intended for use against small, fast-moving, airborne targets. If used to target a human, it would cause unpleasant burns, but would generally be less harmful than conventional weaponry.

The International Committee of the Red Cross, which has worked to develop international law around laser weapons, declined to comment on the specifics of the weapon, but notes that the only current restriction on such arms is a 1995 treaty prohibiting the use of lasers intended to blind.

Aqwest's contract states that the prototype ultrashort pulse laser weapon will be demonstrated by August next year, after which the US Army will decide whether to go ahead with further development. This could lead to laser blasters mounted on ground vehicles and helicopters. ▮

Transport

Smart system can dramatically cut wait to charge electric car

Matthew Sparkes

ELECTRIC cars are becoming more popular, but until the infrastructure to keep them charged expands, there is the potential for very long waits to top up batteries at public chargers. A computer model can help. By taking information about electric vehicle journeys, it can slash waiting times by 97 per cent.

Sven Schönberg at Paderborn University and Falko Dressler at the Berlin Institute of Technology, both in Germany, simulated 5000 electric cars each undertaking a trip of 500 kilometres in a single day on Germany's roads. The average wait to charge was over 6 hours.

To improve on this, the pair first calculated the most efficient routes between nearby charging stations on the road network. They think electric cars' on-board computers can create an optimal route by using a string of these.

The researchers also propose a central database to which drivers upload their planned routes and charging stops – like pilots filing a flight plan to an aviation administration. An algorithm can then process all this to maximise journey efficiency.

For instance, using information from the algorithm, a car's navigation system might suggest going at a slower and more efficient speed if it knows there will be a wait at a charging station. Doing so can reduce total journey time: travelling more slowly is more energy efficient and so when the car does stop to charge, the driver won't have to lose as much time. "It is easy to find the fastest route or the most energy efficient route," says Schönberg. "But sometimes the optimal solution is somewhere in between."

When the researchers reran the simulation of 5000 electric vehicles using the database and algorithm, they found the average wait to charge fell to just 11 minutes (arxiv.org/abs/2102.06503). ▮

18+

WHAT IS AVAXHOME?

AVAXHOME-

the biggest Internet portal, providing you various content: brand new books, trending movies, fresh magazines, hot games, recent software, latest music releases.

Unlimited satisfaction one low price
Cheap constant access to piping hot media
Protect your downloadings from Big brother
Safer, than torrent-trackers

18 years of seamless operation and our users' satisfaction

All languages
Brand new content
One site

AVXLIVE.ICU

AvaxHome - Your End Place

We have everything for all of your needs. Just open https://avxlive.icu

Space exploration

First video on Mars

The Perseverance rover is already giving us a stunning view of the Red Planet

Leah Crane

NASA/JPL-CALTECH

NASA's Perseverance rover has sent back astonishing video footage of its 18 February landing, giving us the most intimate look ever at the process of setting a spacecraft down on the Martian surface.

This still image from one video was captured by the sky crane, a sort of robotic jetpack that used thrusters to slow the rover down after it entered the Martian atmosphere before gently placing it on the ground. No image like this has ever been taken before; while the Curiosity rover also used a sky crane to land on Mars, that crane didn't have cameras.

During the landing, the rover collected about 30 gigabytes of information and more than 23,000 images. The rover also captured the first audio ever recorded on Mars. While its microphone didn't work during the landing, it did record the Martian breeze blowing over the rover once it was on the surface.

Renewables

Green energy solution in them thar hills

USING more mountains as giant "water batteries" that store excess power from wind farms could substantially reduce the UK's need for new nuclear power and save it hundreds of millions of pounds.

New pumped hydro projects, which use off-peak electricity to pump water uphill and release it later to generate electricity, could save the UK energy system between £44 million and £690 million a year by 2050, according to a report by a team at Imperial College London. The exact figure hinges on how much of the storage technology is built as the UK rapidly increases its reliance on variable wind and solar power.

Most of the savings stem from having to build fewer new power stations, followed by fewer new pylons and a fall in the costs National Grid bears to balance electricity supply and demand. The report says that by storing cheap wind power in this way and dispatching it at times of need, each 1000 megawatts of pumped hydro could replace 750 MW of power from a nuclear plant or a gas plant with carbon capture.

"There is massive variation in wind power – this is where this long-duration storage comes in," says Goran Strbac at Imperial, who modelled the savings. The Scottish government welcomed the report in a statement and said it showed the value of pumped hydro storage in a net-zero power system.

Whether the UK needs new nuclear to reach its carbon goals is a big question. Its government is weighing up financial support for a £20 billion nuclear power station in Suffolk that could be built by French energy firm EDF and which would have a capacity of 3200 MW.

The pumped storage report was commissioned by UK-based energy firm SSE, which last October won planning permission for a pumped hydro scheme of up to 1500 MW. But the firm says

"More pumped hydro projects could take the place of new nuclear or gas-fired power plants"

energy market policies aren't yet in place to provide enough certainty for it to raise the nearly £1.5 billion needed to build the Coire Glas project in the Great Glen between Inverness and Fort William, Scotland. Almost all of the UK's existing pumped hydro sites are in Scotland and Wales.

"The challenge for the Coire Glas investment case is although revenue streams are there, they are highly uncertain and short term in nature," says Mike Seaton at SSE. He wants to make a final investment decision by the end of 2023, so construction could start the following year with the scheme operating before 2030.

Adam Vaughan

Microbiology

Deepest land microbes ever found

Intact cells discovered near the bottom of a 5-kilometre hole in China

Colin Barras

THERE are microbes near the bottom of the third deepest hole in the world. The cells, recovered from rocks almost 5 kilometres below the surface in China, are the deepest so far found on land – and they may extend the known heat tolerances of life on Earth.

Until now, the deepest known microbes on land were nematode worms found 3.6 kilometres below the surface in a South African gold mine.

A team led by Hailiang Dong at the China University of Geosciences and Li Huang at the Chinese Academy of Sciences has now discovered bacterial cells at greater depths. The team studied rocks from a 5.1-kilometre-deep borehole in eastern China, made as part of the Chinese Continental Scientific Drilling (CCSD) project.

Microscopic analysis confirmed the presence of cells in CCSD rock samples extracted from a depth of 4.85 kilometres. The team also recovered bacterial DNA from rocks at this depth.

Dong and Huang say that, to the best of their knowledge, these are the deepest known microbes ever found on land (*Geobiology*, doi.org/fwdx). Demonstrating that the cells are living will be a challenge as microbes that live deep below the surface often operate on such a slow timescale that they show few typical signs of life such as movement or reproduction.

But there are reasons to suspect the microbes may be alive. Most importantly, they are intact rather than just cell fragments, which might hint they are carrying out basic cellular repair.

The researchers think microbes may be found at greater depths elsewhere in the world. They suspect that conditions in the CCSD borehole become too hot at 4.85 kilometres for life to survive at deeper levels. But in regions where the local geology means temperature rises more slowly with depth, life might survive several kilometres deeper.

"The limits on life are down to a complex interplay between temperature, pressure and other factors"

"The research community is beginning to consider that the limits are actually down to a complex interplay between a variety of parameters including temperature, pressure and the physical nature of the rocks – their porosity, for instance, and the water penetrating the system," says Barbara Sherwood Lollar at the University of Toronto, Canada.

Regardless of whether these microbes have hit a thermal limit, confirming living microbes that deep would be significant. At 4.85 kilometres down in the CCSD hole, the temperature is about 137°C, far above 122°C, the threshold above which no known organism can survive. Dong and Huang say theoretical calculations suggest life might be possible up to 150°C.

"I don't think any of us would be hugely surprised if there's an organism that grows at 130°C or at 135°C," says Sean McMahon at the University of Edinburgh, UK. Such a microbe would widen the search for alien life. "Astrobiology defines habitability as an environment that can support the growth of at least one known organism," says McMahon. Finding an organism that grows at higher temperatures means our definition immediately changes, he says. ▮

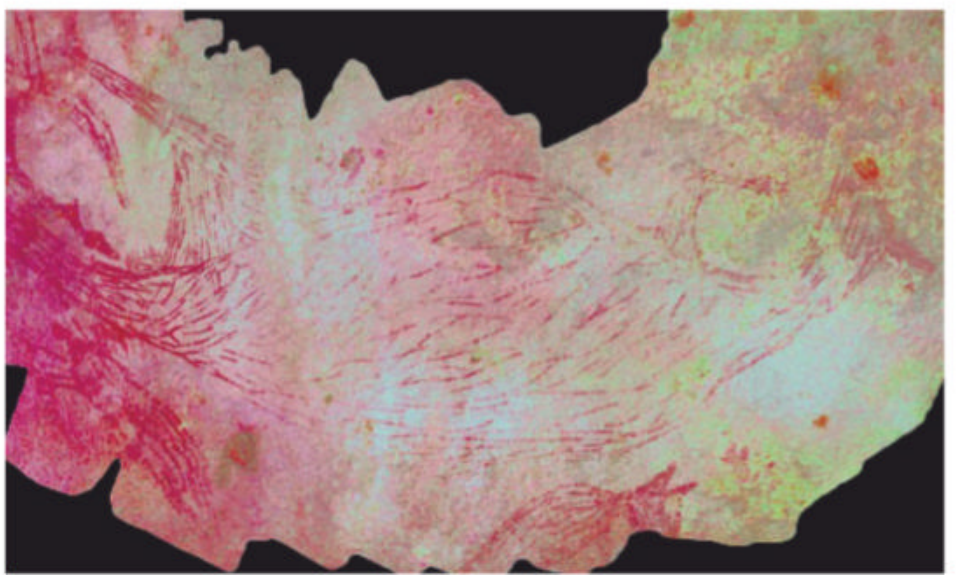
Archaeology

Australian rock painting is at least 17,000 years old

A LIFE-SIZE kangaroo painted in red ochre around 17,300 years ago is Australia's oldest known rock art, indicating that early artists in the country focused on animals.

Rock art sites are found all over Australia, with the Kimberley region of Western Australia containing a particularly rich record. But dating the images is challenging without the minerals or organic material used to determine an artwork's age.

Now, Damien Finch at the University of Melbourne and his colleagues have dated the images in eight rock shelters in Balanggarra Country, in the north-eastern Kimberley region. Finch and his colleagues worked with the Balanggarra Aboriginal Corporation, which represents the Traditional Owners of the land. Members of the corporation reviewed the team's paper.



DAMIEN FINCH

This image of a kangaroo is the oldest of its kind so far discovered in Australia

Finch's team dated the images by measuring the radiocarbon signal from ancient wasp nests that lie beneath and on top of the artwork.

They discovered that a kangaroo image (pictured) on the ceiling of a rock shelter containing thousands of ancient mud wasp nests was painted between 17,500 and 17,100 years ago. "Wasps have been building nests at this site consistently for 20,000 years", says Finch (*Nature Human Behaviour*, doi.org/fwsg).

"The dating of this oldest known painting in an Australian rock shelter holds a great deal of significance for Aboriginal people and Australians and is an important part of Australia's history," said Cissy Gore-Birch, chair of the Balanggarra Aboriginal Corporation, in a media statement.

Analysis of other images in the rock shelters showed that these naturalistic animal paintings were common until 13,000 years ago. Younger art from elsewhere in Australia predominantly features images of humans. ▮

Alison George

Astronomy

Neutrino blasted out by a star-munching black hole

Leah Crane

IN A distant galaxy, a supermassive black hole ripped a star to bits, sending out an enormous blast of energy. For the first time, researchers have observed a tiny particle called a neutrino that probably came from this type of cataclysm, which is called a tidal disruption event or TDE.

Neutrinos rarely interact with other matter, making them extremely difficult to detect. On 1 October 2019, the IceCube Neutrino Observatory in Antarctica spotted a neutrino with relatively high energy that appeared to come from beyond our galaxy.

Meanwhile, Robert Stein at the German Electron Synchrotron (DESY) and his colleagues were using the Zwicky Transient Facility in California to watch a star that had got too close to a supermassive black hole.

The extreme gravity of the black hole shredded the star, creating a TDE that lasted for months. The TDE and the IceCube neutrino came from the same location in the sky, indicating that the ripped-up star may have produced the neutrino (*Nature Astronomy*, doi.org/fwzd).

"Theorists had proposed that some neutrinos might come from TDEs and what we have here is the first observational evidence to support that claim," says Stein.

To produce a high-energy neutrino, a particle – generally a proton – must first be accelerated to an extraordinary speed. It must then collide with another proton or with a particle of light – a photon – causing it to smash apart into smaller particles, including neutrinos. There are few events in the universe that produce the acceleration needed to generate high-energy neutrinos. Now it appears that TDEs can do so.

MARTIN WOLF, ICECUBE/NSF

The IceCube Neutrino Observatory at the South Pole

However, we don't know the exact mechanism of this particle acceleration. It is a mystery that is made even more confusing by the fact that the neutrino was detected 154 days after the peak of the TDE's activity. Neutrinos travel close to the speed of light, so the particle should have arrived at Earth only slightly later than the light from the TDE.

154

Days between the peak of a star's destruction by a black hole and a neutrino's detection

"You have to explain why the neutrino comes so late after the peak," says Walter Winter at DESY. He and Cecilia Lunardini at Arizona State University have come up with a scenario that could explain this tardy arrival.

After the star in a TDE is ripped apart, its matter spreads out to form a disc around the black hole. The pair suggest that some of this matter could be funnelled by magnetic fields into a jet, which would accelerate protons in it.

But to create a neutrino, the fast-moving protons have to crash into something. Winter and Lunardini suggest that the delay may be caused by the need to wait for photons to build up around the black hole, in a sort of cloud of light. Then there is a chance of a proton-photon collision (*Nature Astronomy*, doi.org/fwzf).

X-ray observations showed that although this TDE emitted more X-rays than most of the others that have been spotted, they faded rapidly at around the same time the neutrino was produced. Winter and Lunardini suggest that this could be due to the photon cloud obscuring the X-rays while also giving the protons in the jet something to smash into to generate neutrinos. ▮

Solar system

Juno spacecraft spies meteor lighting up Jupiter's skies

Will Gater

NASA's Juno probe, which is currently circling Jupiter, has spotted what appears to be the fiery blast of a meteoroid plunging into the planet.

The chance discovery was made by one of the spacecraft's spectrometers that captures ultraviolet views of the planet. The instrument was observing the ultraviolet glow from aurorae dancing in Jupiter's upper atmosphere when it detected a powerful burst of light that appeared in the giant planet's night-time skies in April last year.

Only a handful of Jovian impacts have been spotted from Earth-based observatories in recent years. If Juno can detect more of these events, it could give scientists a clearer picture of how many chunks of interplanetary debris smash into Jupiter each year (arxiv.org/abs/2102.04511).

"With just one observation, there's a limit to the statistical analysis we can perform," says Rohini Giles at the Southwest Research Institute in Texas, who led the team that made the discovery. "But the mission was recently extended to 2025 and hopefully we will be able to catch more impacts."

One reason why the impacts are of interest to researchers is because Jupiter's sweeping-up of material can influence the composition of its stratosphere. Fragments of a comet called Shoemaker-Levy 9 collided with Jupiter in 1994, and even 15 years later the water the comet contained was responsible for 95 per cent of Jupiter's stratospheric water, says Giles. "Constraining the impact rate is an important element of understanding the planet's composition."

Such studies can also illuminate the history of our impact-scarred planetary neighbourhood, says Ashley King at the Natural History Museum in London. ▮

Field notes Iceberg A-68

On the trail of icy ocean invaders

We travelled to the Southern Ocean to investigate one of the world's largest icebergs, says expedition leader **Povl Abrahamsen**

IT IS a relief when we finally see the iceberg, first as a line on the ship's radar and then as a wall of ice emerging from a foggy horizon, stretching further than we can see.

This is part of the remains of iceberg A-68, the third largest iceberg ever recorded, which broke away from Antarctica's Larsen C ice shelf in 2017. After drifting northwards, A-68 was on a collision course with the island of South Georgia in December 2020 before being swept back into deeper water south of the island.

It has begun to disintegrate and is no longer a continuous island of ice. There are now 12 named iceberg fragments from A-68 and countless smaller icebergs. The largest of these, dubbed A-68A, is 50 kilometres long and 200 metres thick in places, and covers an area of around 900 square kilometres, similar to that of the Isle of Mull in the UK.

Ships have to be very cautious around icebergs due to the damage that can be caused by the hard, freshwater ice, so we keep a distance of 1 nautical mile from the largest icebergs, and the crew navigate carefully around the smaller pieces. But we can still hear when larger parts break off, even above the sounds of the ship's whirring engines and machinery.

Whether in one piece or dozens, A-68 could have a large impact on the ocean and ecosystems around South Georgia, which sustain large colonies of penguins and seals, as well as whales.

The cooling and freshening that takes place as the giant iceberg breaks up and melts might affect the life forms at the very bottom of the food chain: tiny algae called phytoplankton. At the same time, large icebergs can also stir up nutrients from the deep, increasing biological productivity in their wake.

To find out, I am near the island of South Georgia in the Southern Ocean, which surrounds Antarctica, on the research ship RRS James Cook. We will monitor the temperatures, salinities and plankton concentrations in the water, and compare the findings with long-term data from oceanographic studies in the region.

ALICE MARZOCCHI, NOC

Researchers on the RRS James Cook launching an underwater glider

Leading an oceanographic expedition to the Southern Ocean is always exciting and unpredictable. It is even more so when the target of your observations is spinning around in meandering currents while gradually breaking up.

Due to the pandemic, we have a reduced team of just 11 scientists, engineers and technicians from the National Oceanography Centre in Southampton, UK, and the British Antarctic Survey in Cambridge in addition to the ship's crew and a doctor.

After two weeks of quarantine, we are trying to fit our research into the iceberg into a short time window between our other work carrying out annual monitoring of the ecosystems and climate of the Southern Ocean. Luckily the A68-A iceberg has ended up in a location that doesn't require a large detour.

We are spending three days near this iceberg as part of five intensive weeks of research at sea. The weather is typical for the Southern Ocean at this time of year: cloudy, windy and chilly, with daytime temperatures just above freezing.

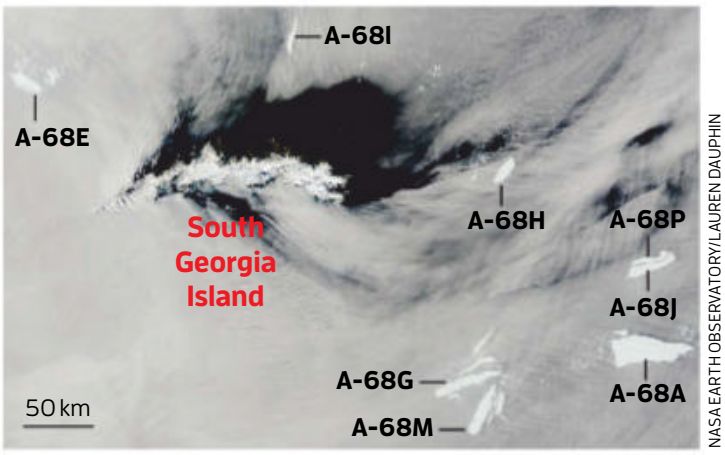
After admiring the iceberg briefly, we carry on with our measurements. On our second day, we deploy an underwater robotic glider. This 1.5-metre-long submersible will continue monitoring the ocean around the iceberg for months after we leave. We can barely see the iceberg through the fog, and hope that our third day affords us better views.

The ship circles around the iceberg overnight, and this time we approach it from the north as the weather clears, only to find that the many fragments of ice, large and small, that have broken off the iceberg impede our passage.

In the end, we deploy our second glider near A-68P, the newest named iceberg, which is "only" 100 square kilometres big. It will make its way to A-68A, through iceberg-infested waters unsafe for the ship to navigate.

As we start heading north to our next study area, I look back on the vast field of icebergs in the sunset. One small iceberg has a few penguins on it, and albatrosses and smaller seabirds are flying around the ship.

The oceans around Antarctica are a remarkable place to work, constantly changing. Although icebergs are a fact of life in these parts, who knows what we will find when we return. ▮



NASA EARTH OBSERVATORY/LAUREN DAUPHIN

Satellite imagery from 12 February shows the position of some of the iceberg pieces

Animal behaviour

Knifefish use electric fields to develop complex social hierarchy

Jake Buehler

THE rivers of the tropical Americas hum and crackle with electric fields generated by knifefish. The fish use electric discharges to search their murky surroundings for food and to communicate with mates. But new research suggests these electric signals may also be used to develop and maintain a sophisticated social order.

In 2016, Till Raab at the University of Tübingen in Germany and his colleagues went to study brown ghost knifefish (*Apteronotus leptorhynchus*) in their natural habitat in Colombia. They were surprised to find 30 fish communicating electrically in just a 9-square-metre area.

The researchers knew "there must be some kind of hierarchy to avoid constant, repetitive fighting", says Raab, so they brought some of the knifefish back to the lab.

They paired 21 of the fish in 37 different combinations in tanks each containing a shelter made of PVC pipe. The fish competed for access to the shelters, and the researchers recorded behaviours using infrared cameras and monitored electric discharges using electrodes in the tank.

The team found that fish denied access to a shelter by a competitor would commonly target the other fish with electric "rises": gradual increases in discharge frequency followed by a rapid fall to normal. Initially, Raab thought these might be submissive gestures, but what he found "was way more complex".

They seemed to be provocations, triggering the dominant fish to chase and bite the subordinate agitator. While this didn't allow the loser to supplant the dominant position of the other fish, it appeared to provide a slight increase in social status – one that seemed to boost the chances of success in future conflict (bioRxiv, doi.org/fv58).

For instance, Raab recounts one pairing where a subordinate male repeatedly made rises against a dominant female and she eventually granted access to her tube shelter.

In that way, the rises may allow knifefish to improve their standing while recognising and respecting the social hierarchy, which suggests the fish are capable of surprisingly complex social manoeuvring, says Raab.

Such a system might keep violence to a minimum, allowing competitors to come to a mutual understanding. "They don't have to fight too much, but everyone gets a little bit of what they want," says Raab.

A juvenile brown ghost knifefish (*Apteronotus leptorhynchus*)

PROF. DR. RÜDIGER KRAHE

"The fact that rises occur before attacks and not in response to them is intriguing to me," says Rossana Perrone, a neuroethologist at the Clemente Estable Biological Research Institute in Uruguay, adding that other electric fish make submissive signals following conflicts.

Perrone cautions that since each knifefish took part in multiple pairings during the experiments, winner and loser effects – where a win or loss makes a repeat outcome more likely in the next contest – might influence some results.

Next, Raab wants to see how these electrically charged encounters alter relationships across an entire group of knifefish. It is possible that a knifefish can estimate its chances of winning a competition by watching other fish, he thinks.

Raab says he and his colleagues are only just beginning to get to grips with the social convolutions of knifefish. The fish also have an entirely different set of electric "chirps", with which they communicate. ▮

Palaeontology

First million-year-old DNA comes from Siberian mammoths

FOR the first time, preserved DNA has been recovered from animal remains that are over a million years old. The DNA belonged to two mammoths that lived around 1.2 million years ago – and it paints a complicated evolutionary picture.

Patrícia Pečnerová, now at the University of Copenhagen in Denmark, and her colleagues extracted DNA from three mammoth teeth discovered in north-east Siberia. Two of the teeth, from Krestovka and Adycha, are respectively 1.1-1.2 and 1-1.2 million years old. The third, from Chukochya, is between 500,000 and 800,000 years old.

The team found that the Adycha and Chukochya teeth both looked like they belonged to animals ancestral to the famous woolly mammoth (*Mammuthus primigenius*), a species that survived until 4000 years ago.

But the Krestovka tooth was a surprise. Despite being about the same age as the Adycha one, its DNA was quite different. The mammoth it belonged to was a member of a separate Eurasian lineage that branched off from the other Eurasian mammoths at least 1.78-2.66 million years ago.

Team member Love Dalén at the Centre for Palaeogenetics in Stockholm, Sweden, believes that the Krestovka mammoths then colonised North America, crossing a land bridge to what is now Alaska perhaps 1.5 million years ago.

"Two teeth looked like they belonged to ancestors of the woolly mammoth, but the third was a surprise"

Later, sometime about 500,000 years ago, "a small band of woolly mammoths [also] crossed the Bering land bridge and entered North America", says Dalén.

These woolly mammoths then hybridised with the Krestovka-like mammoths already living in North America to give rise to a new species, the Columbian mammoth (*Mammuthus columbi*).

The DNA of this species had previously been sequenced and it appears to be a 50:50 mix of "Krestovka" and woolly mammoths (*Nature*, doi.org/fv67). ▮

Michael Marshall

DESIGNPICSINC/ALAMY

Climate change

Frogs may struggle to make the leap to a warmer world

WHEN some frogs lose too much water they also lose their ability to jump – evidence of the problems they could face with climate change.

Dan Greenberg at Simon Fraser University in Burnaby, Canada, and colleague Wendy Palen looked at three species: the coastal tailed frog (*Ascaphus truei*), the great basin spadefoot toad (*Spea intermontana*) and the Pacific tree frog (*Pseudacris regilla*), pictured.

The researchers measured the jumping distances after placing the animals in chambers to control body temperature and dehydration.

The more dehydrated the animals were, the shorter the distance they could jump. Once dehydration had led the frogs to lose 30 per cent of their body weight – 45 per cent for the toad – they wouldn't jump at all.

The researchers also found that a combination of dehydration and higher temperatures, ranging from 15 to 30°C depending on species, led to even shorter jumps. Jumping ability returned after being placed back in water (*Proceedings of the Royal Society B*, doi.org/fwb4).

The pair think they may know why dehydration has this effect. It disrupts ion exchange in cells as well as nutrient supply and removal of waste in the muscles, affecting function, says Greenberg. It can also make the blood more viscous, challenging the heart's pumping efficiency, and making physical movement more difficult.

The work highlights the need to consider water loss, in addition to increased heat, when estimating the impact of global warming on frogs and other animals, says Greenberg. **Christa Lesté-Lasserre**

Animal behaviour

Spider is a master of many webs

AN ISLAND spider decides which of its three kinds of webs to make depending on location.

Spiders usually make only one kind of web, but the *Wendilgarda galapagensis* species – found only on Cocos Island, off the western coast of Central America – can make three different webs.

High above ground it makes "aerial" webs attached to nearby stems and leaves. Nearer to the ground it makes "land" webs with long horizontal strands secured to branches and with vertical strands anchored to the ground. Finally, over pools it makes "water" webs that are a bit like the land webs, but with the vertical strands attached to the water surface itself.

Darko Cotoras at the California Academy of Sciences in San Francisco wondered whether this flexibility indicates the spider is undergoing speciation, splitting into three species, each with unique behaviours and exploiting a different food source. So with his colleagues he ran genomic analyses on 142 of the spiders.

To their surprise, the results revealed that all belonged to the same species. This means they haven't genetically diversified since arriving on the volcanic island up to 2 million years ago.

The researchers then marked the 2-millimetre-long spiders and moved them to different locations on the island to track their behaviour. For example, they took water-web-making spiders away from water sources and placed them in high bushes nearby. Again, the researchers were surprised to see that the spiders often built a new web with the architecture suited to the new location (*Proceedings of the Royal Society B*, doi.org/fwcf).

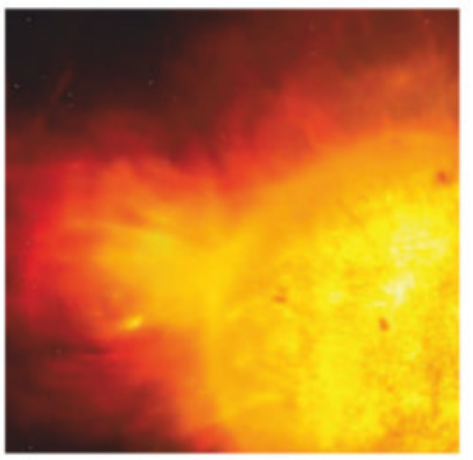
Such flexibility probably helps these animals thrive on a small, isolated island, says Cotoras. **CL-L**

Solar system

Unwrapping secrets of the sun's layers

A SMALL rocket that launched from the New Mexico desert in 2019 is helping us understand the layers of the sun. Mapping the magnetic fields that control those layers may allow us to predict solar flares that can harm satellites and other technology on Earth.

What we think of as the surface of the sun is a layer called the photosphere. The layer above the photosphere, the chromosphere, is transparent to the naked eye, which has made it hard to study.



SCIENCE PHOTO LIBRARY/ALAMY

David McKenzie at NASA's Marshall Space Flight Center in Alabama and his team used a sounding rocket, called the Chromospheric Layer Spectropolarimeter-2 (CLASP-2), to measure the magnetic fields in the chromosphere in detail for the first time. This is important because those magnetic fields are intimately tied to solar flares, which are currently impossible to predict, and the transfer of heat and energy in the sun.

The researchers found that the boundary between the layers of the sun is less smooth than we thought, with the magnetic field strength varying widely along the border (*Science Advances*, doi.org/fwpz).

Understanding these structures could also help us figure out why the outermost part of the sun's atmosphere, the corona, is hundreds of times hotter than the sun's surface. **Leah Crane**

Really brief

GRANGER WOOTZ/GETTY IMAGES

‘Nudges’ can lead to healthier shopping

In a small trial in the UK, 28 per cent of online food shoppers were willing to buy a healthier version of a product when presented with the choice. Accepted swaps reduced calorie content in the average shopping basket by around 30 kcals, showing the power of “nudging” (*PLoS One*, doi.org/fwb3).

Dogs playing fetch may be body aware

Dogs seem to be conscious of their bodies. When asked to retrieve a toy that was attached to a mat on which they were sitting, eight out of 10 dogs stepped off the mat – recognising their bodies were in the way. Just half of dogs left the mat if the toy was attached to the floor instead (*Scientific Reports*, doi.org/fwp2).

Our activity harms life in many rivers

Fish biodiversity in some 53 per cent of river basins around the world has been severely affected by human activity, with Europe and North America worst hit. As well as overfishing, dams are a problem because they block migrating fish (*Science*, doi.org/gh4jbr).

Psychology

Shaping someone’s dream as it happens

TALKING to people while they are asleep can influence their dreams, and in some cases the dreamer can respond without waking up.

Ken Paller at Northwestern University in Illinois and his team found that people could answer questions and even solve maths problems while lucid dreaming – a state in which the dreamer is aware of being in a dream and is sometimes able to control it.

The researchers asked dreamers yes-no questions relating to their backgrounds and experiences, along with some simple maths problems. The dreamers weren’t aware of the questions they would be asked before they went to sleep.

They answered the questions correctly 29 times, incorrectly five times and ambiguously 28 times, by twitching their face muscles or moving their eyes. They didn’t respond on 96 occasions.

After waking, some dreamers reported hearing the questions as if from outside the dream, while others perceived them as being part of the dream. One participant who was dreaming about being in a car heard maths problems coming from the radio (*Current Biology*, doi.org/fwck).

“One thing that this method puts forward is that while the dream is happening, we can affect the content,” says Mark Blagrove at Swansea University, UK. In the future, Paller hopes that this could help improve sleep in people with conditions like anxiety. “If you’re facing something that makes you anxious, you might want to try it out in a lucid dream and therefore overcome the anxiety that you’re feeling,” he says. **Krista Charles**

Public health

TOM MUELLER/IMAGEBROKER/SHUTTERSTOCK

Soil deals with massive amount of human waste

NATURE sanitises around 38 million tonnes of human waste a year – the equivalent of around £3.2 billion of commercial water treatment.

Alison Parker at Cranfield University in the UK and her team looked at 48 cities in Africa, Asia, North America and South America. They analysed how much human waste is produced and where it ends up by reviewing existing data.

They looked at waste systems not connected to sewers. This included pit latrines (pictured) and septic tanks, in which waste is primarily contained on-site below ground.

Liquid waste from pit latrines and excess water from septic tanks can gradually filter through soil. In areas where groundwater isn’t too shallow, this can remove the waste. With 892 million people, mainly in low and middle-income countries, using this type of waste system, the team estimates that nature safely treats around 38 million tonnes of human waste per year (*Cell Press: One Earth*, doi.org/fwpv).

More than 4 billion people don’t have access to safe sanitation, a third of them in low-income nations. Unsafe sanitation is responsible for 775,000 deaths a year. “Sanitation that involves the ground naturally treating waste can be part of the solution,” says Parker. Priti Parikh

Bionics

Robo muscles that are more like ours

OUR muscles get stronger when put under stress and now robots could do the same, thanks to a soft gel that becomes harder when exposed to vibration.

Zhao Wang at the University of Chicago and his team created the gel by embedding zinc oxide nanoparticles into a cellulose mixture. They then vibrated the material and found that the nanoparticles emitted an electrical charge that created new links within the gel, toughening it.

The team found the strength of the gel increased as it was shaken. The strengthened gel maintained its shape when squashed with a press, but the untreated material was deformed permanently, demonstrating that the gel had become up to 66 times stiffer from the vibrations (*Nature Materials*, DOI: 10.1038/s41563-021-00932-5).

The team now aims to make the process reversible by trying to create bonds in the gel that will decay over time. The material could then have a range of applications such as artificial robotic muscle that adapts to tasks and becomes stronger at performing repetitive motions, but could also lose strength and gain flexibility to better suit a new task, says Wang. **Matthew Sparkes**

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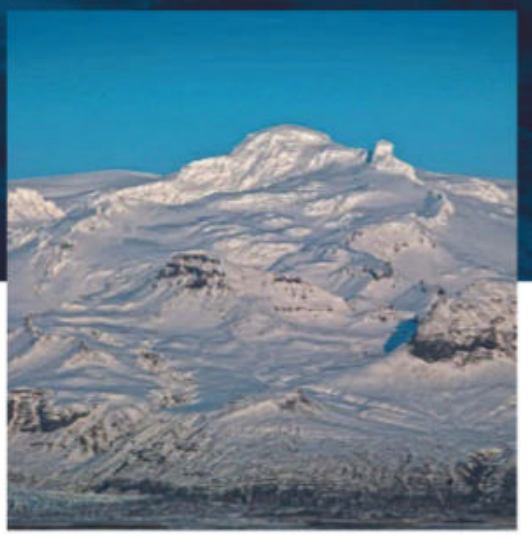
Land of fire and ice: Iceland



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Highlights

- Join talks and walking seminars from Oliver Shorttle.
- Tour Þingvellir National Park, the site of Iceland's first parliament, founded in 930, and a geological wonder where the American and Eurasian tectonic plates are pulling apart.
- Visit Iceland's Geysir geothermal area, where you'll see the Strokkur geyser shoot water 30 metres into the air. Be spellbound by the immense beauty and sheer power of the Gullfoss Waterfall.
- Super jeep drivers will take you to the elegant Seljalandsfoss waterfall, which is unique in its kind, as you can walk behind the plummeting falling stream without getting (too) wet, for a unique viewing angle.
- Cross the deep and roaring rivers that guard the wooded surroundings of Thórsmörk, where you will have time to hike around the area and admire some of the many viewpoints it offers.
- A trip to the eerily beautiful Skógafoss waterfall, one of the biggest waterfalls in Iceland. 25 metres wide with a 60-metre drop. You will feel the immense power of the waterfall close-up, as you climb a long windy set of stairs to a truly stunning viewpoint.
- Visit the famous Jokulsarlon Glacier Lagoon, a stunning sea of floating icebergs. Weather permitting, there will be an opportunity to step outside and witness the natural wonders of the Northern Lights.
- Walk on Europe's biggest ice cap – Vatnajokull, which has around 30 glaciers flowing out from it.
- Enjoy lunch in the black sand seaside town of Vik. The sea on one side and high cliffs on the other, dramatically positions this quaint little village as Iceland's most southerly mainland settlement.
- Visit the Lava Centre, an interactive, high-tech educational exhibition depicting volcanic activity, earthquakes, and the creation of Iceland over millions of years.
- Relax in the warm thermal waters of natural hot springs in the village of Fludir.

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Views

Comment

Mental slander

We too often turn to insulting people's brain power – and that closes off our ability to understand others, argues **Melanie Challenger**

BELITTLING the minds of others is commonplace. Stupid! Brainless! Imbecile! Dozy! Just scroll through the comments on pretty much any contentious article and you will find criticism by mental slander. Social media is littered with words like "unthinking" and "idiot", especially when people are confronted with views with which they disagree.

Indeed, Twitter is a lightning rod of prejudices about minds. Former US president Donald Trump was perhaps the kingpin here, before Twitter banned him. Not only did he routinely boast of his own mental prowess – "sorry losers and haters, but my I.Q. is one of the highest" – but he persistently used mental slurs to silence critics: "dummy!".

Yet we can all be guilty of mental slander. Right-wing supporters frequently call those on the left "libtards". Meanwhile, according to the Oxford English Dictionary's New Monitor Corpus, conservative voters in the US are often derided as "nutjobs". Mental slurs are a fast and simple trick to silence an unwanted voice and to lower trust in evidence we resist.

A growing body of research is allowing us to understand where this prejudice comes from.

Humans are group-living animals. Probing and judging other minds is a part of how we coordinate with each other, cooperate and make and break alliances. By the age of 5, children make assumptions about people's mental states, such as understanding that someone can be mistaken in their beliefs. Particular parts of the brain are implicated: the medial prefrontal cortex, the temporal poles and the posterior superior temporal sulcus. These work in concert to enable us to detect and make judgements about minds – both our own and those of others.

All this doesn't stop at the neck. When we bond in a group – whether that is with kin or co-workers, friends or football fans – our bodies produce hormones like oxytocin that play a role in bringing us together. But, as psychologist Carsten De Dreu points out, these hormones don't just unite us; they encourage exclusivity. This – directly or indirectly – can alter our views on other minds. In effect, we believe those in our group more readily, often exaggerating the mental abilities of those with whom we feel allegiance.

What follows from this is that we can undervalue the intelligence of those whose views differ from our own. Even more troubling, we can find ourselves responding more slowly to signals of emotion or experience from outsiders. Social psychologists Susan Fiske and Lasana Harris have used neurological imaging and behaviour studies to show that we shut down the medial prefrontal cortex, which is involved in social cognition, when confronted with minds we wish to ignore. When we suspend parts of our brain key to recognising another's mental and emotional states, we not only close our minds to one another, we cease to care.

All this has real-world consequences for whom we listen to and whose voices we trust. In an age of political polarisation and misinformation, the echo chambers created by social media do more than just seal us off from diverse possibilities and points of view; they muffle our ability to care about those whose views we might not like.

What can we do about it? First, we need to recognise the biases that prevent us from keeping one another in mind. We must make it less socially acceptable to use mental slander in the service of an argument. Beyond this, we would benefit from greater opportunities to hear one another out.

This pandemic is a reminder that we have very few mechanisms for listening and deliberating together. That needs to change. But a more radical option lies in a much larger paradigm shift. Is it time for our species to stop using the idea of own superior cognition as validation? ▮

Melanie Challenger is the author of *How to Be Animal: A new history of what it means to be human*

MICHELLE D'URBANO; HEADSHOT: ALICE LITTLE

#FactsMatter

The truth about MSG

Monosodium glutamate is eaten without problems in many countries, yet in the West there is a strange cultural aversion to it. **James Wong** investigates what's going on

James Wong is a botanist and science writer, with a particular interest in food crops, conservation and the environment. Trained at the Royal Botanic Gardens, Kew, he shares his tiny London flat with more than 500 houseplants. You can follow him on Twitter and Instagram @botanygeek

James's week

What I'm reading
The largest pile of seed catalogues in the universe.

What I'm watching
I know I am late to the party, but Schitt's Creek *is my essential antidote to troubled times.*

What I'm working on
I have just released an online houseplant course, which is, to be honest, a flimsy justification for living with 500 houseplants.

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

DURING my master's degree, I lived high up in the mountains of rural Ecuador, studying the practices of traditional Andean medicine. I was fascinated by beliefs of culturally specific syndromes, like *susto*, thought to be caused by spiritual attack, resulting in insomnia, depression and anorexia, or *mal de ojo*, in which a stare from another person can cause severe fever, diarrhoea and even death in children.

What always stood out when I asked about the basis of these ideas was that the explanations seemed far-fetched to me but common sense to them. That is the thing about culture: to the people enveloped in it, even beliefs that defy explanation can seem like unquestionable reality. Ours is, unsurprisingly, no exception. To illustrate this, let's look at the evidence supporting what is arguably one of the West's culturally specific syndromes: "Chinese restaurant syndrome".

Coined in the US in the 1960s, it describes a constellation of symptoms such as numbness, palpitations and nausea that are thought to occur after consuming the food additive monosodium glutamate (MSG), often associated with East Asian restaurants. This belief is so pervasive that it has been propagated in bestselling books, espoused on blogs and has even led many restaurants to advertise food as "MSG free" to avoid a backlash. So what could be behind this worrying reaction?

Well, as I found when talking to Andean communities, the exact explanation for beliefs can vary dramatically depending on who you ask. Some cite the fact that MSG doesn't exist in nature, others its synthetic means of production, or even its "unpronounceable" scientific name. Still others cite the fact that scientific trials clearly prove its toxicity. However, perhaps surprisingly, when we look at the evidence, none of these "facts" is really a fact.

While it is true to say that since as early as 1969 studies have reported startling symptoms such as stunted skeletal development, marked obesity and female sterility associated with MSG, it is crucial to consider the design of these studies. You might be forgiven for thinking that scientists set up a clinical trial, in which they fed unfortunate volunteers MSG-laced food and witnessed the terrible effects. This wasn't the case. These studies actually involved doing things like injecting enormous doses of the compound into newborn lab mice. Many harmless compounds found in all sorts of foods, including key nutrients, would probably show similarly undesirable outcomes in a similar set up.

"This belief is so pervasive it has even led many restaurants to advertise their food as 'MSG free'"

If you take such poor-quality studies out of the equation, and focus on human clinical trials, you are presented with a different picture. One of the earliest was carried out in the 1990s, on a small group of people who self-identified as experiencing MSG sensitivity. They were fed randomly assigned meals with varying levels of MSG, including a placebo, and then asked about their reactions. Around 36 per cent of them did indeed report these effects after a meal containing a threshold of about 2.5 grams of MSG. However, around 30 per cent of them had no reaction to any meal, including placebo. A difference of 30 per cent to 36 per cent can still be statistically significant with enough participants, but in this study we are only comparing 18 people with 22.

How much MSG is there in a typical serving of food containing the compound? According to the US Food and Drug Administration, 0.5 grams, meaning that to get the results in the study, you would have to eat five times the average serving in one go. Even in countries like Japan, where daily consumption of MSG is among the highest on the planet, the amount eaten daily has been estimated at between 1.2 and 1.7 grams. I am game for the experiment of eating two days' worth of Japanese food in one meal, but even for me that might be hard to achieve.

What of concerns about the "synthetic" nature of this food additive? Well, in actuality, MSG is naturally found in all sorts of foods eaten in the West, like cheese and tomatoes. In fact, the glutamic acid, the alleged problematic component, is even produced by our own bodies.

The MSG in food additives is made by fermenting plant extracts like tapioca or sugar-cane molasses using naturally occurring bacteria, which makes calling it "synthetic" a stretch.

So does Chinese restaurant syndrome count as a culturally bound syndrome? Well, although the scientific consensus is pretty resounding, it is also fair to say that the studies to date are few in number and, in some instances, contradictory. Indeed, many food intolerances once dismissed on the basis of poor evidence are now being taken more seriously. So I, for one, can't wait to learn what new evidence turns up. ▮

Editor's pick

One reason why advanced life may be extremely rare

13 February, p 46

From Eric Wynter, North Curry, Somerset, UK

While discussing possible alien explanations for the insterstellar object 'Oumuamua, astrophysicist Avi Loeb agrees that there is greater resistance to considering the existence of advanced life in the universe, as opposed to primitive life, though he thinks it is a "psychological barrier". Surely it is a real barrier: one between chemistry and physics.

Beyond primitive life, complexity demands information; information demands power. The "mitochondrial event" on Earth – the symbiosis between two cells that led to much greater complexity – happened long after primitive life began. Each blossoming of life must cross this barrier to have a hope of sentience. With no mitochondria or similar, there can be no Dyson spheres.

This seems to be a more significant event than the emergence of life itself, and a barrier that is yet to be evaluated in the search for intelligent life elsewhere.

Native plants may be the enemy of climate efforts

30 January, p 24

From Allen Reynolds, Auckland, New Zealand

James Wong is correct when he asks: "What's so great about native [plants] anyway?" Here in New Zealand, there is a strong bias toward native species.

What is sad is that this emphasis could harm carbon capture efforts, which are trumpeted by politicians at all levels. Our native trees are very long-lived, lasting many hundreds of years, and grow very slowly when they are seedlings – exactly the opposite of what is needed for rapid carbon dioxide removal. There are much better alternatives, but they aren't native species. More science and less politics are required on this issue.

Perhaps this virus variant isn't such a disaster

13 February, p 7

From Alan Bundy, Edinburgh, UK

What are we to make of the small study in South Africa that found the Oxford/AstraZeneca covid-19 vaccine doesn't prevent mild or moderate illness from the B.1.351 variant found there? The South African health minister's decision, on 7 February, to put the vaccine's roll-out in the country on hold seems to be based on the assumption that it isn't very effective for this variant.

It seems unlikely, however, that the vaccine would only prevent severe infection. A more likely explanation is that it reduces the severity of nearly all cases, so that people who might otherwise have had a severe illness only get a moderate one and that people who might otherwise have had a moderate illness get a mild one. If so, then the sooner the vaccine is rolled out there, the better.

Herd immunity level may be location-specific

23 January, p 12

From William Hughes-Games, Waipara, New Zealand

It doesn't make sense to try to put a percentage figure on the achievement of herd immunity to covid-19. Going to the extreme for illustration, in a sparsely populated country where you rarely interact with other people, your chance of getting covid-19 is slim, even if the incidence is somehow high.

On the other hand, in a country where you are shoehorned together on trains and in markets, you are more likely to catch the virus if even a small percentage of the population is infectious. We need some measure of how often you are likely to breathe in the air expelled by a fellow citizen multiplied by the incidence of the virus in the population.

Let's equip the world to produce vaccines

6 February, p 21

From John Sharvill, Deal, Kent, UK

Rather than the industrialised West supplying vaccines to low-income countries, we should spend some money helping them build the facilities to self-supply, which would produce long-lasting economic and employment benefits at the same time.

If you can't hug a person, try hugging a tree instead

13 February, p 8

From Allan Smith, London, UK

The article "How to give your vaccine a boost" mentions hugging, which is tricky right now. It seems likely that hugging a tree would have similar benefits.

Green hydrogen push could save us trillions

6 February, p 44

From Lyn Williams, Neath, West Glamorgan, UK

Your look at the pros and cons of using hydrogen as a fuel was great, but it failed to delve into the positive impact on the UK's balance of payments. Investing billions into truly clean hydrogen could save trillions by reducing imports of oil and gas.

Free public transport: Let me tell you about subsidies

Letters, 13 February

From Emma Montgomery Parkinson, Bath, UK

Roger Elwell writes that, as a non-city dweller, he would be unhappy to see his taxes pay for free travel in the likes of London. He appears to be perfectly happy, however, to take advantage of cost-inefficient rural highways and services, all – inevitably – subsidised by those who live and pay taxes in high-density urban centres. If the UK is to work for all of us, sometimes it is necessary to think a little further than your own doorstep.

Please don't rely on an AI to raise Rover

23 January, p 17

From Patrick Laughlin, Placitas, New Mexico, US

Artificial intelligence may be great for specific tasks, but teaching your dog to sit isn't one of them. Dogs, like humans, undergo brain maturation at specific time periods during development. If this doesn't happen, they won't be emotionally well-adjusted.

If you don't have a bit of spare time each day to train your dog with some treats, you shouldn't be allowed to own one.

A tasty solution to the Australian carp issue

13 February, p 20

From Peter Hopkins, Boscastle, Cornwall, UK

The problem of carp in Australian rivers has one simple solution: eat them. Baked carp is an excellent dish. Your correspondent Sam Wong could provide a recipe.

Considered alongside the article on the fishing industry in the same issue (p 36), it seems cavalier to throw away a source of maybe 40,000 tonnes of fish per year whose production would produce no extra carbon dioxide.

For the record

We should have credited the middle image in the Don't Miss column to Zoonar GmbH/Alamy (6 February, p 31).

COVI-VAC, Codagenix's vaccine against covid-19, is administered as nose drops (13 February, p 14).

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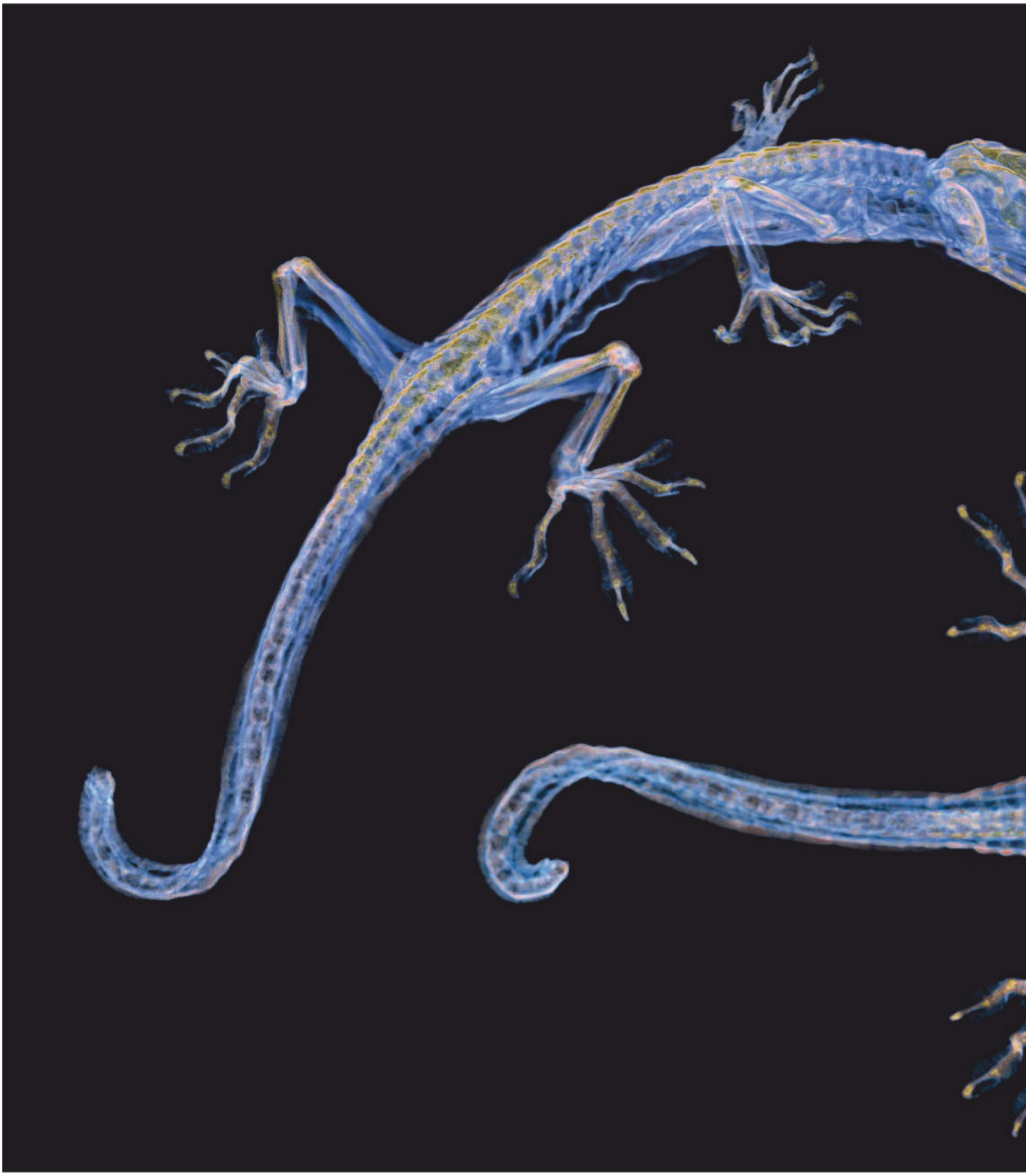
“2021 must be the year to reconcile humanity with nature”

António Guterres,
United Nations Secretary General, Paris, December 2020



Inside story

Image **Gary Ruben, Florian Schaff, Marcus Kitchen, Steve Morton. School of Physics & Astronomy, Monash University, Melbourne, Australia**

INTRICATELY preserved with its internal make-up laid bare, this composite image of a mummified Schlegel's Japanese gecko (*Gekko japonicus*) shows the power of the high-energy X-rays emitted by a special type of particle accelerator.

Gary Ruben, Florian Schaff, Marcus Kitchen and Steve Morton at Monash University in Melbourne, Australia, captured the image with a synchrotron, which accelerates electrons to close to the speed of light so that they emit high-energy X-rays. The main difference between a synchrotron's X-rays and those from a hospital X-ray machine is brilliance: a synchrotron can produce X-rays that are 100 billion times brighter.

Synchrotron beams can also be produced at a specified wavelength, letting them reveal more about specimens by distinguishing between very subtle changes in density. This makes synchrotrons a promising candidate for obtaining better medical images of humans in the future.

"The gecko was an interesting specimen to show the fine detail we can achieve," says Morton. The particularly high-intensity beams of radiation from a synchrotron increase the image's contrast and reduce exposure times, he says, helping with the clarity and visibility of the image.

The team could even get a 3D shot of the gecko by capturing it from thousands of different angles in the synchrotron's X-ray beam before combining the views and using a computer to remove image artefacts and to distinguish between materials, such as tissues, for example.

Gege Li

Effects of a time-warping drug

Starring Anthony Mackie and Jamie Dornan, *Synchronic* is a thrilling film about a strange drug that sends you back in time, says **Bethan Ackerley**

Film

Synchronic

Justin Benson, Aaron Moorhead

Now available to rent online

SIGNATURE ENTERTAINMENT

Jamie Dornan (left) and Anthony Mackie play paramedics

WHEN they aren't busy being the darlings of indie horror cinema, film-makers Justin Benson and Aaron Moorhead are, by their own admission, armchair enthusiasts of astrophysics, philosophy and futurism. That heady cocktail of interests has influenced all their films to date, but perhaps none more so than their latest and most ambitious creation: *Synchronic*.

The film stars Anthony Mackie and Jamie Dornan as paramedics and friends Steve and Dennis, who are called out to a series of unusual drug overdoses across New Orleans. Although the victims are found in very different circumstances – one has been stabbed by a centuries-old sword, while others have been burned or frozen to death – they have all taken Synchronic, a designer drug based on the hallucinogen DMT.

Aside from those grisly incidents, the first third of *Synchronic* is a slow-burning drama about the quiet miseries that Steve and Dennis are mired in. Steve is a disaffected womaniser who has recently been diagnosed with a brain tumour, while Dennis's marriage is strained by a new baby and his daughter Brianna's teenage angst. Thankfully, these personal troubles are just a vehicle for a much more intriguing concept.

When Brianna (played by Ally Ioannides) vanishes after taking Synchronic at a frat party, Steve starts to buy up the remaining supplies. He eventually meets the drug's creator, Dr Kermani (Ramiz Monsef), who matter-of-factly reveals that Synchronic manipulates your pineal gland, the same region of the brain as Steve's brain tumour. It is reminiscent of the resonating device in H. P. Lovecraft's short story *From Beyond*, which lets the user see alternative planes of existence. However, instead of seeing monsters from another dimension, Synchronic changes how you experience the flow of time.

"Time works like a vinyl record: you play one track, but the other grooves are always there"

Kermani explains that time isn't linear, instead working like a vinyl record: you play one track, but the other grooves are always there. "Synchronic is the needle," he says, letting people travel to the past while physically remaining in the present. The catch is that you have no control over where you end up, and if you manifest in the middle of a forest fire or in the path of a rampaging bull, you will still die in the present.

As soon as Steve starts experimenting with Synchronic in an attempt to find Brianna, the film's real potential emerges. He approaches the task methodically, rationing out his limited supply to establish the rules of the drug. I won't reveal much about which time periods Steve travels to, but his encounters are surreal and upsetting in equal measure. The past is a particularly dangerous place for a Black man, and the film is at its best when it explores how time travel is disproportionately terrifying for Steve.

While there are a few holes in the plot – why does the drug never take people to the future, for instance – the potential of *Synchronic*'s central conceit is obvious. Unfortunately, while the film-makers are no strangers to small budgets, their ambitions were clearly hamstrung by a lack of funds.

The environments in the past are severely limited, with a few brief glimpses of deserts and snowstorms being about as adventurous as the film-makers can afford. Although they make up for that with some clever tableaux and eerie, roving camerawork, you still sense that *Synchronic* would have benefited immeasurably from having twice as much cash, and twice as much time spent mining the horrors of history.

All that said, Benson and Moorhead have still created a grim, uneasy thriller with truly hair-raising moments. For all that I mourn the unfulfilled potential of the concept, *Synchronic* is yet more evidence that these film-makers should be given the tools with which they can fully realise their mind-bending ideas. ▮

Cloning makes perfect

A darkly funny sci-fi story explores how an "improved" version of yourself affects your relationships, says **Robyn Chowdhury**

Book

The Echo Wife
Sarah Gailey
Hodder & Stoughton

LOVE, death and human cloning have never been brought together so well as they are in *The Echo Wife*, a fast-paced thriller that is as funny as it is thought-provoking.

The book is set in a reality where human adults can be grown in a lab and then manipulated to think and act in a certain way. In their debut science-fiction novel, Hugo award-winning author Sarah Gailey takes us on a journey unlike those in their fantasy and alternative historical fiction, but one that retains its intensity and intrigue.

The complexity of the characters adds to the sense of unease throughout the novel, leaving the reader questioning who to trust. The story centres on Evelyn Caldwell, a developmental biologist whose cutting edge research into adult cloning comes at a cost. She finds that her husband (also a scientist) is having an affair – with her clone, Martine. And when Martine leaves an urgent message asking to meet, things take an unexpected turn.

The book is full of such twists as the lives of Evelyn and Martine become deeply intertwined. We see glimpses into the failing relationship between Evelyn and her husband, and snapshots of his more ideal life with Martine.

From the start, Gailey adds emotional depth, forcing us to ask ourselves how we would feel if a loved one opted for a version of us they had designed to be "perfect". Details of Evelyn's childhood add extra layers to a character already struggling with thoughts of being unloved, unappreciated and literally replaceable.

The science and technology in the book isn't too far-fetched – it is possible to create cloned embryos from adult human cells – but in reality it is harder and takes far longer. Instead of using an embryo and surrogate, as with Dolly the sheep, Evelyn works with large tanks holding the nutrients needed for a growing clone. The embryology of cloning is slightly glossed over, but Gailey adds enough detail about Evelyn's work to make the science seem believable.

One of the most interesting aspects of cloning, both in the book and in the real world, is the ethics behind the technology. Martine reminds us that there is a risk of it being misused.

Novel neural programming that can affect personality has also been developed in the world in which the novel is set, which accounts for the main distinction between the two women: Martine is more obedient and passive than Evelyn. She also has different wants and needs. She is Evelyn – but a little altered. In a *Blade Runner*-esque style, Gailey asks us to consider whether clones are just as human as us by showing Martine growing, learning and questioning her own existence.

Clearly, the idea of programming a brain to think a certain way is a stretch. Although we can grow mini brains in a lab, manipulating a developing brain is unlikely to be effective, or possible, in reality. But this aspect of the story is used more as a device to expose the twisted motivations of the characters and to raise issues about the purpose of cloning.

As well as having a fascinating storyline, the book gives us realistic insights into the pressures of being a female scientist: how research has to be fought for and how women in science must have impossibly thick skin. Overall, *The Echo Wife* is an emotionally driven novel that leaves us both hopeful and afraid of the potential of cloning technology.

Robyn Chowdhury is a writer based in Sheffield, UK, who is interested in pop culture and social justice

The lives of biologist Evelyn and Martine, her more obedient clone, intertwine

GEORGE PETERS/GETTY IMAGES

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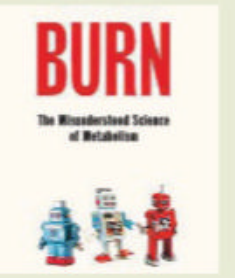

Read

Burn promises to change the way we think about food, exercise and life, as evolutionary biologist Herman Pontzer brings his 20 years of research experience to bear on the mysteries of human metabolism (read more on page 32).

Watch

The Big Freeze, the Scott Polar Research Institute's arts festival, launches online on 4 March with the European premiere of *Polar Self Portraits 2*, a creative project connecting artists and their work from six continents.

Read

Klara and the Sun is Kazuo Ishiguro's first novel since he was awarded the Nobel prize for literature in 2017. It tells the story of an artificial friend who is learning not to invest too much in the promises of humans.

MIDDLE: ZSUZSANNA ARDÓ

The film column

Of dirt and virtue

Space Sweepers is a silly but lovable space opera that punches above its weight to deliver sharp moral truths. It brilliantly conjures the stark, soul-grinding realities of life spent cleaning junk from space, says **Simon Ings**

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

NETFLIX

In *Space Sweepers*, the crew of the Victory makes an astonishing discovery

Like so much of South Korean cinema, it explores the ethical consequences of disparities of wealth – how easily poorer people can be corrupted, while the rich face no moral tests at all.

But what do all these high-minded, high-octane shenanigans have to do with space junk, like the 20,000 artificial objects with orbits around Earth that can be tracked? Or the 900,000 bits of junk between 1 and 10 centimetres long? Or the staggering 128 million pieces that are smaller still and yet could wreak all kinds of havoc, from scratching the lens of a space telescope to puncturing a space station's solar array?

Nothing, and everything. *Space Sweepers* is a space opera, not Alfonso Cuarón's *Gravity*. The director's interest in the physics of low orbit begins and ends with the mechanics of rapidly rotating bodies. And boy, do they rotate. On a surprisingly small budget, the movie ravishes the eye and overwhelms the ear as Victory hurtles through a cluttered, industrialised void, all right angles and vanishing perspectives. You can't help but think that while space may never look like this, it could easily feel like it: frenetic, crowded, unreasonable, ungiving, a meat grinder for the soul.

Similarly, while the very real problem of space junk won't be solved by marginalised refugees in clapped-out spaceships, this film has hit on some truth. Cleanliness isn't a virtue because it is too easy to fake: just dump your filth on somebody else. It is just wealth, admiring itself in the mirror. Real virtue, says this silly but very likeable film, comes with dirt on its hands. ▮

Film

Space Sweepers
Jo Sung-hee
Netflix

TAE-HO is a sweeper-up of other people's orbital junk, a mudlark in space scavenging anything of value. In Jo Sung-hee's new movie *Space Sweepers,* he is someone who is most alone in a crowd – that is to say, among his crewmates on the spaceship Victory. They are a predictable assortment: a feisty robot with detachable feet; a heavily armed yet disarmingly gamine captain; a gnarly but lovable engineer with a past.

Tae-ho is played by Song Joong-ki, who also starred in Jo's romantic smash hit *A Werewolf Boy* (2012). Song is the latest in a long line of South Korean actors whose utter commitment and lack of ego can bring the sketchiest script to life (think Choi Min-sik in revenge tragedy *Oldboy*, or Gong Yoo in zombie masterpiece *Train to Busan*).

Tae-ho has a secret. As a child soldier, culling troublemakers in orbit, he once saved the life of a little girl, adopted her, was ostracised for it, hit the skids and lost his charge in a catastrophic orbital collision. Now he wants her back, at any cost.

The near-magical mega-corp UTS can resurrect her using her DNA signature. This is the same outfit that is making Mars ready for settlement, but only for an elite 5 per cent of Earth's population. The rest are left to perish on the desertified planet. All that is needed to restore Tae-ho's ward is more money than he will ever see in his life, no matter how much junk he and his mates clear.

"You can't help but think that space could easily feel like this: frenetic, unreasonable, a meat grinder for the soul"

Then, as they tear apart a crashed shuttle, the crew discovers 7-year-old Kang Kot-nim (Park Ye-rin), a girl with a secret. She may not even be a girl at all, but a robot; a robot who may not be a robot at all, but a bomb. Selling her to the highest bidder will get Tae-ho's daughter back, but at what moral cost?

South Korea's first space-set blockbuster is, in one aspect at least, a very traditional film.

Simon also recommends...

Films

Valerian and the City of a Thousand Planets
Luc Besson
Dane DeHaan and Cara Delevingne pout their way across the stars in Luc Besson's sumptuously overdesigned and much-hated space opera. Had the reviewers never heard of camp?

Aelita: Queen of Mars
Yakov Protazanov
From her observatory, a Martian royal (Yuliya Solntseva, later the first female winner of the Best Director Award at Cannes) peers down at Russia in revolution and falls in love.

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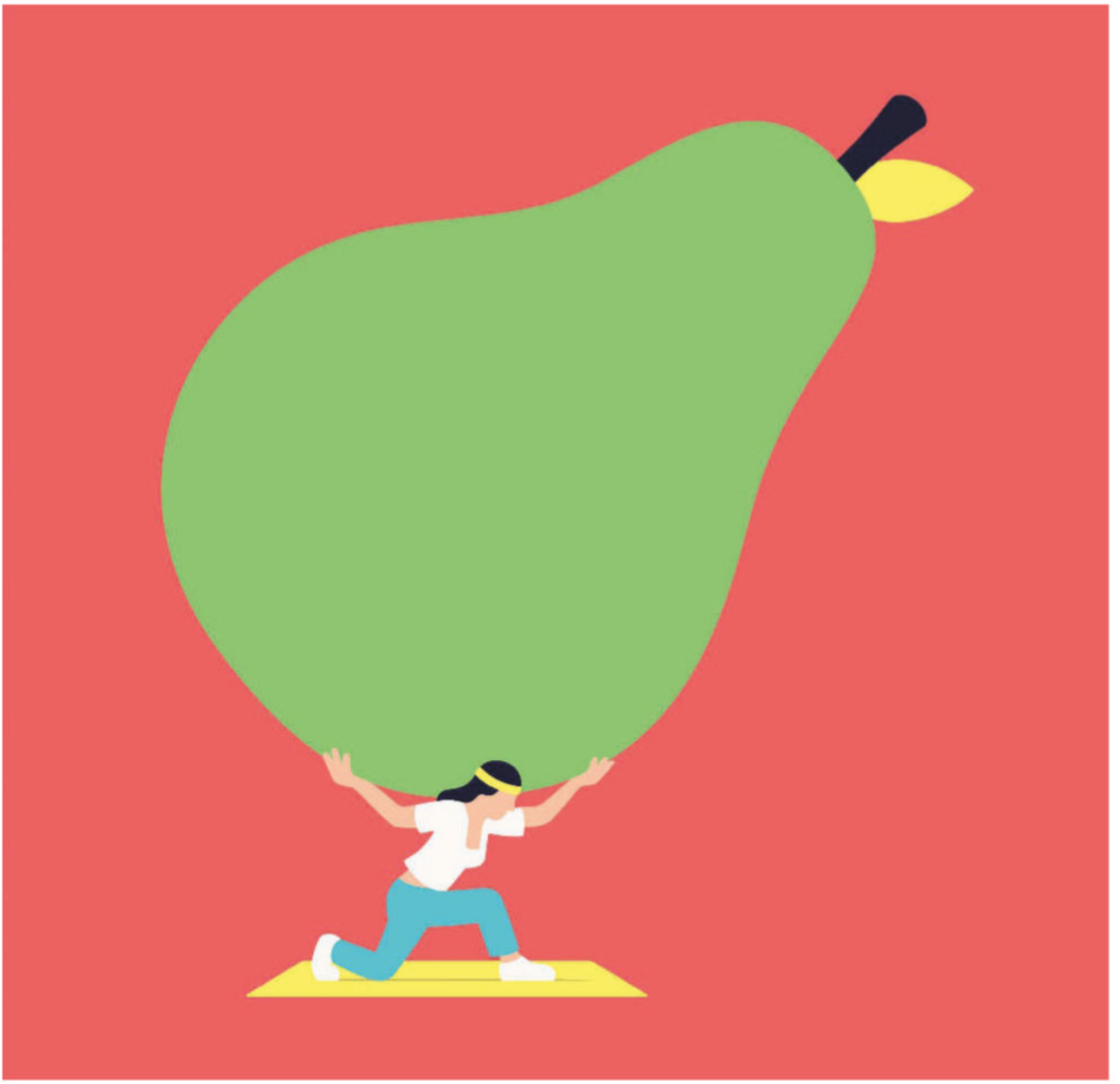
Metabolism myths

To discover the truth about diet and exercise, we need to look at our evolutionary past, says anthropologist **Herman Pontzer**



FRANCESCO CICCOLELLA

THE universe of good reasons for putting a live guinea pig in an insulated metal pot is small. I can think of only one: in France, in the winter of 1782, the chemist Antoine Lavoisier and his polymath friend Pierre-Simon Laplace placed their unwitting subject into a double-walled metal chamber, the world's first calorimeter, and sealed the lid. They had packed snow into the space between the walls, and by comparing the rate at which the guinea pig's body heat melted the snow to the rate of carbon dioxide it exhaled, they discovered metabolism – the "fire of life" that drives our very existence. At last, science had a physical measure of the life force that enables us to grow, reproduce and move. Physiologists like myself have been counting calories ever since.

Today, a widespread obsession with fitness and body weight has led to a new era of calorie counting. Diet books and magazine workouts promise a kind of shiny metabolic nirvana of calories burned, villainous foods avoided, waistlines melted and health and vitality restored. The reasons they fail – and they almost always do – are as varied as the schemes themselves, but the common theme is a fundamental misunderstanding of metabolism. Yes, diet and exercise are critically important for our health, but they don't work in the ways we are usually taught. Our bodies aren't simple calorie-burning engines that we can easily manipulate to keep us looking trim and feeling good. They are complex and dynamic metabolic systems meticulously shaped by evolution for survival and reproduction.

My own metabolic research has taken me and my colleagues across the globe, measuring calories burned by hunter-gatherers in Tanzania, East Coast urbanites in the US, horticulturalists in the Amazon and ultramarathon runners pounding across North America. We have also explored the expenditures of our closest living relatives – chimpanzees, bonobos, gorillas and orangutans – taking the tools of metabolic science out of the lab and across the tree of life.

Recent studies from my lab as well as from others' have reshaped our understanding of how our bodies burn calories, and how exercise and diet affect metabolism and health. In an era of obesity, diabetes and heart disease, societies struggling with these issues would be happier and healthier if we built these advances into our public health programmes and personal routines. We can start by recognising – and tossing aside – seven of the biggest metabolic myths that hold us back.

"Diet and exercise simply don't work in the ways we are usually taught"

1 Exercise burns through calories and boosts metabolism

It is the bedrock belief of pretty much every workout routine featured in magazines: exercise more, burn more calories. In the short term, it is correct – you burn energy while you are exercising, and if you start a new workout routine, you will burn more calories, at least in the beginning. But recent studies show just how dynamic and adaptive our metabolisms can be.

In 2010, my colleagues and I decided to investigate exactly how many calories our evolutionary ancestors, who were hunter-gatherers, were likely to have burned each day. We spent weeks with the Hadza people in northern Tanzania, conducting the first study to measure the calories burned during a day in a modern hunting and gathering community.

As you might expect, subsisting on wild plants and game, with no guns, machines or domesticated animals, is a physically demanding way to live. Hadza men log 19,000 steps each day hunting, and gathering wild honey, while women log 12,000 steps collecting wild tubers and berries, often with a child on their back in a sling. Yet despite doing about five times more physical activity each day than the average for Western lifestyles, we found that Hadza men and women burn the same number of daily calories as sedentary ›

office workers in industrialised populations. It isn't just the Hadza: farmers and foragers in other small-scale societies, with equally high daily workloads, have the same daily expenditures as people in high-income countries. It seems our bodies work to keep the daily number of calories burned within a narrow range, regardless of our lifestyle.

And your new workout routine? It will be subjected to the same metabolic adjustment. Daily expenditures measured for participants in exercise studies routinely increase at the beginning of a new workout regimen, but those gains diminish over time. Their bodies adapt, so that within a few months, the daily energy they burn is only marginally higher, and sometimes exactly the same, as before they started working out. The boost is a bust.

DEEPOL BY PLAINPICTURE/JOHN FEEDELE

Working out doesn't always translate to weight loss

2 Exercise will make you lose weight

Even those who do manage to increase the amount of energy they burn through exercise typically still find it hard to lose weight. A recent review of 61 exercise studies, totalling more than 900 participants, lays out the grim evidence that will be familiar to many.

Weight loss often starts off well at the beginning of a new exercise regime, but it fades over time, so that a year or so later, the weight lost is a vanishing fraction of what we would expect from all the calories burned through working out.

In one of the longer trials, men and women in the US burned 2000 calories per week during supervised exercise sessions for 16 months. After nine months, the men had lost around 5 kilograms, after which their weight plateaued. Women in the study lost no weight over the entire 16 months. Neither men nor women lost what we would have expected based on their exercise workload, despite the fact that their daily energy expenditures had edged up slightly.

The reason for this is frustratingly simple: when you burn more calories, you eat more calories. You might not mean to, of course, but that is the problem. The complex systems working subconsciously to regulate your hunger and satiety do an exceptional job of matching energy intake to expenditure. What else would we expect from half a billion years of evolutionary tuning, where losing weight was generally a sign of impending doom? As a result, the amount of weight you can expect to lose from exercise alone over the course of a year is a paltry 2 kilograms or less.

"Exercise seems to fine-tune the unseen tasks our bodies do all day"

3 Your workout programme isn't succeeding unless you are losing weight

Not losing weight? Don't give up! Exercise might not change the number on your bathroom scales, but that isn't what it is for. Humans evolved as hunter-gatherers, and a heavy dose of physical activity was an inescapable part of the daily routine for more than 2 million years.

Our bodies are built to move, and there are good reasons why the Hadza avoid heart disease and diabetes, despite the fact that they burn the same amount of calories as sedentary people. Regular exercise keeps our hearts healthy, our muscles strong and our minds sharp, especially as we age.

Intriguingly, recent studies suggest that the metabolic adjustments that frustrate weight loss are a big reason why exercise is so good for us. My lab and others are working to track down the precise nature of these changes, but it seems our bodies respond to increased daily activity by reducing the energy expended on other tasks. For example, immune systems quieten down, reducing inflammation, which is important because we know that inflammation is a serious risk factor for cardiovascular disease and a range of other health problems.

People who exercise regularly also respond to stressful events with smaller surges of the stress hormones cortisol and adrenaline, reducing their risk of stress-related disease. Even reproductive hormones seem to be produced more judiciously. Comparisons of oestrogen and progesterone in women and testosterone in men commonly show reduced levels among adults in physically active populations. These reductions don't appear to harm fertility, but they have been linked to a lower risk of reproductive cancers such as prostate and ovarian cancer, as well as breast cancer. Exercise seems to fine-tune all the unseen tasks our bodies do throughout the day, helping to protect us from heart disease, diabetes and cancer.

4 Calories don't matter

Gaining weight is fundamentally a physics problem: when we eat more calories than we burn, those extra calories pile up as fat. Since it is futile trying to boost the energy we burn each day with exercise (or superfoods, or ice water, or the latest gimmick), the primary cause of being overweight or obese is clearly diet. We gain weight because we eat too much.

Yet counting calories has become passé. We are told it is the types of foods we eat, or the way that we eat them, that get us into trouble, and that the "calories in, calories out" view of the world is for suckers. Low-carb evangelists tout ketogenic diets – which rely heavily on fat, rather than carbohydrates – as a way to lose weight without cutting calories (some even claim you can eat more). Intermittent fasting fanatics promise much the same.

These and other weight-loss regimes *du jour* get a few things right. First, people around the world are notoriously bad at counting the calories they eat. When people claim to consume around 2000 calories per day, the real number, based on week-long, gold-standard physiological measurements from thousands of adults living their normal routines, is closer to 2300 calories a day for women and 3000 for men, on average.

With all the metabolic sleight of hand our bodies perform, tracking calories in and out can feel hopeless. However, just because we are bad accountants doesn't mean that calories are a meaningless currency. All weight-loss diets work by reducing calorie consumption, the concept is simply hidden behind different guises.

Which brings us to the other thing these diverse diets get right: we are an adaptable species, able to thrive on a broad range of diets from carnivore to vegan. Meat-based diets work wonders for many, but so do plant-based ones and everything in between. The science over the past couple of decades is clear that any diet can help you lose weight if you stick to it, and there is no single one that is easier to adopt. A 2005 study in the US randomly assigned 160 adults with obesity to four different diets, and found no differences in the ease with which people adhered to their assigned diet, nor in the weight loss and health benefits obtained.

If you are attempting to lose weight, the trick is to find a diet that you can maintain without feeling miserable. Foods high in protein and fibre tend to make us feel full. It also helps to avoid crash diets that can cause our clever, evolved metabolisms to hit the brakes and reduce daily energy expenditure.

For anyone who has found a diet that works for them, stick with it. But don't expect it to work for everyone. There is no singular, naturally perfect human diet, which brings us to the next metabolic myth.

ANUP SHAH/NATUREPL.COM

A Hadza man in Tanzania smoking out bees to gather honey

5 Humans evolved to eat a Paleo diet

Striving to eat the kinds of foods our ancestors ate makes intuitive sense. But emulating ancient diets, the idea behind the fashionable Paleo or "caveman" diet movement, in which people eat similarly to how our ancestors did in the Palaeolithic era, isn't as straightforward as it might appear.

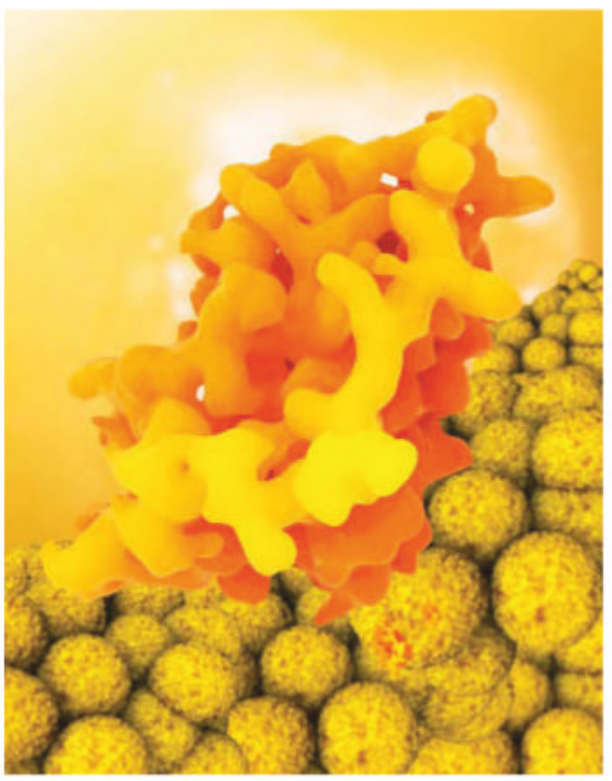
Cast your mind across the dizzying array of cultures on this planet, and consider the staggering variety of foods we eat. Clearly, there is no single human diet today, and it would be laughable to claim otherwise.

Yet when we consider our Palaeolithic past, somehow it has become reasonable to suggest that cultures around the globe, over millennia, ate a single, uniform, "natural" diet. Even stranger to those of us in the fields of human ecology and anthropology, some popular Paleo-style diets, for instance the so-called carnivore diet, suppose that ancestral diets were heavy on the meat, with only a few grams of carbs each day and essentially no sugar.

My team's work with the Hadza community, along with ethnographic accounts gathered over the past century of other hunter-gatherer groups and much older evidence from the fossil and archaeological records, paints a very different picture.

First, hunter-gatherer diets are (and were) just as diverse as diets in industrialised populations, with lots of variety among groups and through time in the proportions of meat and plants, fat and carbs. Some diets, particularly those of Indigenous people in the Arctic, are meat-heavy; others, especially in warmer climates, are plant-heavy. The Hadza eat a balance of plants and game, as well as a huge amount of honey (forbidden in Paleo diets), which accounts for around 15 per cent of their calories, on average.

Second, outside the Arctic, there is no evidence for meat-heavy diets among hunter-gatherer groups today or in historical records. Even in the Palaeolithic, we see plenty of archaeological and fossil evidence for a balance of plants and meat in the diet. ›



RAMON ANDRADE 3DCIENCIA/SCIENCE PHOTO LIBRARY

A model of leptin, the hormone that tells your brain when you are full

6 A slow metabolism dooms you to obesity

Like most other biological traits, the amount of energy burned in a day varies from person to person. Daily energy expenditure in two people who are the same age and sex, and have the same lifestyle, can easily differ by 500 calories or more. Surprisingly, that variation in energy use doesn't predict someone's weight. People with obesity have the same daily energy expenditure, on average, as those who are slim. That's after accounting for body size, since a larger body tends to burn more calories per day simply by virtue of having more cells at work. If we don't correct for size, people with obesity burn more energy. Weight gain and obesity aren't products of a slow metabolism.

So why do some people find it easy to stay trim while others struggle? Although there is probably no single answer, a major factor seems to be the way our brains are wired. For most, weight gain comes on slowly over months and years, reflecting tiny errors in the regulation of energy intake. The vast array of processed and engineered foods available to us overwhelms neural reward systems evolved to handle unprocessed wild foods. Our brains err on the side of overconsumption.

Support for this view has come from recent work on the physiology of hunger and satiety, as well as advances in the genetics of obesity. Of the hundreds of genes associated with obesity in humans, the vast majority are most active in the brain. The variants you carry are likely to affect your ability to control your weight.

7 Obesity and weight gain are a sign of personal failure

As powerful as our genes are, DNA isn't destiny. Today's gene pool is essentially unchanged from that of our great grandparents' generation because genetic change is slow. They didn't face a global obesity crisis. What's different in much of the world is our environment, specifically our food environment – the access we have to specific foods. In engineering our industrialised world, we have surrounded ourselves with foods that drive us to overconsume. The battle with obesity is often framed as a test of willpower, pitting the virtues of exercise and portion control against the vices of gluttony and sloth. New metabolic science says otherwise.

"We have surrounded ourselves with foods that drive us to overconsume"

Shops are stocked with ultra-processed foods, laden with added sugars and oils, symphonies of sweet and savoury that overwhelm our Palaeolithic brains.

Recent work at the US National Institutes of Health has shown that eating ultra-processed foods leads to weight gain, although we don't yet know precisely why. These foods are on the rise worldwide. In the US and the UK, they account for more than half of food consumed. In wealthy countries, ultra-processed options often dominate the foods available in low-income neighbourhoods and those where the majority of inhabitants are from minority groups, contributing to inequities in health and nutrition. In low and middle-income countries, the growing dependence on ultra-processed foods has helped to fuel the global rise of obesity and related disease. Those maladies, including heart disease, stroke and diabetes, and other non-communicable illness, kill more people globally than infectious disease. This shows why obesity has grown into a crisis that disproportionately affects the economically disadvantaged, including people of colour.

Recent breakthroughs in metabolic science are a call to action. Obesity isn't a choice, but that doesn't mean our choices don't matter. We can start by getting ultra-processed foods out of homes. We don't need to wait for societal changes in our food environment to take action in our daily lives. And we need to learn from the Hadza and others to weave physical activity into our daily routines. Exercise won't make us thin, but it will keep us alive.

From guinea pigs in metal pots to detailed studies of obesity genes, the science of metabolism has advanced over the past two centuries with new approaches and new technologies. Yet some of the biggest advances in recent years have come from societies like the Hadza, modern communities that hold on to ancient ways and provide a window into our collective past. Our bodies were shaped by evolution to be clever, adaptable and dynamic. We will need that same flexible creativity to tackle the obesity crisis. ▮

Herman Pontzer is an evolutionary anthropologist at Duke University in North Carolina. His book *Burn* will be published on 2 March

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A trillion dollars to fix the world

Let's imagine you have inherited a fortune and want to solve humanity's most pressing problems. What is the best way to make a difference, asks **Rowan Hooper**

MOST of us have had that conversation: what would you do if you won the lottery? Pay off the mortgage, quit your job, maybe start a small business doing something you have always dreamed of. But what if you acquired a truly vast fortune – not just a few million but a trillion dollars? And what if you had to spend it on making the world a better place?

I know, a trillion dollars – a thousand billion dollars – sounds like a vast amount of money, especially during the twin crises of recession and pandemic. But in the grand scheme of things, it isn't. A trillion dollars is about 1 per cent of world GDP. It is what Jeff Bezos, the founder of Amazon, is on course to be worth by 2026. The world's richest 1 per cent together own $162 trillion in assets. And it's just one-twelfth of what governments around the world found in 2020 alone for economic stimulus packages in response to the new coronavirus.

What could you do with such a relatively modest sum, if charged to spend it on the world's biggest challenges? This is the central question of my book, *How to Spend a Trillion Dollars*, in which I choose 10 megaprojects (all things scientists are working on now) and explore what could be achieved if we showered them with money. Here we examine three of the most urgent of those challenges: solving world poverty, halting runaway climate change and curing all disease.

ANDREA UCINI

Eradicate world poverty

Perhaps the most important thing we could do for human welfare would be to alleviate poverty. According to the World Bank, about 10 per cent of the planet's population, or 760 million people, earn $1.90 or less per day. The hardship is such that the life expectancy of the world's poorest people is nearly 15 years lower than that of the richest.

The widespread policy of easing taxes on business and wealth with the expectation that money will "trickle down" hasn't helped the world's poorest. So let's try something else. We will give everyone in extreme poverty a lump sum of up to $1000, or equivalent assets. One objection often raised against such proposals is that people will waste such gifts. However, a 2014 review of cash handouts by the World Bank found that this is hardly ever the case. People tend to use handouts wisely. Even one-off cash and asset transfers seem to genuinely change people's lives.

In a trial in Bangladesh, for example, ultra-poor families were given assets in the form of livestock. Follow-ups showed that the handouts had sustainably changed their lives and put them on a new trajectory out of extreme poverty.

Similar asset-transfer programmes have been rolled out in Ethiopia, Ghana, Honduras, India, Pakistan and Peru, involving a total of more than 10,000 people. After the second year of this project, families enrolled in the ›

> A one-off payment gives ultra-poor people what they need to escape the poverty trap, often permanently

treatment groups had more assets, better diets, better physical and mental health, higher political engagement and increased female empowerment compared with control groups.

The evidence could hardly be clearer: a one-off investment gives ultra-poor people what they need to escape the poverty trap, very often permanently.

Most of the cash-transfer experiments done so far are on a scale of hundreds of thousands to millions of dollars. We don't know what might happen if we showered larger amounts on entire populations. Might people give up work? It is hard to say, but the little evidence that exists suggests not. In Alaska, for example, all residents receive a yearly dividend derived from oil revenue, and this has no negative effect on the rate of employment. Nor do such cash transfers seem to have much impact on inflation, judging by a study in Kenya.

What we know for certain is that the benefits can be huge. In Brazil, a countrywide initiative called Bolsa Família introduced in 2003 helped to reduce financial inequality by 15 per cent, and the proportion of the population in extreme poverty shrank from 9.7 to 4.3 per cent. Cases of infant mortality caused by malnourishment also halved. Payments from the programme aren't universal: they are made only to families earning under a certain amount, but in 2015 that was still a quarter of the population, almost 52 million people.

Educational value

In Peru, there was a cash transfer scheme that came with conditions. In enrolled villages, the female head of households with children received the equivalent of $143 every two months if she had been sending the children to school, had obtained identity cards for them and had taken under 5s for health checks.

This hints at the kind of lasting change you can make if you simply give away money, albeit with the proviso that children are educated. The non-profit Brookings Institution in Washington DC discovered that a woman who has never been to school has around four to five more children than a woman with 12 years of education. It also found that women who went to school earn more, are less likely to marry as children, are less likely to have HIV or malaria, and tend to farm more productive plots of land, which results in better nourished families.

The United Nations estimates that just an extra $39 billion per year could ensure universal education in low and lower-middle income countries. (The UN currently spends $13 billion a year on international aid projects for education.) Universal education, for just $39 billion a year. It is a shockingly small amount to ensure a basic human right.

So that is one way to spend a trillion dollars: $600 billion up front to raise hundreds of millions of people out of the poverty trap, which leaves us enough to pay for universal education in low and lower-middle income countries for 10 years.

A favela in Rio de Janiero, where many people live on less than $1.90 a day

PATRICK ALTMANN/GETTY IMAGES

XINHUA/SHUTTERSTOCK

Men planting trees in Inner Mongolia, China. Afforestation is expensive but pays huge dividends

> “We need to extract carbon dioxide from the atmosphere on a massive scale

Stop climate change

Climate change is a global tragedy unfolding in front of our eyes. If we don't keep temperatures from rising more than 1.5°C above pre-industrial levels, we could be locked into devastating sea level rise, droughts, famines and conflict. We urgently need to cut emissions. That is the only way to stop the disaster getting worse. But we have available, right now, the means to cool the planet and remove carbon dioxide from the atmosphere.

We will want to invest in geoengineering, defined as any deliberate intervention of a nature and scale capable of counteracting human-made climate change and its knock-on effects. We will focus on one of the most promising ideas, solar geoengineering, comprising methods to screen out some of the sunlight reaching the surface of the planet and thereby cool global temperatures.

Let's imagine we stump up a few hundred million dollars for testing one such approach, that of seeding the skies with sulphate particles, which are considered the most plausible planetary sunscreen. After extensive trials, we find that it doesn't wreck the monsoon in South Asia, for example, and that the benefits of a temperature decrease aren't offset by a reduction in crop yields.

Let's also imagine that our trials, scaling up each time, have garnered enough positive data and political and social support to drive the drawing up of a manifesto of responsibility and the agreement of an international treaty for a global solar geoengineering effort. We will need specially made aircraft that fly high in the stratosphere and release their sulphate payloads. Following research by Wake Smith at Yale University and Gernot Wagner at New York University, we will commission a fleet of autonomous drones with giant wingspans, capable of cruising in the stratosphere, steadily releasing their sulphur payload.

We will purchase an island, build a port to receive shipments of sulphur and a runway from which we can launch thousands of flights to seed the skies. We will allocate $6 billion for all this. That isn't much. The trouble is that if we started it, we couldn't stop. A sulphate shield only lasts a year or so because the particles drift slowly back to the surface. Only once we are capable of pulling huge amounts of carbon out of the atmosphere can we let the shield come down for good, which brings us to our next investment.

We have to remove a good chunk of the CO_2 we have released into the atmosphere. Here I would fund two different approaches: technologies designed to suck up CO_2 and good old-fashioned tree planting.

For all its world-changing power, CO_2 is a trace gas, making up just 0.04 per cent of the atmosphere. That makes it difficult to extract. We can do it on a small-scale now but we need to do it on a planetary scale.

Carbon capture

Climeworks is a Swiss firm trialling a number of carbon-capture projects, the most ambitious of which is in Iceland. There, carbon-capture units running on the country's geothermal energy collect 50 tonnes of CO_2 a year and pump it underground where it reacts with basalt and turns to stone. But 50 tonnes per year is nothing. In 2018 alone, humans emitted 37 gigatonnes of CO_2. Climeworks says it wants to capture 1 per cent of global CO_2 emissions by the mid-2020s, which would ›

require gigantic and unprecedented growth. Other carbon-capture start-ups require similar expansion before we get to a capacity where it will make a global difference. So we will invest in this sector, let's say $100 billion or so, but save most of our money for the organic approach.

A trillion trees?

The method can be summarised in three words: grow more trees. Trees draw down CO_2 and lock it up, at least for the lifetime of the tree. If you plant enough of them, you could suck out a lot of the CO_2 in the atmosphere. The problem is that we would need to do this on a gigantic scale, which brings multiple problems. Perhaps the biggest hurdle is the question of where they will all go. A team at ETH Zurich in Switzerland used data on forest cover from Google Earth and a machine-learning algorithm to predict which new areas could support forests. There is enough land, it seems, for 900 million hectares of forest, an area about the size of the US.

Let's say we paid to plant around 500 billion new trees. According to the ETH Zurich analysis, once the trees are mature, that number might draw down and store 205 gigatonnes of CO_2. Given that each part per million (ppm) of CO_2 is equal to 2.13 gigatonnes, that would bring the ppm down to about 320, its level in the mid-1960s. Currently, we are at around 416 ppm.

This seems to be the best way to buy us some time at least. Of course, there are lots of details to work out. Simon Lewis at the University of Leeds, UK, who studies the interactions between forests and climate change, thinks the 205 gigatonnes is an overestimate. It is also fair to say that there are many demands on "spare" land, not least agriculture, housing and recreation. But there does seem to be a lot of currently wasted land that we could redevelop in a massive tree-planting scheme. Allowing land to regenerate on its own can also be hugely effective, as can forestry management incentives aimed at locking away more carbon.

This epic afforestation is going to be expensive at roughly $400 billion per year, yet it would surely be a sound investment. A 2018 report from the Intergovernmental Panel on Climate Change found that keeping us below 1.5°C of warming above pre-industrial levels would cost about $2.5 trillion per year until 2050 in investment in the energy sector, and $775 billion per year on measures to reduce energy demand. The financial cost of global warming above 1.5°C is so diabolical that the economic benefits of staying below this threshold are four or five times the size of the investment.

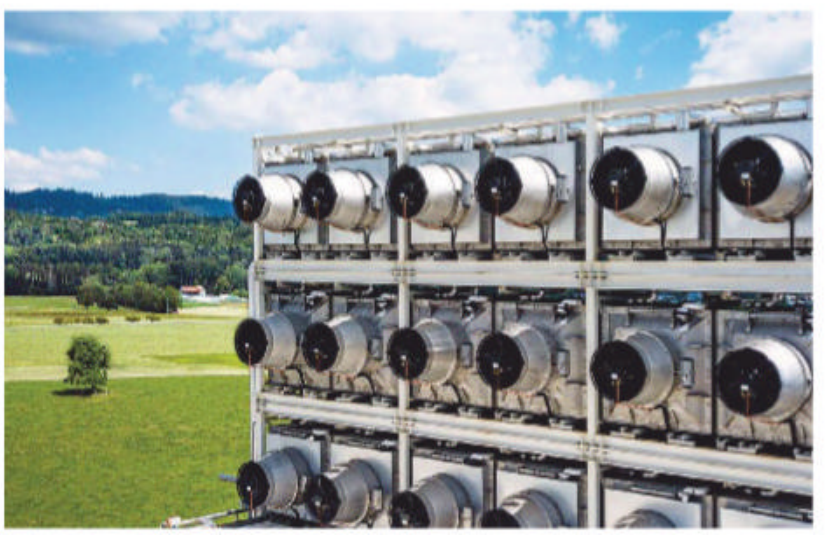
ATUL LOKE/PANOS PICTURES

Cure all disease

In 2016, Priscilla Chan took to the stage at a meeting in San Francisco and announced that her foundation would work to ensure that an entire generation of people would never get seriously ill. "We'll be investing in basic science research with the goal of curing disease," she said. To that end, Chan and her husband, Facebook CEO Mark Zuckerberg, put $3 billion into research aimed at preventing, managing or curing all diseases by the end of the 21st century. Tha isn't merely curing breast cancer or Alzheimer's or diabetes or strokes, but curing all disease. Oh, and increasing global life expectancy to 100.

Even by Silicon Valley standards, it is an ambitious goal. Even if Chan and Zuckerberg end up investing their entire fortune, currently around $60 billion, it would be a drop in the

A Climeworks carbon-capture plant in Hinwil, Switzerland



CLIMEWORKS

The coronavirus pandemic has shown that tackling emerging infectious diseases must be a priority

bucket when it comes to what is required to free humanity of all disease and extend everyone's lifespan. But what if we set our trillion dollars to the same goal? When I put this to Jeremy Farrar, head of Wellcome, one of the world's largest medical research charities, with an endowment of around £30 billion, he laughed. A trillion dollars is nowhere near enough money, he said.

When you look into what needs to be done, you get a better idea of the scale of the task. Much of the research and spending on public health work is siloed as a result of being directed at specific diseases. Take the global effort to eliminate malaria, which kills about 400,000 people each year, most of them children under 5, and mostly in sub-Saharan Africa. Around $4.3 billion per year is spent on malaria. But it is just one of dozens of infectious diseases. And as well as targeting those, we would also need to spend globally on the other three main disease categories: heart disease, neurological disease and cancer.

We would burn through our trillion dollars and only make a fleeting impact on health and lifespan. If you want to make immense gains in public health on a global scale, and make them equitable and sustainable, there is one thing that needs to be implemented. It is difficult, complex and expensive, which might be why it isn't something that is much talked about or invested in by billionaires. It is universal healthcare (UHC): free healthcare, for everyone.

> “Universal health care is by far the best way to make immense gains on a global scale

In 2013, an international *Lancet* commission put together an investment framework to achieve what it called a "grand convergence" in health by 2035. By this they meant reducing deaths from infectious disease, as well as child and maternal mortality, in low and middle-income countries to the levels seen in the best-performing middle-income countries. This, the framework predicts, could prevent more than 10 million deaths in 2035.

The commission found that UHC isn't only the most efficient, but also the only sustainable way to achieve a convergence in global health. Their framework was written before the coronavirus pandemic, but the response of countries like Singapore and South Korea, in contrast to that of the US, shows that UHC is a good protector for pandemics, too.

As Farrar says, a trillion dollars isn't enough to change the world's healthcare system, so here's another idea. We allocate some of our money to building a universal healthcare system in one country, which becomes a flagship, an advert to other countries of the benefits of UHC investment.

Let's choose Ethiopia. With a population of more than 100 million, it has a large economy, but only about three doctors per 100,000 people. The UK has almost three doctors per 1000 people. Maternal and child mortality in Ethiopia are relatively high, mainly because most births take place at home, without the presence of a trained modern midwife. Our investment would make Ethiopia more like Ghana, where there are around five midwives per 1000 births and much lower maternal mortality rates. Ghana operates a universal service through its National Health Insurance Scheme.

So a sizeable chunk of our trillion goes on a demonstration of UHC. Another should go on vaccines. The development, testing and equitable distribution of a vaccine is a huge and costly undertaking – but one that could save millions of lives.

We will fund the Coalition for Epidemic Preparedness Innovations, a global partnership working on vaccines for many so-called emerging infectious diseases, including covid-19. We can help boost vaccination rates around the world, but we can also move the dial at the basic research level. As well as covid-19, effective vaccines against HIV, malaria and tuberculosis would be transformational. In all, 320 or so emerging infectious diseases have been identified since the 1940s. And if we can create a universal flu vaccine, we would be protected from what is still one of the greatest health threats to our species: a flu pandemic.

Jessica Metcalf, an infectious diseases biologist at Princeton University, has proposed a programme of sampling people's immune systems that would allow scientists to pick up signs of new pathogens as they emerge. The coronavirus won't be the last such threat. But Metcalf says her Global Immunological Observatory would help "rapidly detect, define and defeat future pandemics".

Again then, this is money that could hardly be better spent – a sentiment that came up time and again as I was researching the book. The lesson I learned along the way was clear. A trillion dollars might sound like an immense amount, but the benefits of spending such a sum on these projects would pay back handsomely, and often quite quickly. ▮

Rowan Hooper is podcast editor at *New Scientist* and author of *How to Spend a Trillion Dollars* (Profile Books, 2021)

STUART MCREATH

The first urbanites

Proto-cities in eastern Europe challenge our ideas about the origins of civilisation, finds **Laura Spinney**

AROUND 6200 years ago, farmers living on the eastern fringes of Europe, in what is now Ukraine, did something inexplicable. They left their neolithic villages and moved into a sparsely inhabited area of forest and steppe. There, in an area roughly the size of Belgium between the modern cities of Kiev and Odessa, they congregated at new settlements up to 20 times the size of their old ones.

This enigmatic culture, known as the Cucuteni-Trypillia, predates the earliest known cities in Mesopotamia, a civilisation that spanned part of the Middle East, and in China. It persisted for 800 years, but then, as mysteriously as it had begun, this experiment in civilisation failed. The inhabitants left the lightest of footprints in the landscape, and no human remains have been found. "Not a pinkie, not a tooth," says palaeogeneticist Alexey Nikitin at Grand Valley State University in Michigan.

This puzzling lack of evidence has fuelled a lively debate about what Nikitin calls the "Dark Ages" of European prehistory. "You talk to five Trypillian archaeologists, you get five different opinions," he says.

But the data gap hasn't stifled interest – quite the opposite. Several projects in recent years have tried to make sense of the Trypillian proto-cities. Despite big disagreements, what is emerging is a picture of an early and unique attempt at urbanisation. It may be the key to understanding how modern Europe emerged from the Stone Age – and even throw new light on the emergence of human civilisation in general.

Uruk and Tell Brak, which arose in Mesopotamia early in the 4th millennium BC, are usually considered the world's first cities. Their excavated remains point to an increased density of habitation and a novel, hierarchical social structure – two features that are considered integral to the definition of a city. The idea is that as human populations grew, strangers had to come together in a shared space and get along. "I think that was the real psychological threshold of urbanism," says Monica Smith at the University of California, Los Angeles, an anthropologist and author of *Cities: The first 6,000 years*. But the Trypillian megasites don't meet either of those criteria, so how should we make sense of them?

Ukrainian archaeologists have known about the megasites for more than a century, but systematic excavations didn't get under way until after the second world war, and the sites only came to international attention a decade ago. Today, of the several thousand known Trypillian settlements, around 15 count as "mega" because they cover more than 1 square kilometre. The biggest, Taljanki, is over three times that size, making it slightly larger than London's financial heart, the City, and bigger than Uruk throughout most of the 4th millennium BC.

Although sizable, the megasites weren't densely populated. They were laid out concentrically, with houses made of wattle and daub lining ring roads circling a large central space. The biggest sites had several thousand houses and as many as 15,000 inhabitants – compared with no more than a few hundred people in a typical neolithic village. There is heated debate over numbers, though that, in part, is because it isn't clear whether the sites were fully inhabited year round. This raises another question: what were these places for?

"The Trypillian megasites were very different from the first cities built centuries later"

Some take a traditional view. Archaeologist Mykhailo Videiko at Borys Grinchenko Kyiv University, Ukraine, thinks the megasites were simply a response to growing population pressure. The Trypillians' move may have been facilitated by developments in technology, he says, notably the advent of sledges drawn by bulls or other animals. These made it possible to transport food and other resources over a dozen or more kilometres, from existing villages or outlying fields to the new sites. "There were no roads," he says. "This was a landscape of forests and river valleys."

Johannes Müller at Kiel University, Germany, views the megasites as essentially overgrown villages – an experiment, yes, but only in scale. The concentric design wasn't new, he points out: "You see it from around 4800 BC, in older settlements with no more than 50 houses." But John Chapman and Bisserka Gaydarska at Durham University, UK, couldn't disagree more. "It's like saying that an aircraft carrier is a very large yacht," says Chapman.

For Chapman and Gaydarska, it really was an experiment in social organisation – and the appearance of the megasites reflects this ideological shift. Each was laid out in quarters that radiated from the centre roughly in the shape of pie slices, and further subdivided into neighbourhoods comprising a handful of houses. The overall layout seems to have ›

"The essence of Trypillian culture seems to have been egalitarianism"

been imposed from the start, though the quarters took on internal structure gradually, as people moved in. Often, neighbourhoods had their own assembly house, strategically placed on a ring road. A bigger one served each quarter, and there was one, very large meeting house for the site as a whole, near the centre and facing east. These structural subdivisions might have helped contain disputes, says Gaydarska, and the assembly houses could have been where decisions were made and communicated, at a time before writing was invented. "Trypillian sites were basically egalitarian," says Chapman. "There's very little evidence of prestige goods or elites."

Why congregate?

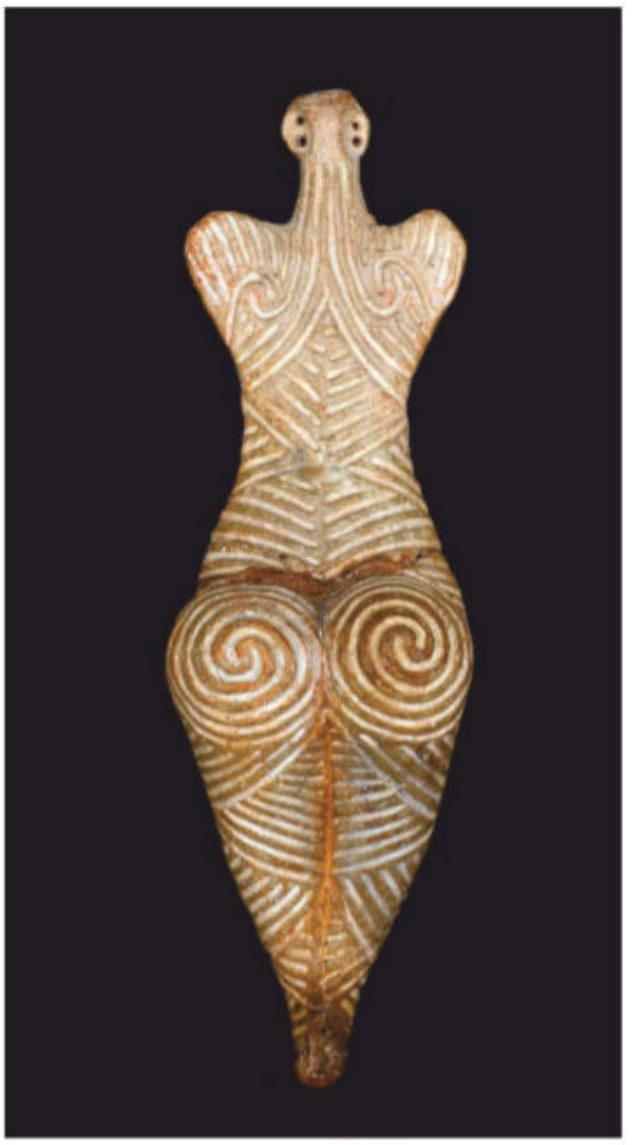
These were cities, in other words, but of a very different kind from those conceived by the hierarchical, slave-owning societies of Mesopotamia a few centuries later. And that being the case, argue Gaydarska and Chapman, our definition of a city needs expanding.

Others don't go quite as far. Smith calls the megasites "collective settlements", and suggests we might think of them as immediate precursors of cities, where people who only knew the small-scale, egalitarian village life had their first taste of something bigger and more heterogeneous. "They could be capturing something of that transition," she says. In fact, she thinks the megasites may have had something in common with Göbekli Tepe in modern Turkey, a building complex which is at least 10,000 years old and seems to have been a place where people congregated periodically to observe rituals. It might have been at such pilgrimage centres that the idea of unfamiliarity – of the need to tolerate and even trust strangers – was first sown, she says.

This is one of several hypotheses that Gaydarska and Chapman explore in a new book, *Early Urbanism in Europe*. Perhaps the megasites served a purely ritualistic purpose, being managed by a group of "guardians" who welcomed pilgrims over four or five months of the year – or maybe more intensively, over a single month, in the style of the Burning Man festival held annually in Nevada's Black Rock desert. An alternative idea is that different clans took it in turns to govern, provisioning the site and leading visitors in rituals for a year, before another clan rotated in.

By contrast, Müller and his German colleagues believe the megasites were fully occupied all year round. The evidence is fiendishly difficult to interpret, partly because Trypillians periodically burned their houses down in a controlled way – possibly in a deconsecration rite when they moved out. At Nebelivka, where Chapman and Gaydarska work, for instance, two-thirds of the 1500 houses were torched over its 200 years of existence. Dating techniques don't offer the precision needed to determine what proportion of the houses were inhabited contemporaneously before being burned. The ecological impact of activities at megasites was light, though, as is clear from detailed analyses of pollen, which can indicate cultivation and forest management, and charcoal in sediment cores taken from surrounding land. But whether that was because the sites were only occupied seasonally or because resources were brought in from elsewhere, is unknown.

Trypillians made beautiful clay sculptures, including this figurine



PICTURES FROM HISTORY/BRIDGEMAN IMAGES/IDS

There is another suggestion for why the megasites came to be: Trypillians congregated defensively against some external threat. Here again, the archaeologists disagree. Megasites are typically surrounded by a ditch. The one at Nebelivka is 5 kilometres in circumference. But at 1.5 metres wide and 0.8 metres deep, it would have been easy for an adult to jump, suggesting to the UK-based researchers that it wasn't defensive. However, Videiko says the ditch once contained a palisade – an enclosure made of wooden stakes – that has long since rotted. Either way, there is also protection in numbers.

Nikitin also favours the defensive hypothesis. He and David Anthony, an anthropologist at Hartwick College in New York, see the emergence of the megasites as a response to broader regional conflicts. To the south, in what is now Romania and Bulgaria, were the heartlands of Europe's oldest farming cultures. By 4600 BC, these Balkan communities had a flourishing copper industry and were fabulously rich. A gleaming symbol of their wealth is the spectacular, gold- and copper-filled grave of a high-status man discovered at a cemetery in Varna, Bulgaria. Then, around 4200 BC, those farming settlements were abandoned. Archaeologists have found signs of violence just before that happened. Nikitin and Anthony believe the survivors fled north to their distant relations the Trypillians, and that the megasites, which arose around the same time, were built to accommodate them. "I think these were refugee camps," says Nikitin.

If there was a massacre, it isn't clear who was responsible. Was it farmer-on-farmer violence, triggered or exacerbated by the impact of climate fluctuations on harvests? Or did nomads from the steppe to the north and east become aggressive when those farming communities went into decline – perhaps for the same reason – and their copper production dwindled? Finds of Balkan copper deep in the steppe indicate that the two groups had traded for several centuries by then. Although, analyses of individuals from Varna and other Balkan cemeteries suggest that, with rare exceptions, there was no interbreeding.

Whatever triggered the slaughter around 4200 BC, the Trypillian farmers further north seem to have been spared – at least to begin with. They continued to interact with nearby

steppe people, as evidenced by a type of steppe pottery known as Cucuteni C that crops up in every layer at the megasites until their abandonment. "The Trypillians managed to work it out with the steppe," says Nikitin. And yet they didn't breed with their neighbours either. Nikitin's team found no steppe genes in human remains at a Trypillian site whose occupation overlaps with the megasite period. One reason, he suggests, was their radically different world views. Steppe people valued individual prowess – as demonstrated by their use of coveted Balkan copper to decorate the bodies of their dead chieftains – whereas the essence of Trypillian culture, with its concentric megasites and assembly houses, appears to have been egalitarianism.

Unsurprisingly, the refugee camp idea doesn't appeal to everyone. "You can't have a crisis for 800 years that people have not dealt with," says Gaydarska. Others have wondered how relatively small bands of nomads, however warlike, could have destroyed the wealthy, densely populated Balkan farming settlements. Nikitin admits the idea has weak points, not least that building the megasites rapidly, to accommodate migrants, would have required an extraordinarily large investment of labour. Nevertheless, he suggests that it could explain the absence of human remains. "If these were temporary camps, the incomers probably didn't stick around for long and did their dying someplace else," he says.

Around 3400 BC, the megasites were abandoned in their turn – though the Trypillians went on, inhabiting smaller, more scattered sites. Anthony thinks that whatever peace the farmers had negotiated with steppe people broke down. Genetic analysis reveals that after the demise of the megasites, the two populations started interbreeding. A tantalising theory that Nikitin is exploring – in collaboration with David Reich's ancient DNA lab at Harvard University – is that the offspring of that genetic mixing were the Yamnaya people. If so, we may need to rewrite the story of these herders, thought to have come from the steppe, who, starting around 5000 years ago, transformed Europe's population genetically, linguistically and culturally. They have been portrayed as a murderous people, but, perhaps, being already part European farmer, they were able to complete this transformation peacefully. Though the question remains wide open, Nikitin says it is possible that the Yamnaya came after a violent period and ushered in a new ideology shaped by the steppe. "At the peak of this despair an idea formed, of a new world order," he says.

Trypillian houses, built from wattle and daub, were regularly burned to the ground

CRISTIANCHIRITA/CREATIVE COMMONS

Others think there is no need to invoke outside forces to explain the abandonment of the megasites. Müller, who has excavated principally at a megasite called Maidanetske, says that by 3700 BC, the assembly houses in its quarters and neighbourhoods had gone. Only the largest assembly house remained. "This shows, at least for me, that there was a kind of centralisation of decision-making processes going on," he says. That might have been incompatible with social cohesion. Gaydarska and Chapman also think the problem was internal, noting that as Maidanetske grew, the central space – which could have served a critical function as a gathering place – was filled in. However, another possibility is that the megasites simply lost their prestige, they say. Perhaps, given enough exposure to steppe ideas through trade, the Trypillians began to question their own.

In a rare instance of unity, most Trypillian researchers agree that environmental depletion cannot be the reason they left. "It is quite clear that the carrying capacity of this area was never reached," says Müller. They also reject an idea proposed in 2018 by microbiologist Nicolás Rascovan at the Pasteur Institute in Paris and his colleagues. Rascovan argued that plague got a foothold in the megasites, from where it spread north and west, eventually turning up in a Swedish cemetery around 2900 BC. Plague victims' bones would have turned up, says Gaydarska. Moreover, the megasites had been gone for 500 years by then, which is too big a gap even for a relatively slow-moving disease like plague.

However it happened, by the time the Yamnaya appeared in Europe, what may have been the world's first urban experiment was over. Far to the south and east, the cities of Egypt and Mesopotamia – built on a radically different model – were thriving, still several centuries off their peak. From then on, civilisation took a new path and the world never looked back. ▮

Pottery known as Cucuteni C has its roots in the steppe

BRIDGEMAN IMAGES/IDS

Laura Spinney is a science journalist based in Paris and author of *Pale Rider: The Spanish flu of 1918 and how it changed the world*

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The back pages

Science of gardening

Stop those slugs!

From copper tape to tiny nematode worms, there are many ways to deter slugs and snails. But which is best, asks **Clare Wilson**

Clare Wilson is a reporter at *New Scientist* and writes about everything life-science related. Her favourite place is her allotment @ClareWilsonMed

What you need

Copper tape
Pots
Nematodes
Garden cloches

Science of gardening appears every four weeks

Next week

Citizen science

OF ALL the gardener's enemies, slugs and snails are among the most hated. Feasting on the soft new growth of plants, they can reduce prized blooms to rags or demolish an entire row of tender seedlings overnight. They regularly top the list of pests that are most enquired about via the UK's Royal Horticultural Society (RHS) helpline, says RHS entomologist Hayley Jones.

There are many possible weapons against slugs and snails, and they have different pros and cons. I used to rely on slug pellets, which leave satisfying numbers of dead bodies, but can also poison wildlife. The UK is set to ban the most deadly kind, based on metaldehyde, from March 2022.

Other slug pellets, like those that contain ferric phosphate, are less harmful, especially when scattered thinly as per the instructions. Research by Jones shows these work nearly as well as metaldehyde. Alternative tactics include covering plants with cloches while they are small and vulnerable, but these can be pricey. A common DIY approach is to surround them with sharp material like grit or eggshells, but Jones has found that this doesn't work – hardly surprising, as slugs and snails can release thick mucus to protect their undersides. They can even crawl over razor blades.

Copper products like copper adhesive tapes can also deter them, although the reason why is unclear. There is mixed evidence for copper, perhaps because it is sometimes laminated, but I have found that putting copper tape around my patio containers works well. It is very satisfying to watch slugs advancing up the pots, intent on my sweet peas, only to be thwarted by the tape. But make sure not to let the protected plants be reached via other overhanging leaves.

FREDERIC HERBIGNIAUX/ALAMY

As well as using physical and chemical weapons, you can go biological by buying microscopic worms called nematodes. Applied as a fine powder added to water, these worms seek out slugs and kill them. These work well in trials, but home gardeners report mixed results, perhaps because they aren't following the instructions exactly, says Jones. A common mistake is to let the powder clump at the bottom of a watering can when sprinkling onto the soil. Ideally, nematodes should be applied every six weeks from spring onwards. So in the northern hemisphere, it is time to order your worms by post.

I now have a dual strategy. For my precious vegetable seedlings at the allotment, I go all-out with copper tape, cloches – home-made from juice bottles – and the odd slug pellet. But in the garden, I have given up on plants that are slug magnets, like dahlias and hostas and stick to those that are relatively resistant, but even these may get somewhat munched.

Jones thinks the secret may be to reach a truce. "You're never going to get to zero damage," she says. "The question is how much can you turn a blind eye to?"

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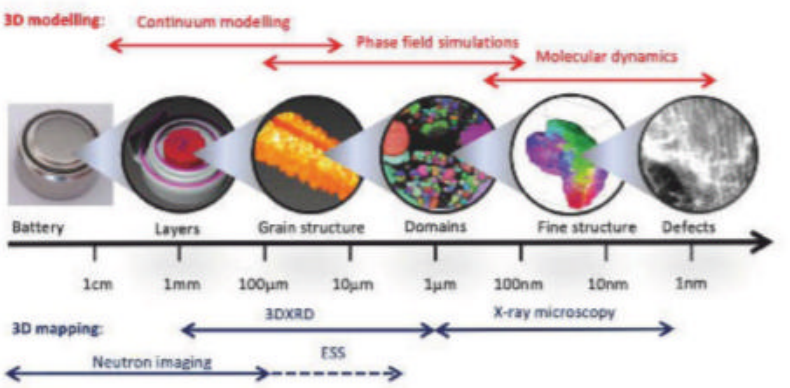
Read more about SOLID at **www.solid.dtu.dk**

Our vision

We aim to visualize the internal structure of all sorts of solid materials, their creation and change during use – in 3D, on all the relevant length and time scales. This means we can generate and apply a new generation of more realistic multiscale material models. This would be a fundamental "game changer" in materials science, because effective models are the door to the dream of computational materials design. Multiscale 3D description is the key to understanding the basics of bone and tooth biology and thus for the development of new drugs and diagnostic methods, e.g. for osteoporosis. Similarly, our new high throughput 3D imaging methods will facilitate massive digitization of fossils and museum specimens, to facilitate progress in understanding human evolution and climate change



Why Denmark?

English is spoken widely and is the working language in the university. Denmark offers an attractive work-life balance, with work hard/play hard expectations. Research benefits from a deep culture of teamwork, creativity and enthusiasm in solving problems together, where students work side by side with senior scientists.

Denmark has a thriving food scene, excellent museums and infrastructure, beautiful natural scenery and friendly people. All of the SOLID partner institutions are in student rich cities. A young population means many cultural and athletic activities and music festivals.

The positions

As a cross disciplinary centre, we seek candidates with a background in physics, chemistry, biology, mathematics, materials science, geology or engineering. For the PhD positions, no specific experience is required in the topic of the research but keen interest and a drive for solving problems are essential. We also expect you to be strong in physics, chemistry and mathematics.

Our expectations about you, as a person

You are excited about fundamental science and applying the results to solve practical problems of importance to society. We expect that you enjoy being part of a team, that you have a sense of humour, you are a good problem solver, enjoy helping others and that you are also able to work effectively and independently.

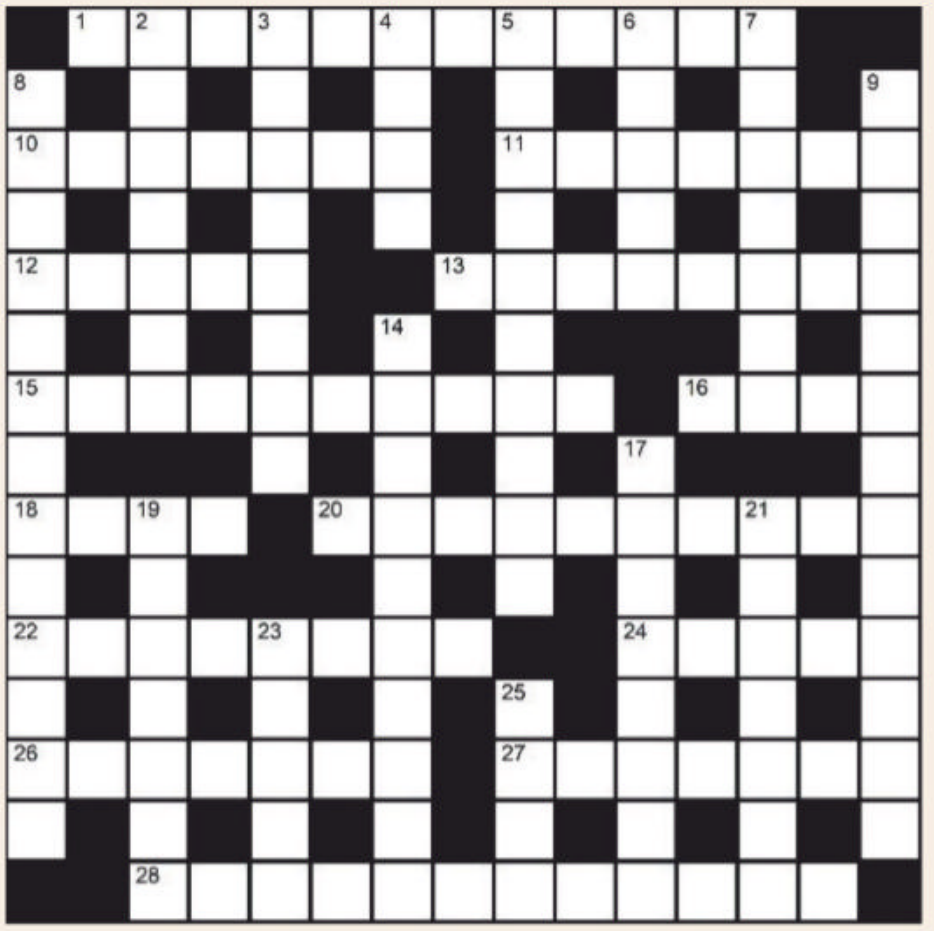
We hope to receive your application

We plan to hire 2 PhDs within the next half year. The openings are listed below but we are open to letters of interest at any time and for future positions. To learn more about the materials, projects and people, and to start your application, we refer to the homepage: **www.solid.dtu.dk**

PhD: High-Contrast Neutron Imaging for Visualising Flows in Porous Materials (Deadline 28 February 2021)

PhD: Diffraction-Based Energy-Resolved Neutron Imaging of Li-Ion Batteries under Operation (Deadline 28 February 2021)

Quick crossword #77 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Maritime heavy industry (12)
10 Eighth planet from the sun (7)
11 Where chromatids or nerve fibres intersect (7)
12 The ordinate, in a 2D graph (1-4)
13 DNA microarray (4,4)
15 Organs in the eye sockets that secrete an aqueous film (4,6)
16 Blueprint; strategy (4)
18 Foot digits (4)
20 In my opinion (2,3,3,2)
22 Origination and development of an organism (8)
24 Projection on a bird's wing (5)
26 Paul ___, German physician, originator of the "magic bullet" concept (7)
27 Set of equipment (7)
28 A "two-mover directmate", for example (5,7)

DOWN

2 Oxygen deprivation (7)
3 + (4,4)
4 Pigmented layer of the eye (4)
5 Sealed portal (6,4)
6 Functional group of two acyl groups bound to N (5)
7 Fuel also called E10 (7)
8 Saying attributed to Galileo (3,3,2,5)
9 Woodworking social insects (9,4)
14 Units equal to 12.7mm (4-6)
17 Human-made underground chamber (8)
19 Relating to the digestive tract (7)
21 Finger joint (7)
23 Of an aircraft, to fly without engine power (5)
25 Proxima Centauri or Sirius A, perhaps (4)

Quick quiz #90

1 Which species of whale has the largest mouth?

2 In October 2020, NASA announced that water particles had been found in which crater of the moon?

3 Name the type of starch that dominates in sticky rice.

4 What invention is US deep sea diver Otis Barton best known for?

5 How many elements were in Dmitri Mendeleev's original periodic table in 1869?

Answers on page 55

Puzzle
set by Zoe Mensch
#102 Passport to success

My nine-digit passport number has some remarkable properties. Not only does it use all the digits from 1 to 9, but if I label the number ABCDEFGHI, then:
A is divisible by 1
AB is divisible by 2
ABC is divisible by 3
ABCD is divisible by 4
ABCDE is divisible by 5
ABCDEF is divisible by 6
ABCDEFG is divisible by 7
ABCDEFGH is divisible by 8
ABCDEFGHI is divisible by 9

You could program a computer to find this passport number, but there are shortcuts to figuring it out with a pen and paper. For example, a number is only divisible by 3 if its digits add up to a multiple of three (eg: 372 is divisible by 3 because 3+7+2=12). And a number is only divisible by 4 if its last two digits form a number that is also a multiple of four (hence 9324 is divisible by 4 because 24 also is.)

What is my passport number?

Solution next week

Dropping off

How do our brains stop us from falling out of bed while asleep?

Michael Barry Henderson
Maroochydore, Queensland, Australia
I occasionally fall out of bed while asleep, and it hurts because I fall onto a ceramic floor. I am a toss-and-turn-in-bed person and move from one side to the other. Every now and then, it just so happens that I go over the edge.

I don't think it is a matter of your brain's control of your body, just your bed-parking.

Michael Bennett
Lowood, Queensland, Australia
I am not sure that our brains do prevent us from falling out of bed.

Recently, I dreamed that I was washed off a cliff by a large ocean wave. This must have caused me to fall out of bed because I woke up on the floor. I didn't have any history of falling out of bed or sleepwalking before this incident.

The question is: how could I have been physically transported by an external force (the wave) that I perceived to be outside

"I dreamed that a large ocean wave washed me off a cliff. This must have caused me to fall out of bed, as I woke up on the floor"

my control, acting through my subconscious mind in a dream?

This seems to be rather different from sleepwalking, in which the subconscious directs you to move. Incidentally, many years ago, I was washed over by a similar wave while rock climbing, but I was securely attached to the rock and was therefore immobile.

Larry Curley
Huntingdon, Cambridgeshire, UK
They don't. When I was a young lad, I would often fall out of bed when I was asleep. On hearing a thud, my mother would enter the bedroom and sometimes find me asleep on the floor.

David Muir
Edinburgh, UK
Rapid eye movement (REM) sleep is a recurring part of the sleep cycle and is associated with dreaming.

We are prevented from physically acting out our dreams by REM atonia, a partial paralysis of the body that is caused by the inhibition of motor neurons, the nerves that control muscles. This is brought about by neurotransmitters that affect the brainstem.

There are people who lack this inhibition and act out dreams with vocalisations and sudden arm and leg movements. This is called REM sleep behaviour disorder. People with this condition can injure themselves or their bed-partners, and they are also more likely to fall out of bed.

A more prosaic way of thinking about the origins of REM atonia is to consider our ancient ancestors, who, a few million years ago, probably built sleeping platforms in trees for their protection. Anyone who lacked the genes that control REM atonia would be more likely to fall from their platforms and be injured or despatched by ground-roaming predators.

Their genome would therefore have been removed from the future hominin gene pool, resulting in people today being less likely to land on the floor during our slumbers.

EDELMANN/SCIENCE PHOTO LIBRARY

This week's new questions

Rowdy roads **Why is the noise from traffic on roads louder when it is raining or the road is wet than it is on a dry day?** ***Kate Macdonald****, Bath, UK*

Cutting the cord **Why are the umbilical cords of human infants tied or cut, when the young of other animals don't need this intervention?** ***Patricia Hodges****, Bromsgrove, Worcestershire, UK*

Why do we cut or tie the umbilcal cord of a newborn baby?

Myopic wildlife

Many people are long or short-sighted. Is this the same for other animals, and if so, how do they cope?

Eleanor Caves
University of Exeter, Devon, UK
There aren't many studies of near and far-sightedness in non-human animals, and those that do exist are mainly restricted to primates.

However, different species of animals vary a great deal in their ability to perceive fine detail. This "visual acuity" can be measured in units called cycles per degree, which measure how much detail can be discerned in a given scene.

Humans have a visual acuity of around 60 cycles per degree, whereas for house cats, it is 10 cycles per degree. Many insects have an acuity of around 1 cycle per degree or less.

In general, visual acuity is correlated with eye size, so species with larger eyes – which also tend to have larger body sizes – have a higher acuity. This holds within species too. In my work on a freshwater fish called the green swordtail, I have found that females can have an acuity ranging from 1 to 5 cycles per degree, depending on their size.

In some insect species, males and females differ in their visual acuity. Males sometimes even have areas of their eyes with increased acuity that they use to spot fast-flying potential mates.

As for how animals cope with the limitations of their eyesight, there may be several answers. Although they may not be able to perceive fine spatial detail, this might not be detrimental to their lifestyle, so they might not need to cope. A shrimp that lives full-time on an anemone and feeds by scavenging, for example, might not require high visual acuity anyway.

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Tom Gauld
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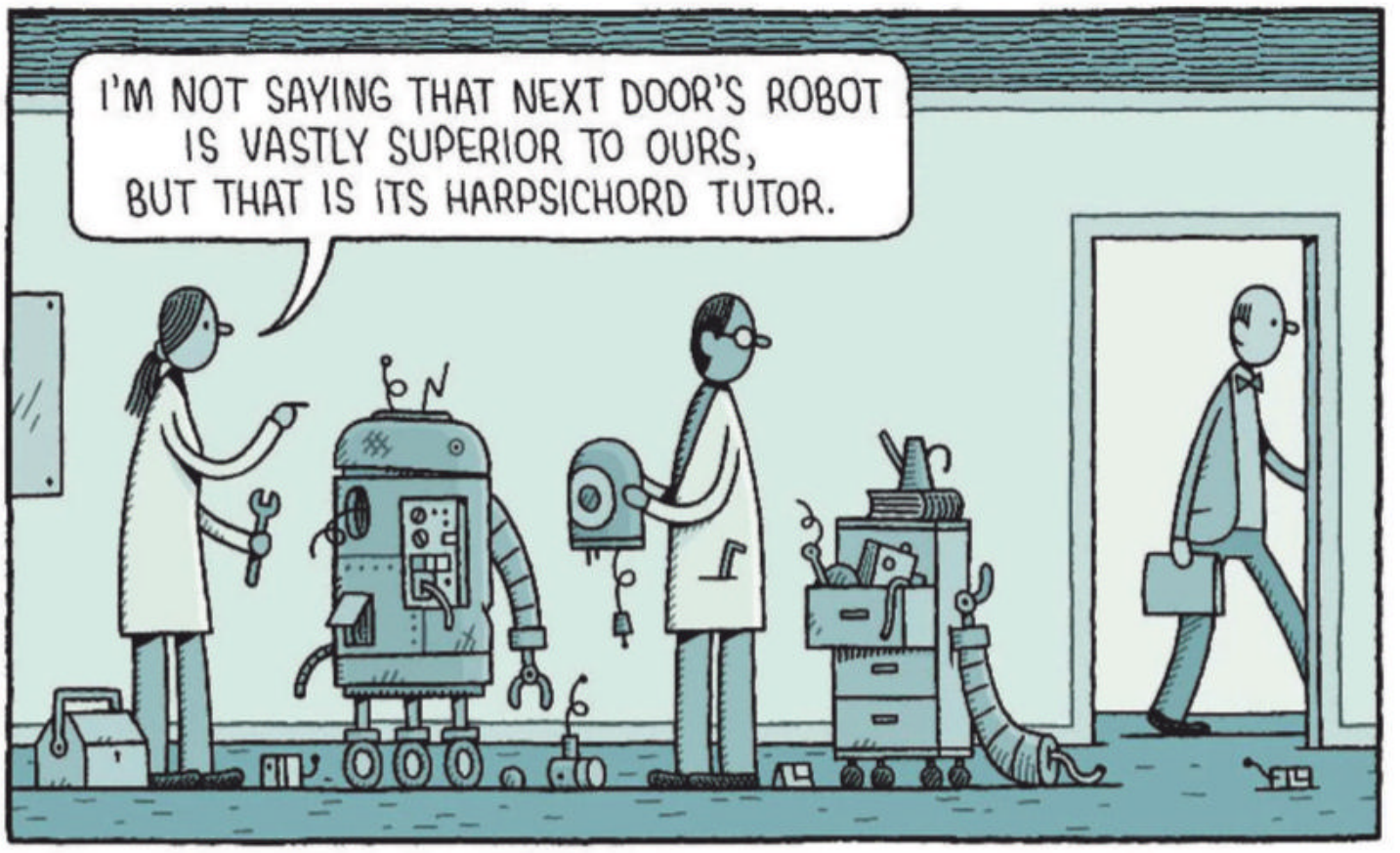


Another thing that an animal can do to discern fine detail is to move closer to objects of interest. This is because visual acuity is distance-dependent: the closer you are to something, the better you will be able to perceive it.

Some reef fish are famous for their complex colour patterns. It turns out that these probably aren't visible to other reef fish from far away and so, in fact, may function as camouflage when viewed from a distance. From close up, however, these patterns are perceivable and so can serve as signals to nearby viewers.

The animal with the sharpest eyesight is the wedge-tailed eagle, with an acuity of 140 cycles per degree, which is more than double that of humans. However, we actually have some of the sharpest vision in the animal kingdom, so it is easy for us to make assumptions about what animals can see based on our own perceptual experience, which may not be accurate.

Next time you are walking your dog or bird-watching, give some thought to the fact that the animals around you probably don't perceive the visual scenes in the same way you do.

Colour confusion


@DOLANSMALIK/TWITTER

I see the shoes (pictured) as mint green and grey, but a friend sees pink and white. Does this mean we continually see different versions of the colours around us? (continued)

Peter Calver
Stansted, Essex, UK
I looked at the picture before I went to bed and saw a grey shoe with mint-green trim. Nothing I did would allow me to perceive any other colours. I put the magazine next to the bed to show my wife the next day, but in the morning, the shoe had changed to pink with greyish-white trim.

Even looking at it from 3 metres away, it still seemed pink. Yet to my wife, it was grey and green. A few hours later, I glanced at the photograph and the shoe had gone back to grey and green!

While the lighting was different on all three occasions, once my eyes perceived one colour or the other, changing the lighting didn't seem to affect what I saw.

Paul Douglas
Wellington, New Zealand
I hate to throw a spanner in the works, but I can see both mint green and grey, and pink and white - sometimes even at the same time, but mainly in different strengths of light.

If I am outside and in normal daylight, I see a pink shoe and white laces. But if I am in my tent (I am homeless) where it is darker, I see the same picture as a grey shoe with mint-green laces.

You can try it yourself. Take a picture using a digital camera in low light and I think you will find that the pink turns grey, even in normal daylight. ▮

Answers

Quick quiz #90
Answer

1 The bowhead whale. Its mouth can be almost 5 metres long, 4 metres high and 2.5 metres wide

2 Clavius

3 Amylopectin

4 The bathysphere submersible

5 63

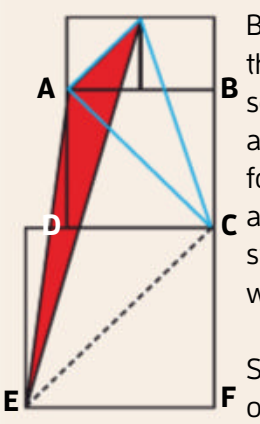
Cryptic Crossword #51 *Answers*

ACROSS 1 Sate, **3** Neap tide, **8** Numb, **9** Emergent, **11** Proportional, **13** Timing, **15** Cicada, **17** Interglacial, **20** Abomasum, **21** Marl, **22** Sinusoid, **23** Post

DOWN 1 Sunspots, **2** Tempo, **4** Enmity, **5** Periodical, **6** Ikebana, **7** Eats, **10** Roundelays, **12** Fall flat, **14** Monsoon, **16** Agouti, **18** Imago, **19** Laps

#101 Red triangle
Solution

The red and blue triangles in the illustration have the same length of base and height, so have the same area. By the same argument, the blue triangle and triangle ABC have the same area.



But ABC is half the area of square ABCD, and ABCD is four times the area of the small square, which is 8.

So the area of the red triangle is 16.

Computer says no job

Is there nowhere left where we are safe from machines judging us? They criticise our writing with their passive-aggressive squiggly underlines, tell us when we haven't taken enough daily exercise and now they are rating our suitability in job interviews.

This latest encroachment comes as some firms have started using artificial intelligence to assess people's performance in online job interviews by rating their personality traits and apparently looking at what else is in view. The approach is said to be more objective than boring old humans.

Researchers tested one AI interviewer by presenting it with actors who gave repeated performances with one variable tweaked each time, and the results were bewildering. One applicant was rated as less conscientious if she wore glasses, but more so if she wore a headscarf. People also got better scores if they sat in front of a bookcase, although at least that makes more sense. Presumably the AIs have picked up on the old mental shortcut: "reads books, must be smart".

Now that TV interviews are usually done from people's homes, those who care about their public image go to great lengths to ensure the camera happens to catch them in front of bookshelves carefully curated for maximum intellectual gravitas.

Feedback recommends the Twitter account Bookcase Credibility (@Bcredibility) for documenting this important societal trend. The account analyses people's literary (and home decor) choices in the manner of the most egregious flights of post-modernist fancy. It is a pandemic must-read.

Twisteddoodles *for New Scientist*

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Send it to feedback@newscientist.com or New Scientist, 25 Bedford Street, London WC2E 9ES
Consideration of items sent in the post will be delayed

Small world

Speaking of strange computer stuff, 32-year-old, Liverpool-based journalist Liam Thorp was baffled when he was invited to receive a covid-19 vaccine because he had no pre-existing health conditions. On ringing up his doctor to ask why, the answer came that it was his weight problem.

This took Thorp aback. True, lockdown had left him a little "on the chunky side", in his words, but not that much. The next day, however, the clinic rang back to confess an error. His weight was listed correctly as 111 kilograms, but his height was recorded not as 6 feet, 2 inches, but as 6.2 centimetres.

That gave Thorp a body mass index (BMI), the standard way of measuring obesity, of 28,000 kg/m^2, some way over the usual healthy BMI range. Thorp now understood the clinic's concern, although he did wonder why no one had been in touch earlier to check up on Liverpool's only clinically obese Tom Thumb. "I knew I had put on a few lockdown pounds but I didn't realise I'd shrunk to the size of a Borrower," he said.

When Thorp shared his story on Twitter, it emerged that he isn't the only one. One person had been previously called in for a flu vaccine because his weight had been recorded not as 170 pounds, but 170 stone – for non-imperial measurement purists, that is 14 times higher. It seems the measurement had been taken at face value, because when the man walked into the clinic the vaccinator looked at him and said: "There must be some mistake!"

Another person's height was recorded with the decimal point having jumped one place to the left, giving her a stature of 16.7 centimetres. She got as far as being ordered to see the practice nurse for "the obesity talk". Even sat down face to face with her patient, the nurse didn't catch on to the problem, and when it was pointed out, the respondent says the nurse turned "rather grumpy".

Up the creek

Lots of us are eager to be vaccinated against the coronavirus, but some are going to extremes to jump the queue. From Florida comes word of two women of 34 and 44 years old, respectively, who turned up at a coronavirus vaccination clinic dressed as "grannies", according to ABC News. Their costumes consisted of glasses, gloves and bonnets, so perhaps they were channelling 19th-century grandmothers. An officer at the scene called the incident "ridiculous".

Even more effort was put in by the wealthy Canadian couple who flew to a remote town in the Yukon territory to get the shot. The region is being prioritised in the vaccine roll-out because it is home to many Indigenous people who are at higher risk. Rodney and Ekaterina Baker chartered a private plane to fly in, and told the clinic they were local motel workers.

Feedback's theory is that their ruse was inspired by Netflix comedy series *Schitt's Creek*. It is about a self-centred and wealthy couple who lose their fortune and are forced to work at... a motel in rural Canada. Like the husband and wife in *Schitt's Creek*, Rodney is an entertainment mogul and Ekaterina an actor. The name of the small town whose vaccine clinic they crashed? Beaver Creek. The coincidences are uncanny – kind of.

The couple's actions are all the more eyebrow-raising considering that at the pandemic's start, Ekaterina posted on Instagram: "During this unique and tender time I stay home for: all the kids so they don't have to say goodbye to their parents and grandparents too soon."

It's a sentiment that *Schitt's Creek* grande dame Moira Rose couldn't have put better herself, but it must have slipped Ekaterina's mind when she visited the vaccine clinic in Beaver Creek last month.

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