New Scientist

WEEKLY January 16–22, 2021

CORONAVIRUS VACCINE ROLL-OUT

Mixing-and-matching vaccines

Which countries are doing best?

Delaying the second dose

Can the UK hit its targets?

How friendship can boost your immune response

HAVE WE GOT INTELLIGENCE ALL WRONG?

Why an obsession with IQ is holding us all back

RISE OF SUPERCONDUCTORS

An energy revolution edges closer to reality

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AN IMPORTANT MESSAGE FROM PROFESSOR NICK LEMOINE MD PHD FMEDSCI, CHAIR OF THE MEDICAL RESEARCH FOUNDATION

Gifts in Wills could be the key to protecting the future of human health

Our experience of COVID-19 shows how suddenly a global health challenge can appear. As someone interested in science, you will understand that while nobody can predict what we will face next, we can be certain that the future will bring many more threats to human health.

As Chair of the Medical Research Foundation – the charitable arm of the Medical Research Council – I have seen the incredible impact that individuals who remember the Foundation in their Wills can have on the future of our health and wellbeing here in the UK. These gifts fund research and researchers which can have far-reaching implications for human health.

With a gift in your Will you can play a key role in providing the science that will protect the health of future generations.

Right now, the Foundation is funding research to tackle antimicrobial resistance, and investing in researchers like Dr Myrsini Kaforou – who will make the fight against antimicrobial resistance her life's work.

Without support at the crucial early stages, researchers like Dr Kaforou can be forced to abandon their passion and leave science altogether, with an immeasurable loss to future human health. Gifts in Wills provide the long term funding and security that allows the Foundation to invest in projects like Dr Kaforou's and lay the foundations for quality research in years to come.

"As scientists, our duty is to secure the future of research for the generations that follow."

Professor Fiona Watt, President of the Medical Research Foundation and Executive Chair of the Medical Research Council.

Your Will can fund the rational response to health challenges that medical science provides.

While we don't know what the future holds for human health in the UK, we do know that research, and the brilliant scientists driving that research forward, are the key to meeting those challenges for years to come.

"The funding I received through the Medical Research Foundation will be transformative for my research." Dr Myrsini Kaforou

But many of these scientists rely on the generosity and foresight of fellow members of the public – people like you, who understand the power of science and are willing to leave a gift to medical research in their Wills. At the Medical Research Foundation, over 90% of our voluntary income comes from individuals who choose to include a gift in their Will – they are crucial in the Foundation's ability to fund research that will enable the next generation of scientists to make real world discoveries in the future.

I firmly believe that a gift in your Will to the Medical Research Foundation is an excellent investment and will have a lasting impact on science and on the future of human health in the UK.

Please consider this very special gift today.

Professor Nick Lemoine MD PhD FMedSci
Chair of the Medical Research Foundation

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The misunderstood science of metabolism

Why do so many diets lead to us gaining weight? Is exercise really essential to losing a few pounds? Evolutionary biologist Herman Pontzer has conducted groundbreaking studies into such questions, including work with Hadza hunter-gatherer communities in Tanzania. In this lecture, he reveals how metabolism controls every aspect of our health. Join us on 25 February from 6pm GMT or watch later on demand. Tickets are available now.

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Weekly

The facts about two new, fast-spreading variants of the coronavirus; the bones of a possible new species of human; do low-carb diets work?

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Newsletter

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Online

Covid-19 daily briefing

All the latest, most crucial coverage of the pandemic, with news, features and interviews. Updated each day at 6pm GMT.

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Metabolic boost Herman Pontzer on how metabolism really works

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Yum without the bun The health effects of a low-carb diet

SHUTTERSTOCK/IVAN SMUK

Beat the heat How new green tech could change how we keep warm

Books

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March: BRILLIANT BUGS from the beautifully iridescent and the downright scary insects that share our planet to those nasty digital bugs that spoil our time online.

April: a visit to **ANCIENT EGYPT** and the River Nile makes for a very popular topic – so not to be missed!

- ✔ **BIG IDEAS** for Curious Minds
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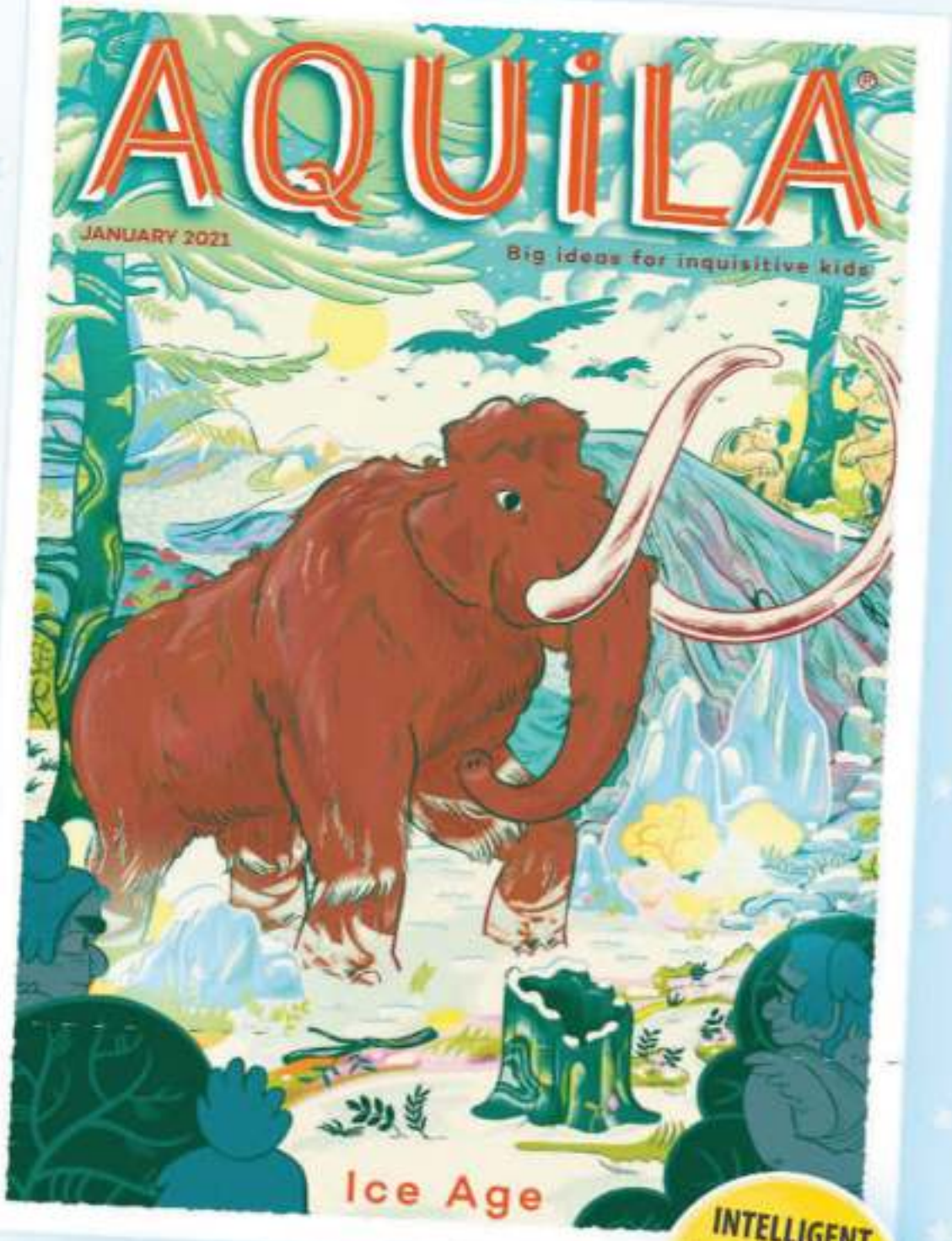

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Time to think smart

Current travails suggest we need a radical overhaul of the way we tackle problems

"It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity…"

We are just a couple of weeks into 2021 and yet that famous opening from Charles Dickens's *A Tale of Two Cities* has never rung truer. On the one hand, we are seeing the roll-out of effective vaccines against a disease that little more than a year ago was unknown to science – a stunning tribute to human wisdom, and to the power of a belief in science. On the other hand, we have the incredible scenes of an enraged mob rampaging through the US Capitol, the fulcrum of what until recently was considered one of the most secure democracies on Earth.

Will wisdom or rage set our trajectory for the coming months and years? It is perhaps too early to say, but what is clear is that the covid-19 vaccines give us grounds for hope that some form of normality will return in 2021, despite all the questions still swirling around how exactly that can best be achieved (see pages 8-10).

What is equally clear, however, is that if and when covid-19 is contained, business as usual isn't an option. The pandemic has ruthlessly exposed the divisions, inequalities and structural weaknesses of societies around the world, not least in established Western liberal democracies such as the US and UK. Meanwhile, global problems such as climate change haven't gone away – 2020, we now know, was the joint hottest year on record (see page 14).

"The pandemic has ruthlessly exposed divisions and inequalities around the world"

To see how best to move on, we would perhaps be wise to ask ourselves how we got here. On page 36, human development researcher Robert J. Sternberg makes the case that at least part of the problem lies in our faulty conceptions of what it means to be smart. Prioritising and rewarding a very limited idea of intelligence has exacerbated social, economic and racial inequalities, while fostering a "me first" culture that leaves us ill-equipped for the collaborative problem-solving we need if we are to survive and thrive as a species.

It is a bold, compelling hypothesis and such back-to-basics thinking may be exactly what we need if, to continue with Dickens's words, a spring of hope is to follow this winter of despair. ▮

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Q: FASCINATED BY QUESTIONS ABOUT THE HUMAN BRAIN BUT DON'T KNOW WHERE TO BEGIN?

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A patient in Brooklyn, New York, arrives at hospital

Coronavirus

UK variant spreads in US

Ten US states have recorded cases of the UK variant, while Australia has brought in measures to curb its spread, report **Donna Lu** and **Adam Vaughan**

THE highly contagious B.1.1.7. variant of the coronavirus, which was first detected in the UK, has officially reached 10 states in the US, but infectious disease experts say the true extent of its spread is unclear due to a lack of monitoring.

Texas, Minnesota and New York are among the states that have detected the variant. Given it has been found in 10 states, it is likely to be present in more, says Lane Warmbrod at Johns Hopkins University in Maryland. Still, she says, "it is hard to know how widespread the variant is because we don't have sufficient genetic epidemiology capacity or capability in the US".

William Hanage at Harvard University says the overall picture is unclear due to insufficient monitoring. Community spread is occurring in at least California, Florida and Colorado, he says, though in each community the variant is rare – for now.

The variant probably accounts for about 1 per cent of cases in the US today, estimates Eric Topol at Scripps Research Translational Institute in California. But the picture is foggy, he says. "Surveillance is extremely poor."

New daily cases in the US currently stand at 245,000 for the seven-day average, but Gigi Gronvall, also at Johns Hopkins University, says the UK variant isn't the reason for the surge in transmission. "The variant is almost certainly not driving our current explosion of cases, or we would have more immediately found it in many states," she says.

Even if B.1.1.7. isn't yet driving an acceleration in US cases, there is reason to think it will in the future, says Warmbrod, given research in the UK has found it to be between 40 and 70 per cent more transmissible than earlier variants. When the variant is established in the US, says Topol, it will trigger "a major surge that makes the US holiday surges look minimal".

Surveillance to detect the spread of the variant in the US is poor, but not as bad as some recent media reports suggest, says Gronvall.

"It's terrible by comparison with the UK. Recall that the UK has sequenced around 5 per cent of cases, which is huge. The comparative figure in the US is 10 times smaller," says Hanage.

In Australia, where the spread of the coronavirus has been brought under control so far, detection of the UK variant has led to swift action to try to prevent any new outbreaks. On 7 January, a cleaner for a hotel quarantine facility in Brisbane tested positive for the variant. It had previously only been detected in returning international passengers in hotel quarantine, but this is the first time someone had been in the Australian community while potentially infectious.

"The UK variant will trigger a major surge in the US that will make the holiday surges look minimal"

The following morning, with no further positive cases, Queensland state premier Annastacia Palaszczuk announced a short, citywide circuit-breaker lockdown affecting some 2 million residents.

The city, where life has been normal for months, hadn't locked down since the first wave in Australia in March.

"Doing three days now could avoid doing 30 days in the future," said Palaszczuk on 8 January.

Within days, contact tracers identified around 150 of the cleaner's casual and close contacts, who have all been quarantined. The city recorded only one new case of community transmission during the lockdown period – the cleaner's partner – but it is too early to rule out further transmission. "We have to wait two weeks since the last possible exposure that index case had," says Raina MacIntyre, an infectious diseases expert at the University of New South Wales in Sydney.

In response to the threat posed by new variants, the Australian government has brought forward its plan for mass vaccinations by a month. They are now set to start in February.

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

Analysis

Vaccine dosing controversy

Faced with surging covid-19 cases and a fast-spreading virus, the UK has altered its vaccination strategy. Is that wise, asks **Clare Wilson**

IN A bid to vaccinate as many people as fast as possible, the UK is taking an unorthodox strategy against covid-19. The country is eking out its vaccine supply by making most people wait three months to get their second dose of the two-shot regimen.

Both vaccines currently being used in the UK were intended to be given over much shorter timescales. Changing a medicine's dosing schedule so dramatically is unprecedented, and some experts have branded it a dangerous gamble, putting lives at risk. But what does the evidence say?

The UK announced its approach on 30 December as it was battling a huge surge in covid-19 cases, partly driven by a new, more transmissible variant of the virus.

This was the same day that the vaccine developed by the University of Oxford and AstraZeneca was approved, and it was immediately put on a timescale of up to 12 weeks between doses.

The UK government also announced that the interval between doses of the vaccine developed by firms Pfizer and BioNTech would be stretched to the same duration. By then, more than 600,000 people had already been given their first injection since the immunisation drive began on 8 December.

Many scientists were shocked by the move because it deviates from the dosing schedules intended in the vaccine trials: three weeks for the Pfizer/BioNTech vaccine and four weeks for the one from Oxford/AstraZeneca.

"A trial tells you that something works, so why would you change that?" says Stephen Griffin at the University of Leeds, UK.

The approach makes most sense for the Oxford/AstraZeneca vaccine because its trial results hint that it works better with a longer wait between the doses. Some people in the trials ended up getting their second shot up to 12 weeks after the first, and the vaccine's effectiveness at preventing symptoms was 65 per cent in this group, compared with 53 per cent in the rest.

DOMINIC LIPINSKI/POOL/AFP VIA GETTY IMAGES

People wait for a covid-19 shot at a vaccination centre in Epsom, UK

> **"We had to get over ourselves and take a pragmatic view. We are in an emergency"**

The numbers involved were small, though, with only about 1800 people getting a delayed second dose. The participants also weren't randomised to the different schedules, so this wouldn't normally be seen as good enough evidence to support such a major change to dosing.

The move to delay the second shot was even more surprising for the Pfizer/BioNTech vaccine, for which all participants in the trials got their second dose after about three weeks. Pfizer and BioNTech say that two doses of its vaccine are required to provide the highest protection against the disease.

There is some evidence to support the change. In a letter to doctors, the UK's chief medical officers said that the Pfizer/BioNTech vaccine's trial shows a good level of protection even before the second dose is administered. The trial results indicate that the efficacy was 89 per cent from 15 days after the first dose. The vaccine has been found to offer 95 per cent protection from covid-19 overall, after both doses are given.

Data from a third vaccine, developed by biotech firm Moderna, showed a similar response after one dose, lasting for 15 weeks. The vaccine – like the Pfizer/BioNTech one – uses mRNA technology, and has been authorised for use in the UK but roll-out hasn't yet begun.

The extended dosing schedule is deemed necessary by the UK government on public health grounds. "The great majority of the initial protection from clinical disease is after the first dose of vaccine," the chief medical officers said in the letter to doctors, adding that immunising many people in the next three months is better than reaching half that number with two doses to give only slightly greater protection.

The only way that the longer schedule would lead to more deaths from covid-19 overall is if the delay more than halves the amount of immunity provided by the first dose, which is highly unlikely, says Stephen Evans at the London School of Hygiene & Tropical Medicine. "The numbers are so obvious."

There are wider considerations, however. Leaving people with only partial immunity to covid-19 for many weeks could make the virus more likely to evolve vaccine resistance, England's chief medical officer Chris Whitty has acknowledged, although he said it was "quite a small worry". On the other hand, if vaccination roll-out were slower, more people would be exposed to infection, which also raises the chance that the virus evolves those critical mutations.

Another concern is that the extended dosing schedule could reduce the number of people who

come back for their second shot. "The longer you leave it, the more time there is for people to forget," says Deborah Dunn-Walters at the University of Surrey, UK, who is chair of the British Society for Immunology's covid-19 task force. The change also raises ethical issues for the people who were given the first dose on the understanding that the second would follow three weeks later as per the trial data.

Overall, it is possible that the shift, and the controversy around it, will undermine confidence in the vaccine programme.

The scientific community is divided on the question of whether the UK strategy is a good one. The US Food and Drug Administration said in a statement that changes in vaccine administration could place "public health at risk".

Legal issues

The answer may depend on whether you take the perspective of an individual or think of the whole population. Much of the backlash has come from the US, where overall public health has a lesser role in the medical system.

The US is also more litigious than the UK, says Evans. Someone in the US who catches covid-19 two months after their first vaccine shot could sue their doctor for delaying the second dose. But a doctor can't be held responsible by infected people if they haven't yet received a vaccine at all.

The British Society for Immunology's covid-19 task force had initial concerns about the changes to the dosing schedule, and sought more information from England's chief medical officer about the evidence. In the end, the society put out a statement backing the decision.

A separate criticism of the UK programme is that it supports giving people a different vaccine for their second dose from the one they received initially, in a mix-and-match strategy. Critics of the tactic include John Moore at Cornell University in New York, who has said that by doing this the UK is "abandoning science".

The move is less controversial than it appears. The UK has only said that vaccines could be mixed if someone was due to receive their second shot and there is no matching vaccine available, or if it is unknown which type they got initially.

Mixing the shots might even give better immunity. Previous work on other vaccines suggests that injecting someone with the same virus proteins in a different package provokes a stronger immune response. Known as a "prime-boost" strategy, it has been investigated in vaccines against HIV and malaria.

The debate rolls on, but the UK may not be an outlier for long. Last week, Denmark approved a delay of up to six weeks between the first and second shots of vaccine, and the German health ministry is debating a longer wait still, according to media reports. "There's still quite a bit of debate, although I feel there's a tilt towards a more flexible schedule," says Leif Erik Sander at Charité – Berlin University of Medicine, who has argued for a delay between doses.

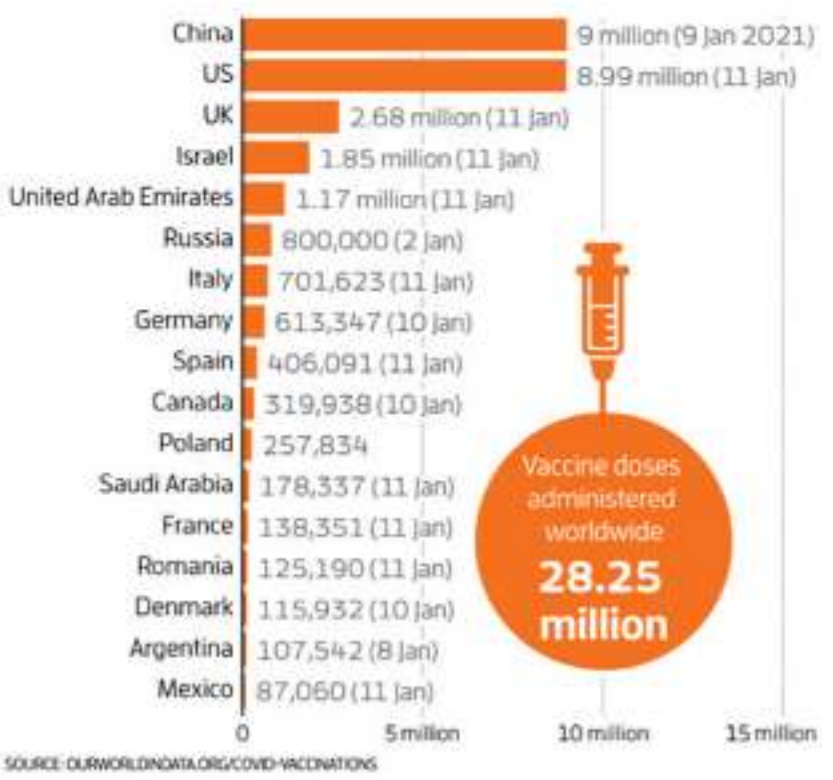
Even if the change to a delayed schedule isn't ideal because it deviates from the time periods that were tested in the vaccine trials, the decision needs to be taken in the context of the pandemic, says Dunn-Walters. "We had to get over ourselves and take a pragmatic view," she says. "We are in an emergency." ▮

Immunisations

Vaccine roll-out around the world

Covid-19 vaccine doses administered

There is great variance between countries in how many doses of vaccines have been given to people so far. The total number of doses administered is shown here for selected countries, which may not equal the total number of people vaccinated, because multiple doses of some vaccines are needed



Covid-19 vaccine doses administered per 100 people

The total number of individual vaccine doses given per 100 people (only selected countries shown). This may not equal the total number of people vaccinated because multiple doses of some vaccines are needed

Israel 21.38 (11 Jan)
United Arab Emirates 11.8 (11 Jan)
UK 3.94 (11 Jan)
US 2.72 (11 Jan)
Denmark 2 (10 Jan)
Italy 1.16 (11 Jan)
Spain 0.87 (11 Jan)
Canada 0.85 (10 Jan)
Germany 0.73 (10 Jan)
Poland 0.68
Romania 0.65 (11 Jan)
China 0.63 (9 Jan)
Russia 0.55 (2 Jan)
Saudi Arabia 0.51 (11 Jan)
Argentina 0.24 (8 Jan)
France 0.21 (11 Jan)
Mexico 0.07 (11 Jan)

SOURCE: OURWORLDINDATA.ORG/COVID-VACCINATIONS • CC BY

Analysis

Can the UK hit its vaccine target?

The UK may struggle to vaccinate nearly 14 million people by mid-February

Adam Vaughan

THE UK's race to vaccinate 13.9 million people in high-priority groups against covid-19 by 15 February is a Herculean undertaking. "Unprecedented" may have become an overused word in the pandemic, but the size and speed of the vaccine roll-out warrants it, though it may still be months before many people receive a covid-19 vaccine.

The numbers tell the story. Figures released on 11 January showed that nearly 2.3 million people in the UK have had a first dose of one of the three vaccines approved by the UK regulator. On

"The supply of doses from vaccine manufacturers is the rate-limiting step in vaccinating the public"

that same day, the UK government said it aims to be vaccinating at least 2 million people a week in England by the end of this month. To reach the mid-February UK target that prime minister Boris Johnson announced on 4 January, 300,000 doses need to be given a day, roughly the rate doses were administered weekly at the end of December and start of January.

"This is the biggest vaccine programme ever that the UK has had to roll out. It's definitely new territory," says Doug Brown at the British Society for Immunology. The biggest previous vaccination effort in the UK, for the flu, normally sees around 9 million people a year vaccinated. That happens over five months starting in September, with 60,000 doses a day on average, peaking at about 150,000 a day in late October.

And there are key differences between flu vaccines and covid-19 ones, says Nilay Shah at Imperial College London. The big one is that flu vaccine manufacturers, and the regulators who then do quality

KIRSTY O'CONNOR/AFP/GETTY IMAGES

The Oxford/AstraZeneca vaccine is one of three approved for use in the UK

control on the batches of vaccines after they are made, have about five months to build up huge stocks before they are used.

By contrast, covid-19 vaccine makers are still in the start-up phase. Mass production of the active ingredients inside the vaccines has been under way for months, but companies don't start putting doses into vials until closer to regulatory approval.

The other inherent hold-up in the start-up phase is the quality control process. In the UK, this involves finished vaccines being sent to a lab to check they have enough of the active ingredient, make sure there are no impurities, test for sterility, and more. The sterility test alone takes at least 10 to 14 days, building in a lag.

UK health secretary Matt Hancock has said the supply of the doses from manufacturers is the "rate-limiting step". Brown agrees. "The biggest bottleneck does seem to be the vaccine supply issue," he says. Reports suggest a few million doses are ready for use on priority groups of the UK population, with 15 million more working their way through the quality checks.

Sandy Douglas at the University of Oxford, who led work to scale up manufacture of the vaccine Oxford created with AstraZeneca, says flu vaccines are made with an existing manufacturing process with slight tweaks depending on the strain of flu virus. For the coronavirus, the processes are new. "People need to understand how difficult it is to get it going for the first time," he says.

A medical worker in the US gets a dose of the Pfizer/BioNTech vaccine

JOSEPH PREZIOSO/AFP/GETTY IMAGES

Until this week, around 210 hospitals and 780 centres run by family doctors were the main sites for vaccinations in England, but seven mass vaccination centres have now opened. Across the UK, a mix of sites will be used, including hospitals, doctors' surgeries and mobile units.

The Pfizer and BioNTech vaccine made in Belgium and the Oxford/AstraZeneca vaccine made in the UK were the first two approved for use by the UK regulator, followed on 8 January by the vaccine created by US firm Moderna.

The European Union approved Moderna's vaccine on 6 January. Some European countries, in particular Belgium and France, have come in for criticism for bureaucratic delays to their vaccine roll-outs after the Pfizer/BioNTech vaccine was approved on 21 December.

Israel, with its relatively small population of 9 million, is the world leader for number of doses given, at 21.38 per 100 people, although this doesn't include the 5 million Palestinians in Gaza and the West Bank. The UK is highest in Europe, at 3.94 per 100 people, according to figures collated by Our World in Data on 12 January.

Israel has reportedly been able to get six doses out of a Pfizer/BioNTech vaccine vial rather than the five each is meant to hold, while the UK is only getting five.

The UK's target will be a tough challenge and opinions differ on whether it can be met. "We will struggle with the February target because I think we will take at least another three or four weeks to get [to peak, steady production of vaccines]", says Shah. "I think this is an achievable target," says Douglas, "but it still requires everything to go smoothly."

Immune system

Positive mood and good friends can boost response to vaccines

Marta Zaraska

AS COVID-19 vaccine roll-out begins in earnest in many countries, there is an extra reason to be cheerful. Such an outlook, along with other personality traits and the kinds of social interactions we have, can enhance how our bodies react to immunisations.

"There is now a large literature that shows that these sorts of psychological factors influence how people respond to vaccinations as measured by magnitude of antibody response," says Anna Marsland, a psychologist at the University of Pittsburgh in Pennsylvania.

In one of the first studies of its kind, in 2006, Marsland and her colleagues found that people who described themselves as energetic, cheerful or relaxed produced a 73 per cent greater antibody response to vaccination against the virally transmitted disease hepatitis B than those who regarded themselves as more nervous, tense or angry.

Since then, numerous studies have expanded our understanding of the impact these so-called soft drivers of immunity can have.

Other research, for instance, has found that even your mood on the day of an immunisation can make a difference. Among 138 older people, those who were in a positive state of mind on the day of a flu shot were better protected by the vaccine 16 weeks later than those who were in a less upbeat mood. The study examined other factors that might have an influence, such as sleep and physical activity in the run-up to the vaccination, but none of these had a significant effect.

Similarly, optimism can act as a vaccine boost, while neuroticism is linked to a poorer antibody response to immunisation.

Social connections can also influence how well our body responds to a vaccine. In one experiment, 83 students receiving a flu shot were asked to name up to 20 people they knew well and with whom they were in contact at least once a month. At check-ups one month and then four months later, those who had listed fewer than 13 friends produced significantly fewer antibodies to the influenza virus.

DGL IMAGES/GETTY IMAGES

Similar effects have been found with the hepatitis B vaccine: students reacted better to it if they felt they had someone who listened to them when they needed to talk or who could help them if they were confined to bed.

10%

The boost in antibodies after a flu vaccination for those happily married or cohabiting

Romantic love, too, appears to be good for vaccinations. One study by a team at the University of Birmingham, UK, found that older people who were highly satisfied with a spouse or partner they were cohabiting with saw their antibody levels rise 10 per cent higher on average in response to the flu vaccine compared with those who were single or in unhappy relationships.

Knowing there are people you can rely on can amplify vaccine response

The link between emotions, relationships and the immune system makes sense from an evolutionary perspective, says Steve Cole at the University of California, Los Angeles. In general, our immune systems evolved to have two basic settings, he says: an antiviral one and an antibacterial one.

In our evolutionary past, being with people meant more exposure to viruses, while being alone on the savannah meant a greater risk of wounds, be they from predators or accidents, which require an inflammatory, antibacterial response, he says. "The immune system doesn't have an infinite capacity and so it shifts resources back and forth between different modes of defence," says Cole.

Even though things that stress us out these days don't routinely injure us – think mortgages or work deadlines – chronic stress and loneliness might switch our immune system from the antiviral setting to the antibacterial one.

In contrast, a positive emotional style, says Cole, may help prevent such an automatic switch to the inflammatory setting when we are feeling lonely – it is as if optimists didn't believe they might be attacked by lions while alone.

Research, including randomised trials, confirms this on a biological level: kindness, optimism and social inclusion have all been shown to switch the genes of the immune system away from an inflammatory response towards gearing the body to fight viruses.

When it comes to the coronavirus vaccines, if they act like other shots, says Marsland, "there is reasonably consistent evidence that psychological factors will relate to the magnitude of antibody response".

Based on her work on hepatitis B immunisations, Marsland believes that such variations may be more pronounced after the first dose, levelling out after the second one.

For Cole, the nub of the issue lies in whether these factors will influence how long the protection will last. "That's our big challenge: how can we prevent this kind of stress biology from quantitatively impairing the vaccine responses, so they look good at first, but they decay relatively quickly," he says. Chronic stress in its many forms, social isolation included, has been repeatedly shown to undermine the immune system and the vaccine response.

The research is all the more crucial given the mental toll of the pandemic and the isolation that can come with social distancing.

One thing is certain, however, although stressing out about your antibody production isn't the way to go, talking to a loved one to boost your mood before your coronavirus shot certainly won't hurt. ▮

Technology

Robot duo set to plant trees

Pair of automatic foresters could plant thousands of seedlings in a day

David Hambling

THE Tin Woodman first appeared in Frank Baum's *The Wonderful Wizard of Oz* 120 years ago. Now real robot foresters are making their debut, planting trees rather than cutting them down.

The robotic foresters are the work of Milrem Robotics in partnership with the University of Tartu, both based in Estonia. Two versions are under development based on the company's range of driverless ground vehicles. One type is a planter, the other a brush cutter, and both are autonomous. Each is the size of a small car and weighs about a tonne.

The planter carries more than 300 seedlings at a time and will plant a hectare of new forest in 5 to 6 hours, totalling between 1000 and 3500 seedlings depending on the species. It also records the exact location of each tree. Armed with this data, the brush cutter, equipped with a cutting tool and precision sensors, removes vegetation around the seedlings.

Gert Hankewitz at Milrem Robotics says the robot foresters' tracks exert less pressure on the ground than human feet and won't damage the soil. Precise navigation is challenging, though, and requires a combination of laser-based LIDAR sensors, cameras and GPS.

MILREM ROBOTICS

One of Milrem's earlier robots, similar to the foresters in development

LIDAR provides a 3D geometric representation of the environment, but gives relatively little data. High-resolution camera images fill in the gaps. "All the data is fused in real-time, complementing each other, and making autonomous driving in a forest a possibility," says Hankewitz.

The cameras are also used for image recognition, and provide a visual display for the operator if they need to drive the robot manually.

The plan is for the robots to be largely autonomous, which presents challenges in surroundings that are unstructured and chaotic, unlike the open roads faced by self-driving cars and other robots.

Developers are tackling this with machine learning, using simulations for conditions that may not occur frequently in real life. This means the robotic foresters should be able to tell whether they can cross a given slope, ditch or stream, for example, without getting stuck.

"The robotic foresters will carry out the operation almost autonomously," says Hankewitz. "The human operator, who will supervise four or five robotic foresters, will intervene only when necessary."

The hope is the robot foresters will cost less than manual forest replanting or mechanised approaches with excavators.

Many countries around the world are looking to plant huge numbers of trees to help fight climate change. There are several plans to plant a trillion trees, which would add to the 3 trillion we currently have.

Andrew Davison at Imperial College London says that in a cluttered forest the cameras and LIDAR sensors complement each other and enable the robots to identify obstacles and plot a course as they go.

3500

The upper estimate for seedlings one of the robots could plant a day

"This is one of many interesting applications emerging which show that mobile robotics technology is maturing fast and enabling robots to tackle new types of task in difficult environments," says Davison.

Development of both robots is scheduled to be completed this year. ▮

Astronomy

White dwarfs seen eating remnants of destroyed planets

FOUR distant white dwarfs, the remnants of dead stars, have been spotted consuming what could be the crust of pulverised planets.

Mark Hollands at the University of Warwick, UK, and his colleagues have discovered that the material is similar to Earth's crust, which could help reveal whether the formation of our own planet is a common process throughout the galaxy.

The spectrum of light emitted by white dwarfs is, unsurprisingly, very white – "like a blank sheet of paper", says Jay Farihi at University College London. So, when an astronomical body hits a white dwarf, its material leaves a signature in the spectrum of light that comes from the star, allowing astronomers to determine what the other body was made of.

The chemical elements seen polluting the spectra of white dwarfs often match what we would expect to see from asteroids, the cores and mantles of planets, or the material you would see if you crunched up the whole of Earth, says Amaury Triaud at the University of Birmingham in the UK.

NASA/SPL

Artist's rendering of a white dwarf surrounded by a ring of debris, with an asteroid breaking up under the gravity of the star

But Hollands's team has spotted four white dwarfs whose spectra contain pollution with a chemical profile that has the same ratio of lithium, sodium, potassium and calcium as Earth's crust alone does (arxiv.org/abs/2101.01225).

"It might be that it's a planet that got destroyed, where bits of crust flew at some point into the white dwarf," says Triaud. He says this could be an opportunity to learn whether the formation of Earth-like continental crust and plate tectonics are common throughout the galaxy.

Fahiri says there are large uncertainties in the data from Hollands's team, and doubts whether the spectrum pollution can be confidently interpreted as being from planetary crust rather than coming from asteroids or other planetary material. ▮

Joe Paul

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Analysis Gene editing

UK may allow gene editing in crops

If a consultation leads to the use of tiny DNA changes to improve the nutrition of food, it could be a potential benefit of Brexit, finds **Michael Marshall**

THE UK government is exploring the possibility of using gene editing to modify livestock and food crops, for instance to make crop plants resistant to disease. Gene editing is strictly regulated in the European Union, in what virtually amounts to a ban, but now the UK has left the EU it has some freedom to set its own rules.

The consultation was announced by environment secretary George Eustice at the Oxford Farming Conference last week.

"Gene editing is a mechanism to precisely edit the genome of an organism," says Lesley Torrance at the James Hutton Institute in Dundee, UK. Instead of inserting entire genes, or changing DNA at random, gene editing allows for highly specific changes, even altering a single "letter" of an organism's DNA sequence.

This is made possible using a technology called CRISPR-Cas9, which in 2020 won two of its pioneers the Nobel prize in chemistry.

One potential use of gene editing is to improve the iron content of white flour, says Janneke Balk at the John Innes Centre in Norwich, UK. In the UK, the law requires that white flour must contain a minimum amount of iron, so the iron is added artificially. Balk's lab is exploring ways to create high-iron wheat by gene editing.

However, before Brexit, such crops had little chance of reaching supermarkets, because the EU has a fraught history with genetic modification. It has strictly regulated "transgenic" crops, which carry genes transplanted from other species. Genetically modified crops like these prompted the 1990s scare around "Frankenfoods" and were opposed by environmental groups like Greenpeace. This opposition was primarily cultural, because the health and environmental risks from these crops were minimal.

Gene editing causes much smaller changes than wholesale gene transplants – no more significant than those associated with a technique used by plant breeders for decades. Since the 20th century, breeders have often created mutations at random by exposing seeds to chemicals or radiation. Plenty of foods were made this way.

1

Gene editing is so precise it can change one "letter" in a genome

For this reason, many researchers had hoped that gene editing would escape the stringent regulation that has stymied transgenic crops in the EU, and instead be governed by the more permissive regulations used for conventional breeding and radiation mutagenesis. However, in 2018, the European Court of Justice ruled that gene-edited crops should be treated as equivalent to transgenic crops, and subjected to the same lengthy approval process.

"Before the ruling from the European Court of Justice, it was eaten in the EU in a limited way, because various countries had independently made a decision that actually, if it is just this small mutation that isn't different from something you can do naturally, it shouldn't be treated as GM," says Wendy Harwood, also at the John Innes Centre.

For many crop biologists, the situation is bizarre. "Radiation mutagenesis creates massive random mutations across the entire genome, yet plants produced by this process do not undergo the same regulatory regime [as gene editing]," says Torrance.

Leaving the EU's gridlocked approval system for gene editing is a potential benefit to the UK from Brexit, although it isn't yet clear how much the UK government plans to change the rules.

For Balk, every new crop should be judged on its own merits. "What gene is it, what have you changed, have you checked everything, yes or no?" she says. Whether the genetic change was achieved by CRISPR, radiation or something else is secondary to its actual effect, she argues. ▮

Rapeseed can be modified with gene editing

JT IMAGES/GETTY IMAGES

Environment

2020 was the joint hottest year on record

Adam Vaughan

LAST year was the joint hottest globally and by far the warmest year recorded in Europe, making the years from 2015 onwards the warmest six worldwide on record.

Global average temperatures in 2020 tied with 2016 at 0.6°C above the long-term average – despite the absence of an El Niño event, a climate phenomenon that has a warming effect. There was an El Niño in 2016.

Europe, by contrast, demolished records by a wide margin in 2020, at 1.6°C above the long-term average. The previous record was 2019, which was 1.2°C above the average.

The figures were released by European Earth observation programme Copernicus. Aggregated figures due shortly from other major data sets, including those of the UK Met Office and US agencies NASA and the National Oceanic and Atmospheric Administration, may yet relegate 2020 to the second or third warmest year on record.

Copernicus's 2020 figures show a clear north-south split, with below-average temperatures in the southern hemisphere and above-average ones in the northern hemisphere. Siberia and other parts of the Arctic reached 3 to 6°C above average in some regions.

Figures published last week by Mark Parrington at Copernicus also show that, while media attention focused on exceptional blazes in the US and Australia, global carbon emissions from wildfires were at one of their lowest levels in two decades in 2020 due to below-average fire activity in Africa.

Separately, the UK Met Office said it expects carbon dioxide levels in the atmosphere this year to pass the milestone of being 50 per cent higher than before the industrial revolution, reaching 417 parts per million between April and June, when seasonal CO_2 levels peak. ▮

Animal behaviour

Sneaky spiders trap frogs

Huntsman spiders stitch leaves together to lure in tree frogs

Joshua Rapp Learn

DOMINIC MARTIN

HOME is your sanctuary, unless you are a tree frog and a nice-looking retreat contains a spider seeking to make a meal of you.

Researchers in Madagascar found a trap in which a huntsman spider (*Damastes* sp.) was feasting on a tree frog (*Heterixalus andrakata*). "The spider had grabbed the frog and was starting to suck out the body of the frog," says Dominic Martin at the University of Göttingen in Germany.

His colleague, Thio Fulgence at the University of Antananarivo in Madagascar, noticed that the spider had been hiding between leaves it had stitched together with its silk. In the following weeks, he found three other instances of leaves sewn together, with huntsman spiders waiting at the back (*Ecology and Evolution*, doi.org/fqc7). The spiders may build these traps specifically to catch tree frogs, which hide from predators in overlapping leaves. ▮

Environment

Pollution made Hurricane Harvey worse

AIR pollution can worsen the local effects of hurricanes, according to a study of 2017's devastating Hurricane Harvey.

Harvey was "one of the biggest hurricanes in the history of the US", says Renyi Zhang at Texas A&M University. It struck Texas and Louisiana in August 2017 and caused particularly severe flooding in the city of Houston, Texas. More than 100 people were killed and the storm also gave rise to major economic losses.

Even at the time, many scientists argued that the severity of Harvey's impact was a catastrophe partly of our own making. For example, Houston's many tall buildings may have funnelled water vapour upwards, making the rainfall and therefore the flooding worse.

Zhang and his colleagues now have evidence that another human-linked factor was at work: aerosol pollution from the many petrochemical plants and factories surrounding Houston.

For rain to fall, water vapour in the air must condense to form droplets of liquid water. "To form droplets, you need cloud condensation nuclei," says Zhang. These can be particles of dust or sand, but they can also be aerosol particles released from burning fossil fuels.

The team found that the heaviest rainfall occurred in the regions around Houston's petrochemical plants. Lightning also clustered there: 230,000 lightning strikes occurred over three days in those regions when the hurricane was stalled over the coastlines of Texas and Louisiana (*Geophysical Research Letters*, doi.org/fqdj).

Zhang and his colleagues used a computer model to simulate Hurricane Harvey's effects in two scenarios: one that included the aerosols from petrochemical plants and one without them. When the aerosols were removed from the simulation, both the flooding and the lightning strikes were reduced and no longer matched the observations. The team estimates that the aerosols doubled both rainfall and lightning in central Houston.

"If you keep injecting aerosols into the storm, you're going to cause more flooding and lightning"

Zhang says the next time a hurricane approaches, it might be wise to shut down petrochemical plants for the duration. "It does seem like if you keep injecting the aerosols into the storm when there's a hurricane, you're going to cause more flooding and lightning." ▮

Michael Marshall

Astrophysics

Black holes leak energy when they eat nearby plasma

Robert Lea

BLACK holes may be cosmological engines. When their magnetic fields disconnect and reconnect, they can accelerate plasma particles near the event horizon – the point beyond which nothing can escape a black hole's gravitational pull.

We expect black holes to spin because they are formed out of a collection of matter that is spinning before it condenses. Around a spinning black hole, there are magnetic fields, which are dragged along and can influence the direction of matter falling towards the event horizon. These provide the power to the engine.

Luca Comisso at Columbia University in New York and Felipe Asenjo at Adolfo Ibáñez University in Chile analysed the effect of those magnetic fields on plasma particles near the event horizon. Some particles are accelerated by the breaking and rejoining of magnetic field lines, and others are decelerated, acquiring "negative energy". A black hole can drag space-time – the fabric of space itself – along with it, flinging some particles away while others pass the event horizon and fall into the heart of the black hole.

When the black hole swallows the decelerated plasma particles and the accelerated particles escape, the black hole's energy decreases, say Comisso and Asenjo (arxiv.org/abs/2012.00879). "It is because of this strong rotation of the space-time very close to the event horizon of the black hole that particles can take a negative energy value," says Comisso. "It's similar to a person eating candies with 'negative calories' and losing weight."

Roger Blandford at Stanford University in California says this finding could help us understand the full picture of how black holes lose energy, and how magnetic fields lead to the jets of matter and energy seen around black holes. ▮

Evolution

Origins of music linked to daredevil behaviour

Colin Barras

OUR primate ancestors might have become "protomusical" to advertise their ability to perform death-defying leaps from tree to tree.

Why humans make and appreciate music is an evolutionary mystery. "Music is a hugely important part of our lives and often involves powerful emotions," says Edward Hagen at Washington State University. But he says we still don't fully understand why it has this hold over us.

David Schruth at the University of Washington and his colleagues have a new explanation. They say the roots of human music can be traced back to the branches of trees more than 50 million years ago, when the first primates appeared. Fossil evidence suggests that those early primates moved around the forest canopy by leaping from branch to branch, a perilous way to travel that relies on extremely good hand-eye coordination and muscular control.

Schruth's team argues that early primates would have benefited if they could judge the acrobatic skills of their peers and

"Species that leap and swing the most tend to have more complicated calls"

identify suitable mates or avoid territorial confrontations with more accomplished leapers. Singing might have helped. Put simply, a primate that calls in an elaborate, musical way is advertising that it has fine control over its vocal cord muscles. Schruth's team says this might have convinced other primates that the caller also had fine control over its limbs.

ANUP SHAH/NATUREPL

Do an orangutan's calls advertise its abilities?

To test the idea, the team assessed the musicality – for instance, the tone and the rhythm – of 830 acoustic calls by more than 50 living primate species, and examined data on how often the species leap and swing from branches. The species that leap and swing the most tend to have more complicated calls, which the team dubbed as "protomusical" (bioRxiv, doi.org/ghrd89).

Schruth prefers not to discuss the work until it has undergone peer review.

Whether the research adds to our understanding of the origin of music depends on how we define the term, says Hagen, who wasn't involved in the study. "Some people would exclude what we see in primates and songbirds as music," he says. "Others, and I'm one of them, do see a continuity between human music and primate vocalisations."

Hagen doesn't think human music has a single, simple explanation. Last year, he and his colleagues argued that our human ancestors originally used music-like vocalisations in two ways: groups vocalised together to send a signal of strength and unity to intimidate outsiders, and mothers used solo vocalisations to communicate with infants. A different paper published last year presented yet another idea: that humans used music to forge social bonds.

All these ideas might be compatible, says Hagen. Protomusic could have evolved in primates both to attract mates and for territorial signalling. Later, as early humans began cooperating in larger numbers, protomusic might have been repurposed so it could attract rather than frighten outsiders, while also strengthening social bonds within groups. This would help explain how our music can stir such a range of emotions and why it is so much more sophisticated and complex than the songs of other species. ▮

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Environment

Groundwater may turn salty

The world's food chain relies on groundwater, but it may be becoming unusable

Bas den Hond

GROUNDWATER basins that provide water for much of the world's food production are in danger of becoming too salty for plants and animals. This risk will remain even if care is taken not to deplete them further.

A groundwater basin is a large geological structure in which vast quantities of fresh water are stored in volumes of buried, permeable rocks called aquifers. Often the basin is in an "open" state, which means water is constantly flushed through it. But if the water level falls too low, the basin can become "closed", and water cannot leave the aquifers via rivers or underground flows.

Once a basin is closed, salt leaching into the groundwater won't be flushed out of the aquifer again, so it accumulates.

Irrigation may cause both the closure of a basin and worsen the resulting problems. As groundwater is pumped up for agriculture, part of it will evaporate and leave behind salt deposits. These are eventually washed into the aquifer again, making it more saline from the top down.

A team led by Graham Fogg and Rich Pauloo at the University of California, Davis, calls this process ABCSAL, which stands for anthropogenic basin closure and groundwater salinisation. They have just conducted a detailed study of the important Tulare Lake basin in the southern Central Valley of California, where just over 12,000 irrigated square kilometres of land produce more than $23 billion in crops annually. They conclude that the first stage of salinisation is already happening there (*Journal of Hydrology*, doi.org/fp62).

The Tulare Lake basin in California is already beginning to turn salty

PATRICIA E. THOMAS/ALAMY

Shallow groundwater may deteriorate over decades, says Fogg. The quality of deeper reserves may only become a problem after two or three centuries. Yet he notes that this could come sooner than the current estimates of the expected exhaustion of a basin.

Marc Bierkens at Utrecht University in the Netherlands agrees that the problem the researchers have identified is important and worrying for the world's food supply in the long term.

"It means that stopping the overexploitation of aquifers is not enough. You must make them open again, for a time adding much more water than is pumped out. In many cases, that won't be realistic," he says.

Bierkens thinks that a number of important aquifers, such as the Indus basin in South and East Asia, the Ogallala Aquifer in the US and the La Mancha aquifers in Spain, could very well be affected. "In most of the important regions, you'll reach that point," he says.

If refilling an aquifer isn't feasible, farmers and cities will have to deal with the salty water as best they can, according to Bierkens. "You could desalinate the water," he says, though doing so costs money, which means the approach may not be economical for many small-scale farmers. ▮

Astrophysics

Jumping into a wormhole could make it collapse

WHEN a wormhole reaches the end of its life, the "mouths" at either end may expand and get closer to one another before disconnecting and carrying on as regular black holes. The trigger for this death could be energy that perturbs the wormhole, including a person leaping in.

Wormholes are hypothetical tunnels between two black holes that connect distant regions of space-time or even separate universes. There is no observational evidence that they exist – nor that separate universes exist – but they are theoretically possible under the laws of physics as we know them.

Igor Novikov at the Niels Bohr Institute in Copenhagen, Denmark, and his team simulated what would happen if a wormhole connecting two universes was pushed out of equilibrium, such as if it were hit by a blast of energy. Previous work has shown that this could unite the universes, but Novikov and his colleagues found that wasn't the case. According to their calculations, the "throat" of the wormhole – the tunnel connecting the two universes – would become wider and wider while shortening in length at the speed of light (arxiv.org/abs/2012.13788). Eventually, the connection between the two black holes would disintegrate, leaving behind a pair of black holes, each in the universe in which it started.

One way to add energy and push a wormhole out of equilibrium is by jumping into it. This would mean that travelling through a wormhole to a different universe is impossible as it would sever the connection between the two universes, leaving the jumper falling into a black hole.

"The tunnel connecting two universes would become wider and wider while shortening in length"

Don Marolf at the University of California, Santa Barbara, says this calculation relies on a type of quantum field that is unlikely to exist. He says these wormholes "violate cherished principles in addition to there being no evidence for their existence". So, a wormhole falling apart in this way is "a hypothetical and highly unphysical event", he says. ▮

Leah Crane

Palaeontology

Some dinosaurs sat on their eggs like birds do

Michael Le Page

A FOSSILISED oviraptor found on top of a clutch of eggs confirms that some dinosaurs sat on or near their eggs to keep them warm, like birds.

There is already strong evidence that some dinosaurs brooded eggs. Several fossils of adult oviraptors – bird-like dinosaurs around 2 metres long – have been found on or near clutches of eggs. But many researchers think even small dinosaurs may have been too heavy to sit atop their eggs without damaging them. Some argue that the oviraptors found on nests died while laying eggs rather than during brooding or while guarding the eggs.

Now a team led by Xing Xu at the Chinese Academy of Sciences in Beijing has described and analysed a fossil found near Ganzhou in China. It consists of the partial remains of an adult oviraptor on top of at least 24 eggs, many of which have embryos inside. Eggs with embryos have been found before, but not in association with an adult, says team member Michael Pittman at the University of Hong Kong.

The fact that the embryos are at a late stage shows the adult wasn't laying eggs when it died. The team also looked at the amounts of different forms of oxygen in the carbonates in the eggshells and embryo bones. The ratios of oxygen-18 to oxygen-16 isotopes reflect the temperature at the time the carbonates formed. For two eggs, this analysis suggests that the embryos developed at around body temperature – between 36°C and 38°C (*Science Bulletin*, doi.org/fp59). This shows the eggs were being brooded, not just guarded, says Pittman.

For the third egg analysed, which was further from the body of the adult, the developmental temperature would have been between 30°C and 32°C. Some modern bird eggs develop at a lower temperature too, says Pittman. ▮

Computing

AI illustrator draws surreal images from text prompts

Chris Stokel-Walker

AN ARTY artificial intelligence gets inspiration from text captions to create outlandish images – such as "armchairs in the shape of avocados" or "a baby daikon radish in a tutu walking a dog". This hints that it has some grasp of how language shapes visual culture.

OpenAI, a company that has partnered with Microsoft, developed the system, called DALL-E. It is a neural network – a form of AI modelled on a brain – and is based on the company's GPT-3 language model that can create expansive written works based on short text prompts, but DALL-E produces images instead of words.

"The world isn't just text," says Ilya Sutskever, co-founder of OpenAI. "Humans don't just talk: we also see. A lot of important context comes from looking."

DALL-E is trained using a set of images already associated with text prompts, and then uses what it learns to try to build an appropriate image when given a new text prompt.

It does this by trying to understand the meaning of the "natural language" text it is given, then producing an appropriate image. It builds the image element by element based on what has been understood from the words. If it has been presented with parts of a pre-existing image alongside the text, it also considers the visual elements in that image.

For instance, if given an image of the head of a *T. rex*, and the text prompt "a *T. rex* wearing a tuxedo", DALL-E can draw the *T. rex* body under the head and add appropriate clothing to it.

The neural network, which OpenAI described last week on the company's website, can trip up on poorly worded text prompts and struggles to position objects relative to each other – or to count.

OPENAI

Images of a chair and a radish, with a twist, made by an AI

"The more concepts that a system is able to sensibly blend together, the more likely the AI system both understands the semantics of the request and can demonstrate that understanding creatively," says Mark Riedl at Georgia Institute of Technology in Atlanta.

"I'm not really sure how to define what creativity is," says Aditya Ramesh at OpenAI, who admits that he was impressed with the range of images DALL-E produced.

The model creates 512 images for each prompt, which are then filtered using a separate computer model, also developed by OpenAI, called CLIP. This system picks what it believes are the 32 "best" works produced by DALL-E.

CLIP is trained on 400 million images with text found online. It looks at nouns, verbs and adjectives, and performs as well as many image classification systems when confronted with images it hasn't seen before.

400m

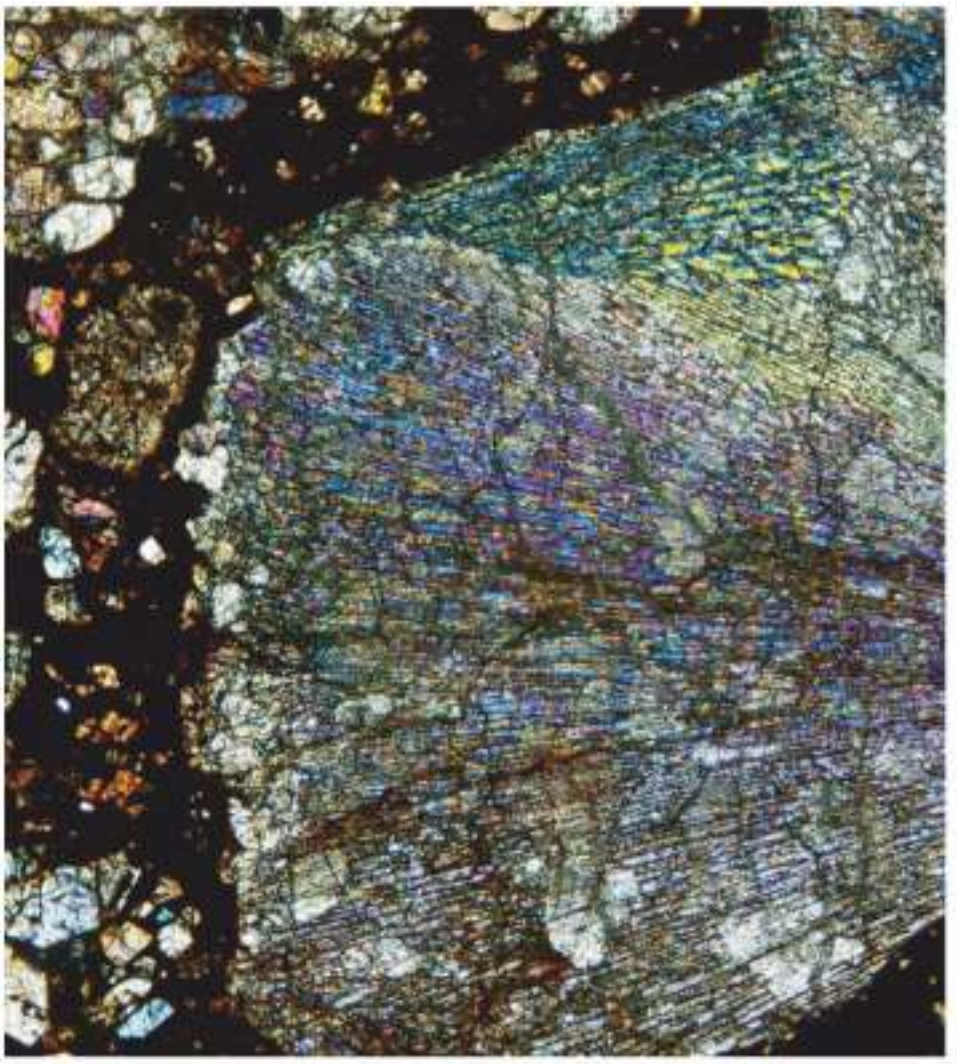
images help train OpenAI's software to assess its output

"We find image-text pairs across the internet and train a system to predict which pieces of text will be paired with which images," says Alec Radford at OpenAI, who developed CLIP.

"This is really impressive work," says Serge Belongie at Cornell University, New York. He says more research is needed to look at the ethical implications of such image creation systems, like the risk of creating totally faked pictures. For example, what if you could fool people into thinking scenes are real, not computer-generated.

Effie Le Moignan at Newcastle University, UK, also calls the work impressive. "But the thing with natural language is, although it's clever, it's very cultural and context-appropriate," she says.

For instance, Le Moignan wonders whether DALL-E, if confronted with a request to produce an image of Admiral Nelson wearing gold lamé pants, would put the military hero in leggings or underpants – potential evidence of the gap between British and American English. ▮



SCENICS & SCIENCE/ALAMY

Solar system

Slices of space rock reveal watery secrets

SOME meteorites that fell to Earth relatively recently may have contained liquid water within the past million years. This means space rocks might have delivered water to our planet's surface throughout its history rather than just early on.

Many scientists suspect that meteorites once brought water to Earth. But previous analysis of the rocks suggests chemical reactions inside them involving liquid water ceased billions of years ago. So there was a question mark over whether they lost their water long ago.

Simon Turner at Macquarie University in Sydney and his team analysed nine meteorites that fell to Earth in the past century. They were once part of asteroids that formed about 4.5 billion years ago.

When ice in a meteorite melts, the water and fluid-soluble elements move from one part of the rock to another, says Turner. Because uranium is water-soluble and thorium isn't, the researchers could look for evidence of water by looking at the distribution of uranium and thorium isotopes.

"Uranium and thorium have very short half-lives and so only record events that happened within the last 1 million years," says Turner. The pattern of uranium and thorium in slices of the meteorites suggests that they were experiencing chemical reactions involving liquid water within the past 1 million years (*Science*, doi.org/fp6t).

These meteorites may have continued to supply water and organic compounds to Earth in the recent past. Samples of rock from asteroids may shed more light on this. **Karina Shah**

Health

Rare cancers jumped from mother to child

TWO children with lung cancer in Japan acquired the tumour cells from their mothers during or shortly before birth – an incredibly rare way of developing the disease.

Chitose Ogawa at the National Cancer Center Hospital in Tokyo and her colleagues made the discovery while sequencing the DNA of the children's tumours for a prospective clinical trial.

The first boy was diagnosed with lung cancer at 23 months old, while the second was 6 years old when chest pain led doctors to find a tumour in his left lung.

Both mothers turned out to have cervical cancer: the mother of the first boy was diagnosed three months after the birth and the mother of the second boy was diagnosed following delivery.

Analysis showed the boys' tumours had genetic mutations that matched those in the cancers of their mothers. It also showed that DNA from the boys' tumours lacked the Y chromosome found in most male cells. The cells also tested positive for strains of human papillomavirus that are known to trigger cervical cancer (*New England Journal of Medicine*, doi.org/fp42).

Some cancer cells probably escaped into amniotic fluid during late gestation, or were transmitted to the children during their birth, says Paul Ekert at the Children's Cancer Institute in Sydney, who wasn't involved in the research.

Such instances of mother-to-infant transmission of cancer are incredibly rare. Approximately one in 1000 live births involves a mother who has cancer, and transmission is estimated to occur in one infant for every 500,000 mothers with cancer. Child cancer specialists might see it once in a lifetime, says Ekert. An infant's immune system would normally destroy any transferred cancer cells, he says. **Donna Lu**

Environment

Does ride-sharing raise car ownership?

THE arrival of ride-sharing companies has been associated with a 0.7 per cent increase in car ownership in US urban areas.

Jeremy Michalek at Carnegie Mellon University in Pennsylvania and his colleagues analysed trends in vehicle ownership in 224 urban areas across the country between 2011 and 2017 to investigate how these changed if a ride-sharing company – either Uber or Lyft – began operating in the area.

KLAUS VEDFELT/GETTY IMAGES

The researchers found that, on average, there was an increase of 0.7 per cent in car ownership. The increase in ownership was larger in car-dependent cities and in cities with a faster rate of population growth (*iScience*, doi.org/fqdk).

Michalek thinks that one explanation for this trend could be an increase in car ownership by those who are or who want to be Uber or Lyft drivers outweighing a decrease in vehicle ownership among riders.

"In a lot of respects, this is not surprising," says Os Keyes at the University of Washington in Seattle. "If there's money to be made in having a car, more people are likely to have cars."

Both Uber and Lyft questioned the way the study was conducted and pointed to their commitment to greener transport, such as pledges on zero emissions and reducing reliance on personal vehicles. **Layal Liverpool**

Really brief

BJORN LARDNER, UNITED STATES GEOLOGICAL SURVEY

Tree snakes spotted making like lassos

Snakes on the Pacific island of Guam have been seen moving in a new way. The technique, dubbed lasso locomotion, involves them making lassos with their lower bodies and wiggling upwards to climb. Bruce Jayne at the University of Cincinnati, Ohio, and his team recorded five brown tree snakes using this method to move (*Current Biology*, DOI: 10.1016/j.cub.2020.11.050).

Progeria gene fixed in mice

CRISPR gene editing has been used in mice to correct the mutation that causes the rapid ageing condition progeria, greatly improving the health of the animals and doubling their lifespan (*Nature*, doi.org/fp65). The average lifespan for children with progeria is just 14 years.

Heat is doubly bad for corals

Two compounding effects hit corals as a result of heat. Normally, they compensate for ocean acidification, but tests found that when the animals are bleached by heat stress, they become less resilient to changes in ocean acidity (*Science Advances*, doi.org/fqdn).

Palaeontology

Huge sharks ate unhatched siblings

ANCIENT megalodon sharks may have been at least 2 metres long at birth – possibly as a result of eating unhatched eggs in the uterus.

Kenshu Shimada at DePaul University in Chicago and his colleagues examined a fossil of *Otodus megalodon* that was recovered in the 1860s from 15-million-year-old rock and is now housed at the Royal Belgian Institute of Natural Sciences. Studying the shark's vertebrae allowed them to estimate its body size at various stages in its life (*Historical Biology*, DOI: 10.1080/08912963.2020.1861608). "Megalodon's size at birth was about 2 metres," says Shimada.

Similar to how a tree trunk has annual growth rings, the shark vertebrae has growth bands. By counting these, Shimada and his team suggest that this megalodon specimen died at 46 years old.

Previous studies have relied on evidence from megalodon teeth to estimate body size. This is because teeth are often the only part of a shark to fossilise, as its skeleton is made of cartilage and not bone. Studying rare vertebral remains is critical to learning more about ancient sharks, says Jack Cooper at Swansea University, UK.

The large birth size suggests that megalodon, like many present-day sharks, ate unhatched eggs in the uterus – known as intrauterine cannibalism. "The consequence is that only a few pups will survive and develop, but each can become large," says Shimada.

While the growth pattern between birth and middle age is now clearer, we know little about megalodon growth later in life. **KS**

Domestication

MEZZOTINT_ALAMY/ALAMY

Spare meat turned wolves into pet dogs

DOGS may have been domesticated simply because our ancestors had more meat than they could eat.

The timing and causes of the domestication of dogs are both uncertain. Genetic studies suggest dogs split from wolves between 27,000 and 40,000 years ago.

It isn't clear if domestication happened in Europe or Asia – or in multiple locations – or why it occurred. One idea is that people domesticated dogs to help them with hunting. Another scenario has wolves scavenging waste dumps and getting used to people.

Maria Lahtinen of the Finnish Food Authority in Helsinki and her team have another idea – they think the key was an excess of meat.

Wolves can survive on nothing but lean meat for months. In contrast, humans cannot. There are limits on how much protein our bodies can handle. Lahtinen's team calculated how much food was available during the Arctic winters, based on the prey species living there. They found there was plenty of lean meat, suggesting humans would have ended up with more than they could eat and may have used it to feed orphaned wolf pups, which they may have viewed as pets (*Scientific Reports*, doi.org/fp6r).
Michael Marshall

Genetics

Living cells turned into data stores

THE DNA in live bacteria has been edited to encode and store information. This could be a step towards creating a new medium for long-term data storage.

Life's genetic information is held in DNA, but there is growing interest in using it as a storage vehicle for other kinds of data. To do so, information is often encoded using the four DNA bases that make up the genetic code. The required sequence of bases can then be chemically synthesised in a laboratory, and even stored in everyday objects.

Harris Wang at Columbia University in New York and his team took this one step further, using a form of CRISPR gene-editing activated through electrical stimulation of cells to directly encode data through the insertion of specific DNA sequences. By assigning different arrangements of these DNA sequences to different letters, the researchers were able to encode the 12-byte text message "hello world!" into DNA inside *E. coli* (*Nature Chemical Biology*, DOI: 10.1038/s41589-020-00711-4).

Wang and his team were subsequently able to retrieve the message by extracting and sequencing the bacterial DNA. **LL**

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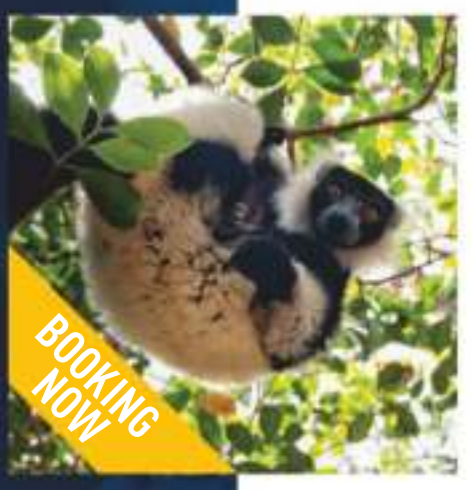

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Views

Comment

Rise of the electric cars

2020 was the best ever year for electric cars. The days of fossil fuel-powered vehicles are numbered, says **Adam Vaughan**

Adam Vaughan is *New Scientist*'s chief reporter.
@adamvaughan_uk

MICHELLE D'URBANO

FOSSIL-fuel-powered cars aren't yet consigned to the scrapheap, but they are fast travelling down a one-way road towards it.

The pandemic triggered dire new car sales in the UK, which fell by 29 per cent back to levels seen in 1992, figures published last week show. Yet sales of new, fully electric cars bucked the trend, rocketing by almost 186 per cent to more than 108,000. That may seem insignificant when you consider more than 900,000 petrol ones were sold over the same period, but look at the rate of change. In the UK, more electric cars were sold last year than in the previous decade.

Motorists, like progressive leaders and car makers, have woken up to the fact that petrol and diesel cars are on the way out, destined to follow incandescent light bulbs into history. It isn't just the UK: the boom is happening across Europe. In Norway, long a pioneer of carrots and sticks to wean people off petrol and diesel, electric models overtook fossil fuels ones in 2020 for the first time.

These tipping points matter. Transport has eclipsed energy to become the biggest carbon emitter in the UK and many other countries. We need this electric boom if we are to stand any chance of avoiding climate change's most devastating effects. Vehicle emissions also harm and kill us in the short term: witness the inquest last month that found air pollution played a role in a 9-year-old girl's death.

Why are the changes coming now? Some of it is down to specific policies. The UK's numbers were turbocharged by the government allowing firms to pay no company car tax on electric cars from April 2020 to April 2021, compared with the 20 to 37 per cent charged on petrol and diesel cars. Most of the plug-in cars sold last year were company ones.

It is also about growing choice. More new electrified models are due in the UK this year than new petrol or diesel ones, although that does include plug-in hybrid electric vehicles, which run a short distance on a battery before a combustion engine kicks in. Strikingly, the UK's bestselling car last December wasn't a Volkswagen Golf or a Ford Fiesta, but the electric Tesla Model 3, which starts at £40,490.

Dieselgate – the revelation in 2015 that many Volkswagen cars had been equipped with devices that let them cheat exhaust emissions tests – and fears over diesel cars being charged to enter towns and cities have already hastened their demise. Recent government pledges to ban new petrol and diesel car sales, by 2030 in the UK's case, signal to buyers that petrol is heading downhill too. New air pollution charging zones, such as London's expanded Ultra Low Emission Zone introduced in October, will speed things up further.

All this is with electric cars that use conventional lithium-ion batteries, before any of the advances in charging speed and driving range promised by breakthroughs from technologies, such as solid-state batteries.

Yes, there are still bumps in the road to overcome. The number and speed of public chargers need to increase. Cars need to be charged at smart times of day to avoid unnecessary costs for energy networks (and ultimately the consumers who pay for them). However, none of the challenges are insurmountable.

Of course, as cycling and walking advocates will point out, electric versions don't solve all of the problems that cars bring. They still generate air pollution from the tyre particles and road dust that they throw up, and we have no techno-fix for that. So we need to get out of our cars too, though – as my colleague Graham Lawton has written – that isn't always easy. Yet given last year's torrent of bad news, 2020 marking the beginning of the end for fossil fuel cars is a moment worth celebrating. ▮

No planet B

Welcome to the green decade

We have been in many last chance saloons with climate change, but there are now reasons to believe we might finally go out and take action, writes **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *This Book Could Save Your Life*. You can follow him @grahamlawton

Graham's week

What I'm reading
I finished the first draft of my new book so, boringly, my own manuscript.

What I'm watching
The new series of my midwinter guilty pleasure, Death in Paradise.

What I'm working on
Covid-19, the story that will not die.

This column appears monthly. Up next week: Annalee Newitz

ONE temptation that is hard to resist when writing about the environment is the narrative of the last chance saloon – the cliché that the next summit or election is the final opportunity to avert climate or biodiversity crisis, and if it is lost, all is lost.

I have written a few dispatches from the saloon and understand its appeal. The analogy is urgent and motivational, while the alternative is to point out that there is, in fact, another saloon over the horizon and that failure isn't terminal. The problem is, if you overuse an analogy, it loses its power. Especially if it isn't true.

But as 2021 gets into its stride, I think we may have seen the last of the last chance saloon. I'm wary of making any firm predictions – 2020 exposed the folly of doing that – but there are increasing signs that humanity spent much of last year sat in that particular bar, drank its fill, stared at the bottom of the glass and finally decided it was time to quit.

Despite the ongoing climate and biodiversity crises, there is a whiff of green optimism in the air. Much of it is emanating from the silver linings of a dismal 2020, which this time last year I predicted would be pivotal for the planet. I was right, of course, though for the wrong reasons.

Back then, we were just months away from important global negotiations on climate and biodiversity. The pandemic meant both had to be postponed. They are now tentatively rescheduled for later this year – and maybe for the better. If they had happened as planned, in the middle of a business-as-usual 2020, they probably would have produced a business-as-usual outcome: warm words but little action.

But times have changed. The pandemic not only exposed how close we are to the environmental precipice, it also proved humanity is actually capable of responding to existential threats. It is perhaps no coincidence that 2020 saw some of the most significant climate commitments ever made by national and transnational bodies: net-zero pledges by China, Japan and South Korea; the European Union's Green Deal; the UK's lead on green finance, including compelling big companies to come clean about their exposure to climate risks; and a greener-than-expected Brexit deal. On top of this, renewable energy continued its drive to outcompete fossil fuels, while the desire to build a better post-pandemic world exploded and remains strong.

"The national political tremors promise to deliver an international earthquake in 2021 and beyond"

There was also a changing of the guard in the US, still the key player in the global carbon casino. Assuming Trump's attempted coup d'etat fails (even after four years of seditious agitation, I still cannot believe I'm writing that), Joe Biden will be inaugurated as president next week. Even better, Biden's party hung on to the House of Representatives and won a controlling vote in the Senate.

With the presidency and both houses of Congress under progressive control – and in possession of a clear mandate for climate action, at least until mid-term elections in late 2022 – there will be no knuckle-dragging on the US rejoining the Paris climate agreement, no knuckleheaded veto of the planned Green New Deal in the US, and a fair wind for other pro-environmental policies.

Taken together, these national political tremors of 2020 promise to deliver an international earthquake in 2021 and beyond. According to a perceptive analysis by Bloomberg Green journalist Akshat Rathi, they are signs that the world is finally moving decisively towards a low-carbon future. Climate action, he writes, "is starting to be 'institutionalized' – that is, getting deeply embedded into how the world works".

This year will also see a ramping up of pressure from those decades-long (and hitherto frustratingly unsuccessful) international efforts to institutionalise environmental action. In June, the United Nations will declare a Decade of Ecosystem Restoration with the aim of preventing, stopping and reversing environmental degradation "on every continent and in every ocean". The 2020s will also be the UN Decade of Ocean Science for Sustainable Development. The Aichi biodiversity targets – which were set in 2010 and expired with a whimper last month, with none of the 20 goals fully achieved – will be updated and rebooted.

On the climate front, the Intergovernmental Panel on Climate Change is expected to release its latest scientific assessment in July, which can only strengthen the scientific case for urgent action. November will usher in the postponed COP26 climate summit, at which that action should materialise in the form of even more ambitious national carbon pledges.

We will be covering these developments as they happen, and we will try not to reach for the last-chance-saloon narrative. We promise. ▮

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 **TIGER in STEMM**

The Inclusion Group for Equity in Research in STEMM, better known as TIGER in STEMM (or simply TIGERS), is a diverse group of passionate individuals working together to improve the EDI - equality, diversity and inclusivity - space within UK higher education.

TIGERS initially formed in 2018 as a group of 50 people, working via Twitter to put together a proposal for #MyScienceInquiry, a government initiative in the House of Commons via its Science & Technology Select Committee, led at the time by Sir Norman Lamb MP. The brief proposal was signed by more than 200 individuals working across higher education in the UK. Prof Rachel Oliver (University of Cambridge) pitched our proposal, representing the newly-formed TIGERS in the House of Commons by invitation of the Select Committee. Our inquiry, "Impact of science funding policy on equality, diversity, inclusion and accessibility", was one of four taken forward, with Sir Norman Lamb writing to the Chair of UK Research and Innovation (UKRI), Professor Sir Mark Walport, to request data regarding research funding and equality, diversity, inclusion and accessibility.

The underwhelming response received from UKRI lacked the granularity and detail TIGERS had hoped for, only confirming why efforts to improve the EDI space within higher education are so necessary. As just one example, the allocation of funding to applicants from ethnic minorities at PI level was 17% compared to 27% of white applicants.

After the dissolution of the existing Science & Technology Select Committee owing to the 2019 general election, TIGERS wrote to the new chair, Greg Clark MP, insisting that the inquiry was still relevant, and urging him to continue the previous efforts, this time co-signed by 429 others. We await a decision, and hope that Greg Clark MP will follow in the footsteps of his predecessor, recognising the inequitable environment those within Higher Education face.

Today, TIGERS has hundreds of members and supporters, including students, technicians, professors and support staff. Together, we are advocates for equity across the HE sector, speaking out on issues affecting our membership and the wider community. To date, we've stood up for trans rights in the *Sunday Times*, published documents highlighting the barriers faced by particular marginalised groups in the competition for research funding, and we maintain a blog and our original Twitter account (@TIGERInSTEMM) for broader discussions.

Find out more

All are welcome to join us, and you can find out more on our website **tigerinstemm.org**

Editor's pick

Perhaps evolution has squared that circle

19/26 December 2020, p 50

From Rachel Mckeown, Aberfan, Mid Glamorgan, UK

You wonder why animals haven't evolved wheels. It is worth noting that the body of an organism isn't the boundary of its phenotype.

Richard Dawkins introduced the "extended phenotype" concept in which a cascade of causality ultimately stemming from genes can eventually lead to non-biological products, examples being architectures like beaver dams. Could the wheel similarly be considered an extended phenotype of humans, constructed once evolution had invented sufficiently advanced intelligence?

Non-biological materials don't face the same inherent limits as living tissue, such as the blood supply requirement. When phenotypes are expanded according to Dawkins's framework, the design book for evolution to explore could massively expand.

From Ian Flitcroft, Dublin, Ireland

The arguments cited against the evolution of wheels in living things include the problem of the environment not being smooth and the challenge of supplying blood to a biological wheel.

Maybe there are exceptions. Tumbleweed lacks blood, but has evolved a rolling solution that is perfectly suited to its flat, desert environment. Its "wheeled" design has a clear advantage, allowing distribution of the plant and its seeds over a wide area.

It is sometimes suggested that we are the only creature to have invented the wheel. I think dung beetles may have beaten us by millions of years, "inventing" a way to get collections of dung larger than themselves uphill: rolling them.

From Martin Jenkins, London, UK

Michael Marshall's article on why animals don't have wheels correctly addresses the issue that they are only useful on firm, flat surfaces, which are rare in nature, but perhaps misses the question: how did such surfaces come to be? In other words, in terms of human technological evolution, which came first, the wheel or the road?

Handshakes may be gone for a generation

11 November 2020, p 41

From Roy Murchie, Wivenhoe, Essex, UK

There is much talk of the impact of covid-19 on how we greet one another. Perhaps the flu pandemic that followed the first world war gives clues to how our behaviour on this may change long term.

I am 88 and my parents, born in 1907 and 1909, were averse to any physical displays when greeting strangers. There was very little handshaking or kissing on meeting anyone. Of course, they grew up through the 1918 flu pandemic and their behaviour was like that of their contemporaries.

When it comes to aliens, N may be large after all

Letters, 28 November 2020

From Liz Berry, Lydbrook, Gloucestershire, UK

In discussing the Drake equation, which estimates the likelihood of the existence of intelligent alien cultures, Tim Stevenson assumed that N – the number of advanced civilisations in our galaxy – was low, as we haven't heard from any such aliens.

With tongue in cheek, may I suggest that such civilisations may not want "developing" ones such as ours to communicate with the advanced worlds around them. They could be perfectly capable of stopping communication both from and to us. When we are considered "advanced", maybe we will be invited to join them.

Our feral horses can't be controlled that way

19/26 December 2020, p 12

From Jamie Pittock, Canberra, Australia

While it would be nice to have a simple solution like birth control for feral horse populations, or to redefine them as beneficial, this risks exacerbating environmental degradation and loss of species.

In Australia, our flora and fauna (for example, the corroboree frog) haven't evolved to cope with the many effects of large, hoofed herbivores. Research I am involved in shows that trapping and birth control are impractical methods to reduce the approximately 25,000-strong feral horse population in the Australian Alps.

Eyes also betray when a right hook is coming

28 November 2020, p 13

From Mark O'Shea, York, UK

You reported how changes in our eyes occur before the decision to initiate strenuous activity. This is one of the first things a novice boxer is taught: "Don't look at the opponent's hands. Look at their eyes. They will tell you when the real attack is about to start."

Maybe combat AIs will just declare a truce

12 December 2020, p 14

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

The clear message from your piece on military robots is that AIs will provide clearer and more logical decisions in warfare than their human minders could offer.

To extend the argument, we can imagine both sides in a conflict having such weaponry, with AI pitted against AI. As warfare is – by any sensible assessment – an irrational and illogical way to resolve conflict, can we assume that AIs left to their own devices would reach that conclusion and end hostilities? In such a case, AI can only be seen as a good thing.

Guts of a computer help me search for stardust

19/26 December 2020, p 53

From Gerald Legg, Hurstpierpoint, West Sussex, UK

When it comes to hunting for micrometeorites that land on my roof, I have often dredged my gutters with a magnet from a computer hard drive in a plastic bag. Remove the sludge adhering to the bag, wash in a Petri dish and examine under a microscope.

Do distant worlds warm as they feel the squeeze?

5 December 2020, p 44

From Thomas Collins, Ifold, West Sussex, UK

Apparent volcanic activity even on the most remote worlds in our system raises the question of the source of its internal energy.

I wonder if, as planets and moons cool and their outer layers solidify, there is a compression of internal material by shrinkage of the outer layer. Could this raise the temperature and be a source of energy for this distant volcanism?

Essential reading in these challenging times

From Michael Scott, Lochcarron, Highland, UK

I wanted to thank *New Scientist* editor Emily Wilson and all the team, especially Adam Vaughan, Graham Lawton, Michael Le Page and Clare Wilson, for keeping me so well informed about coronavirus over the past tumultuous year. Your coverage has been fascinating, enlightening and always informative. ▮

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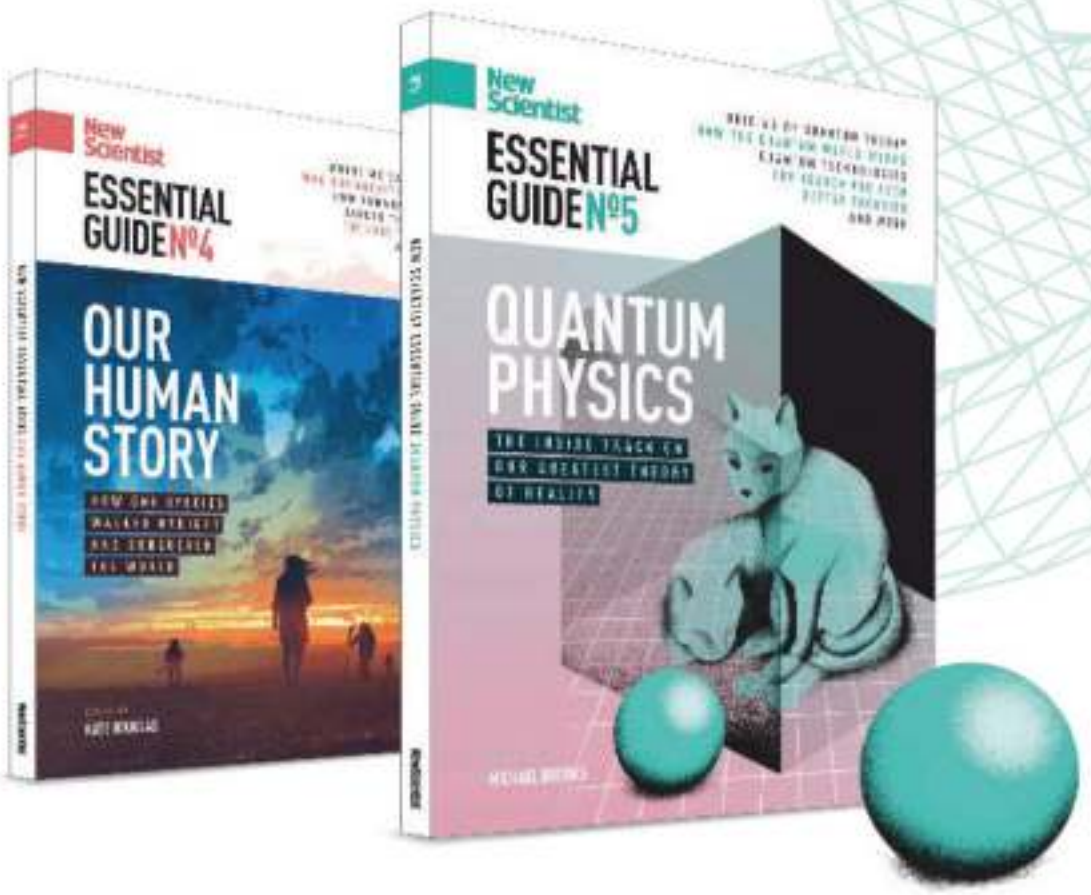

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Virgo 3.0

Photographer Enrico Sacchetti

THIS magnificent instrument, captured by photographer Enrico Sacchetti, is the Advanced Virgo+ interferometer. The image has been shortlisted for a major science photography prize, while the detector itself is on a quest for another sort of glory.

Run by a European consortium and located in the village of Santo Stefano a Macerata, Italy, Advanced Virgo+ is an upgrade to one of the detectors that hunt for clues about the universe's origins contained in gravitational waves. Virgo has been used alongside two other detectors that make up the US-based Laser Interferometer Gravitational-wave Observatory (LIGO).

The waves were predicted by the general theory of relativity, and they are made when massive objects in space move, creating ripples in space-time that stretch and squeeze everything they pass. LIGO and Virgo use this stretching and squeezing to work out what caused the ripples. Last September, they pulled off one of their biggest successes yet when they spotted two black holes smashing together to form another one with a mass 142 times that of the sun.

Advanced Virgo+ is the third incarnation of the Virgo dectector, each one improving its sensitivity to gravitational waves. The detector's 3-kilometre-long north arm can be seen in the left of the image, while on the right is its squeezing cavity, which helps reduce "quantum noise", a phenomenon limiting sensitivity to the waves.

Sacchetti's shot has been shortlisted for the 2020 Science Photographer of the Year competition, organised by the Royal Photographic Society.

Gege Li

It’s hard to know what lies ahead

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Dementia's identity crisis

A film that explores a lesser-known form of dementia poses interesting questions about agency and well-being, says **Francesca Steele**

Film

Second Spring

Andy Kelleher

Digital release in February on iTunes, Google Play and Amazon

IF YOU want a maudlin film about the devastating effects of early onset dementia, you might be better off with *Still Alice*, which tracks the life of a 50-year-old professor following her Alzheimer's diagnosis and for which Julianne Moore won a Best Actress Oscar in 2014. In that film, despite deteriorating to the point where she cannot recognise her own daughter, Alice clings to the remnants of her old self. She is, ultimately, still Alice.

By contrast, *Second Spring* isn't about cleaving to old identities in the face of illness but forging new ones. Kathy Deane, played by Cathy Naden, is a successful archaeologist living rather unhappily with her architect husband, Tim (Matthew Jure), when she starts to behave erratically. She forgets a friend's birthday and struggles with certain words in lectures; she tells people they have put on weight with no regard for their feelings; and she has sex with a stranger in his car on impulse. Friends beg her to see a doctor. "You've changed and not in a good way," one tells her. 'You're right, I have changed," she replies. "I'm happy."

Frontotemporal degeneration, which is what Kathy is soon diagnosed with, is a rare group of conditions caused by the death of nerve cells and pathways in the frontal and temporal lobes of the brain. Unlike better known forms of dementia, its primary symptom isn't forgetfulness, but changes in behaviour and personality, often causing people with the condition to act inappropriately, with fewer inhibitions and less empathy.

The script approaches Kathy's transition soberly, almost entirely without sentiment. We never meet the Kathy from before her illness, only the Kathy that she is now, who is more adventurous and curious but also cold. "This is so boring," she tells Tim, as they sit in their sterile, sexless bedroom reading the paper, together but apart. He looks surprised rather than hurt. Kathy is absolutely not still Kathy. But is that such a bad thing, asks the film.

"The movie is beautifully framed, packed with long landscape shots bursting with colour"

To some degree, we must take Kathy at her word. Perhaps she is happier. Maybe the loss of impulse control prompted by those dying neural pathways is precisely what has gifted her this "second spring", a new-found confidence that enables her to follow her new lover Nick (Jerry Killick) to the countryside, to make love on his houseboat in the afternoons and while away hours thinking about a new, more selfish life in search of self-fulfilment. Perhaps, amid the decline, there is a renaissance.

Of course, Kathy's behaviour puts her in frightening positions too. It becomes increasingly clear to everyone except Kathy that she is a risk to herself and that she is reluctant to accept she is ill. One morning she awakes alone on a towpath, head in the dirt, knees bruised and grubby, remembering only that the previous night she went into the woods with a strange man and a bottle of whisky. Is this second spring worth it?

The movie is beautifully framed, packed with long landscape shots that are bursting with colour and depth as a result of being shot on film rather than digital. The camera lingers on peaceful estuary scenes, blue sky everywhere, as Kathy contemplates her new and old lives. These long shots do keep characters at a distance though: Kathy is hard to relate to, her eye always on the horizon rather than the people around her. As Tim and then Nick lose Kathy to her new self, so do we.

It's a difficult emancipation from societal norms to watch, and *Second Spring* is at times listless, a touch too uninterested in narrative. But it is undoubtedly a brave film too, asking philosophical questions of a frightening illness and giving people agency instead of confining them to victimhood.

Francesca Steele is a film critic and writer working in London

NEAT FILM

Kathy (Cathy Naden) and her husband Tim (Matthew Jure)

18+

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Taming the flames

As a warming world brings more wildfires, we have a lot to learn about how best to live with them, finds **Sandrine Ceurstemont**

MATTHEW MCFARLAND/UNIFIED FIRE AUTHORITY/HANDOUT VIA REUTERS

A hillside blaze during the Elkhorn fire, near Red Bluff, California, in August 2020

Podcast

Life with Fire

Amanda Monthei

IT ISN'T surprising that most people associate fires with death and destruction. Wildfires are getting worse every year around the world, destroying property, killing people and wiping out wildlife and habitats.

But for Jeremy Bailey, a fire manager at the Nature Conservancy in Utah, fire is a natural process that revitalises the landscape, much like rain. "When I think about fire, it always brings me a pleasant feeling," he says.

He is the first guest on *Life with Fire*, a podcast hosted by former wildland firefighter Amanda Monthei. After an introductory show, each episode features an interview with an expert, perhaps a historian or a meteorologist, that sets out to show that harrowing news accounts of wildfires during fire seasons don't tell the whole story.

"Wildfire is a deeply nuanced subject that shouldn't be minimised to the same talking points every summer and then forgotten about every winter," says Monthei.

The effect of climate change on wildfires is a big talking point on the show because it creates more favourable conditions for fire and lengthens fire seasons. However, a few guests suggest that climate change isn't the only culprit.

In a compelling episode about the historic firestorm that hit northern California in September, resulting in some of the area's largest ever blazes, Nick Nauslar at the National Interagency Fire Center in Idaho talks about the factors that had to line up for such unprecedented fires to occur. As well as the absence of summer monsoons and presence of persistent heatwaves, it still took lightning and strong winds to generate those vast blazes.

Another big issue the show tackles is the fact that we can't put out all wildfires, so we will have to manage them. Bailey is a fan of controlled fires. These "prescribed fires" are often started to clear the low vegetation, such as bushes and dead plants, that typically fuels severe wildfires. Planned blazes are mainly used to mitigate the risks of catastrophic fires, but he thinks they have wider potential.

The podcast also discusses how to encourage women and ethnic minority groups into fire-related jobs, and how to retain them, as these jobs are still largely done by white men. Lenya Quinn-Davidson, who started a training scheme for women in fire, thinks people with diverse backgrounds are needed to help tackle the growing severity of wildfires. "Innovation at its core requires diversity because you have to have people thinking about issues in different ways and bringing different types of solution to the table," she says.

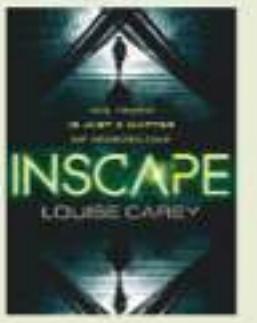
One criticism of *Life with Fire* is that although later episodes are accessible to a general audience, the podcast takes time to get into its stride. Presenting the topics it covers in a different order would have helped guide people with no knowledge of fire science.

Upcoming shows will be more international as Monthei talks to fire practitioners from around the world.

She is particularly excited about an episode that will focus on fire management techniques used by Native American people in northern California. The hope is that these could inspire better solutions. "I think telling stories and sharing new perspectives and communicating important research is a critical first step," says Monthei. ▮

Sandrine Ceurstemont is a science and technology writer based in Morocco

Don't miss

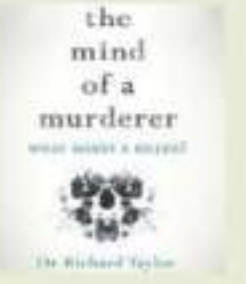


Read

Inscape is Louise Carey's first solo novel: a science fiction tale of near-future corporate surveillance in which a young soldier is sent to discover the source of an attack on her home, and gets more than she bargained for.

Explore

V&A and CERN Classroom Live invites online visitors to explore ALICE, a detector dedicated to heavy-ion physics at the Large Hadron Collider, ahead of the March opening of Alice: Curiouser and curiouser at the V&A Museum in London.



Play

The Mind of a Murderer sees forensic psychiatrist Richard Taylor revealing the "whydunnit" behind some of the most tragic, horrific and illuminating cases of murder. Can we find common humanity even in the darkest of deeds?

MIDDLE: ANTONIO SABA/CERN

The games column

Playing nicer The real Vikings have traded their image as violent marauders for a bit of nuance, but new game *Assassin's Creed Valhalla* has it both ways and features people playing nice while still wanting to invade and rule, says **Jacob Aron**

Jacob Aron is *New Scientist*'s deputy news editor. He has been playing video games for 25 years, but still isn't very good at them. Follow him on Twitter @jjaron

UBISOFT

There is action in *Assassin's Creed Valhalla*, but harming civilians is off-limits

VIKINGS have undergone a bit of a rebrand of late. Once seen as violent barbarians, rampaging in horned helmets across Europe, we are increasingly finding evidence that they were an advanced, civilised people with everything from frozen food to navigational crystals.

Assassin's Creed Valhalla, the latest in the historical action series, seems to want it both ways. You play as a Viking called Eivor (male or female), who after a brief introduction in snowy Norway boards a longship for England in AD 873 to establish a settlement. Throughout the game, you build up your new home, Ravensthorpe, by raiding churches and monasteries for supplies that you can use to establish trading posts and other amenities.

So far, so Norse, but every time I launch into a raid I can't help laughing, because it seems Eivor and their chums are nice Vikings. Although you cut through swathes of enemy soldiers, Eivor seems to have signed up to the Geneva Convention, refusing to harm civilians. It isn't that I want to hack a bunch of monks to death, but it is a bit ridiculous for the game not to acknowledge that the player is essentially leading an invading force that aims to subjugate the population.

That aside, I am enjoying pootling about in 9th-century England. Each region has its own self-contained (and mostly forgettable) story, which makes them feel like episodes from a TV show. Then there are "mysteries", brief encounters that often serve as comic relief. One involved helping a man who didn't realise he had an axe stuck in his head.

"Historical sightseeing is a big draw. I've visited Stonehenge unblemished by today's A303 road"

As with all *Assassin's Creed* games, historical sightseeing is also a big draw. I visited Stonehenge in Wiltshire, unblemished by today's A303 road (this was particularly fun as I was editing an article on it for the 9 January magazine). I also took a trip to its more enigmatic counterpart, Seahenge, a wooden circle built 4000 years ago, the remains of which were discovered in 1998 on the north Norfolk coast. Back in the 9th-century, it stands in all its glory, surrounded by seals.

I had to check out London, or Lunden as it was then. Unlike the painstakingly recreated modern London of *Watch Dogs: Legion* (reviewed in my last column), Lunden is almost unrecognisable. It is dripping with Roman ruins,including an amphitheatre, and I loved experiencing the history: the long-gone Romans are almost mythologised, with one character describing Lunden as a "city built by giants".

All this makes for great escapism, although *Valhalla* does also mention the coronavirus pandemic that so many people would like to escape. This is because the slightly silly sci-fi conceit of the *Assassin's Creed* series is that people can relive historical memories stored in an ancient genome – nonsense, obviously – and the game occasionally cuts away from Viking times to put you in control of Layla Hassan, an archaeologist who has discovered Eivor's remains in 2020. You can access her email and see a message reassuring a relative she doesn't have covid-19.

Thankfully, these interludes are brief and it is easy to forget you are playing someone playing as a Viking. I feel developer Ubisoft Montreal only keeps them for die-hard fans who care about the modern-day plots that span multiple games in the series. Who needs a metanarrative when you have a whole country to pillage? ▮

Game

Assassin's Creed Valhalla

Ubisoft Montreal

PC, PlayStation 4 and 5, Xbox One, Series X and S, Google Stadia

Jacob also recommends...

Game

God of War (2018)

Santa Monica Studio

PlayStation 4

The God of War *series stars Kratos, an extremely angry man who murders his way through the Greek gods. In this soft reboot, the action shifts to Norse mythology, and a more restrained Kratos has to mend his relationship with his son following the death of his wife. Oh, and he also kills a LOT of monsters with a big axe.*

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Rethinking intelligence

Our dominant idea of what makes people smart is exacerbating world problems and needs a radical overhaul, says researcher **Robert J. Sternberg**

IMAGINE a world in which admission to the top universities – to Oxford or Cambridge, or to Harvard or Yale – were limited to people who were very tall. Very soon, tall people would conclude that it is the natural order of things for the taller to succeed and the shorter to fail.

This is the world we live in. Not with taller and smaller people (although taller people often are at an advantage). But there is one measure by which, in many places, we tend to decide who has access to the best opportunities and a seat at the top decision-making tables: what we call intelligence. After all, someone blessed with intelligence has, by definition, what it takes – don't they?

We have things exactly the wrong way round. The lesson of research by myself and many others over decades is that, through historical accident, we have developed a conception of intelligence that is narrow, questionably scientific, self-serving and ultimately self-defeating. We see the consequences in the faltering response of many nations to the covid-19 pandemic, and a host of other problems such as climate change, increasing income disparities and air and water pollution. In many spheres, our ways of thinking about and nurturing intelligence haven't brokered intelligent solutions to real-world problems.

We need a better way. Fortunately, at least the starting point for this is clear. By returning to a more scientifically grounded idea of intelligence, who can have it and how we set about cultivating it in ourselves and others, we can begin to reboot our decision-making smarts and reshape our world for the better.

Our conception of intelligence has come both a long way and not very far in the past century or so. Historically, intelligence has been defined simply as an ability to adapt to the environment. People who are intelligent can learn, reason, solve problems and make decisions that fit their real-life circumstances.

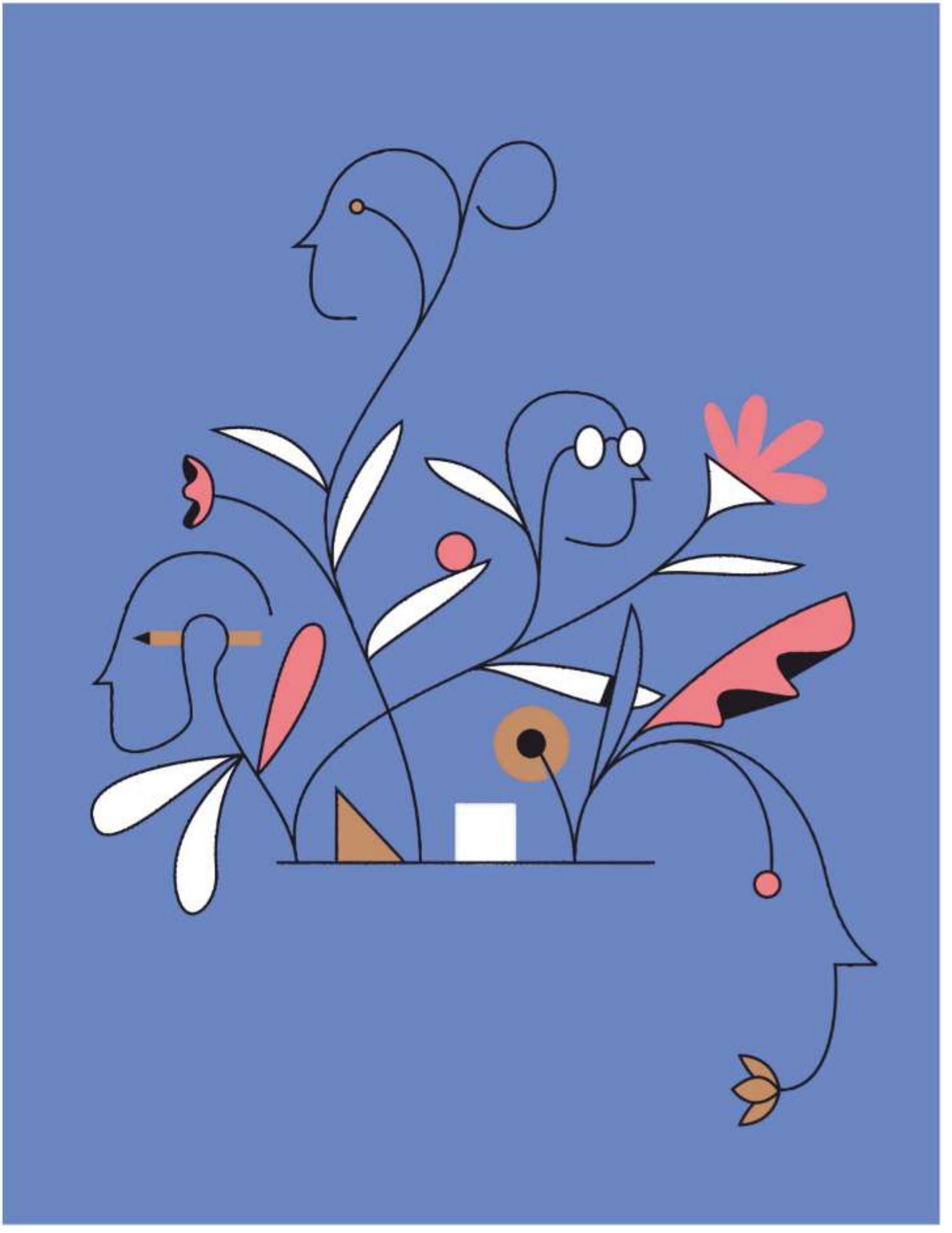
This "adaptive" intelligence consists of different things in different environments. According to where you are in the world or your mode of life, it might be shown in negotiating city life or the environment of a rural farm, or in approaches to ice-fishing or using natural herbal medicines. Adaptive intelligence – rather than intelligence as something you either have or don't have, that is hardwired in your genes – is something you can learn, and that can change through life. It is constantly updated by your interactions with your environment.

> "Intelligence is something you can learn, and that can change through life"

This notion is quite alien to the modern, Western way of thinking about intelligence, but it was clearly understood by Alfred Binet, the co-creator of the first modern intelligence test. This test was published in France in 1905 and translated into English a few years later. Binet believed that intelligence is modifiable, and he wanted to serve children and schools by identifying those children who didn't respond well to regular schooling, but instead needed special instruction. He intended to introduce mental "orthopaedics" to help children become smarter and open up opportunities for them, regardless of social class. Binet died in 1911 and didn't live to develop his idea fully. Soon enough, the law of unintended consequences kicked in.

The kinds of tests pioneered in those early days measured memory skills and a narrow range of analytical skills: things such as vocabulary recall, information-processing speed, the ability to perform numerical operations and complete number series, spatial visualisation and the like.

Things started to go off the rails when intelligence researchers adopted a technique pioneered by a distinguished English psychologist, Charles Spearman. He had discovered in 1904 that the results of various tests he was using to measure mental ›



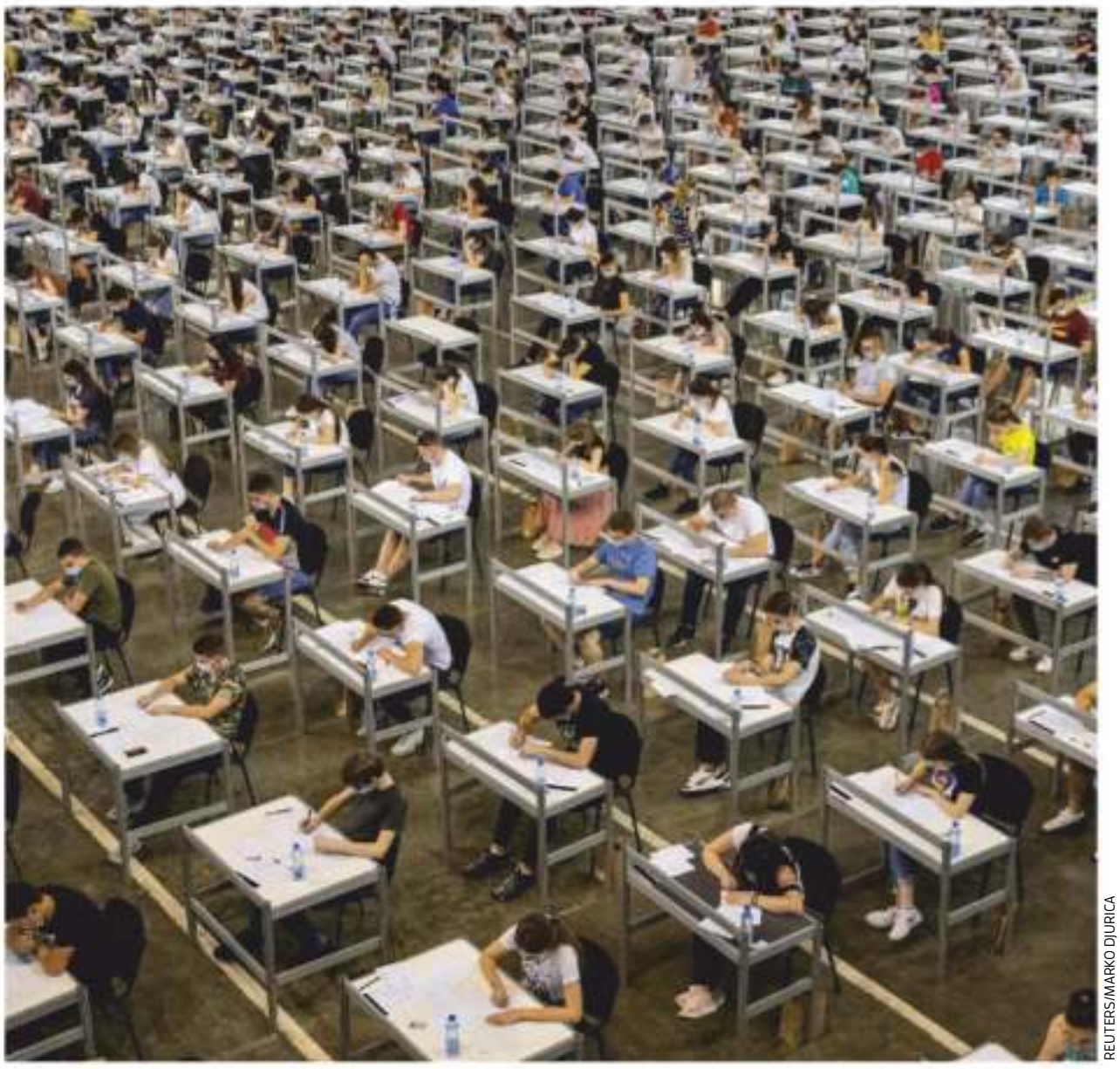
TIMO KUILDER

REAL-WORLD PROBLEMS...

Dilemmas such as tackling climate change or dealing with the coronavirus pandemic differ from the narrow problems used to measure intelligence in many regards. Among other things, they tend to:

- Be for high stakes, sometimes life-changing ones
- Be emotionally arousing, to the point that emotions often cloud people's better judgement
- Be highly context-driven, requiring people to balance many conflicting interests
- Lack a single "correct" answer
- Lack any indication that there even is a problem; or else, the nature of the problem is unclear
- Need a collective solution, often by people with different backgrounds and interests
- Offer only vague paths to a solution, or seemingly no good paths at all
- Unfold and need to be solved over long periods of time
- Make it hard to figure out what information is needed or where that information is to be found
- Come riddled with numerous bits of false or misleading information, sometimes deliberately posed to make a valid solution more difficult

Solving such problems requires a mixture of creative, analytical, practical and wisdom-based skills – the foundation of the notion of adaptive intelligence (see main story).



REUTERS/MARKO DJURICA

abilities tended to correlate with one another – if you scored highly in one, you tended to do well in them all. He interpreted that as suggesting that the tests all measured largely the same thing: a number he called "general intelligence", or g. Differences in g, he believed, resulted from different levels of "mental energy", whatever that was, or is.

Thus was born the idea of intelligence as one largely unmovable number, the guiding principle of IQ tests to the present day. The correlations many researchers found between Binet-style tests and academic performance weren't terribly surprising: after all, Binet created his tests using academic types of problems to predict academic performance under regular schooling. But those correlations meant that many testers never made a fully serious effort to independently measure other, broader ability constructs: the ability to think creatively, for example, or to solve practical problems. New tests were simply validated against old tests, with a new test labelled "good" if it correlated with old ones. Instead of scientific theories about intelligence generating hypotheses, which in turn generated empirical tests to revise the theories, the science got stuck. Data from tests drove the development of theories about intelligence, which drove more tests that measured the same things.

At the same time, in many parts of the world, access to education expanded rapidly during the 20th century. IQ tests and their proxies – for instance school assessments and examinations measuring that same narrow range of recall and analytical skills – became ever more important in determining the opportunities and career paths open to people. Rather than being primarily tools to help individuals realise their full potential,

Standard examinations and assessments don't capture the full picture of intelligence

as Binet had envisaged, their function was to restrict people's opportunities in the service of employers, colleges, universities and other institutions.

Narrow and biased

Rather than intelligence tests helping to break down social and economic barriers, they perversely helped to increase them. Parents who were able to give their children the schooling, socialisation and other experiences that allowed them to do well on narrowly focused tests and examinations gained a huge advantage – a self-perpetuating one, as those children then gained the opportunities that allowed them to pass on the same advantages to their own kids. Meanwhile, the tests themselves were shot through with the narrow views about what constituted intelligence held by the largely white, well-to-do individuals with a certain academic background who created the tests.

This narrow focus has been a recurring theme in my own research. Nearly three decades ago, my colleague Lynn Okagaki and I showed that different socially defined racial, ethnic and socio-economic groups in the US tend to emphasise different skills in socialising young people to be intelligent. For example, European-American and Asian-American parents typically focused on cognitive skills, whereas Latino-American parents emphasised social skills. Because teachers were predominantly European-American and Asian-American, they estimated the abilities of the children of similar-thinking parents to be higher.

Different groups show not only different views of intelligence, but also different patterns of skills as they grow up. The tests that determine success don't reflect that. My research has shown, for example, that the particular skills measured by traditional university admissions tests in the US tend to favour the skill patterns of white and Asian students and disfavour those of black and Hispanic students. These differences reflect many things, including conceptions of intelligence slanting towards or away from what the tests measure, and also the socialisation opportunities parents want to, or are able to, provide. When members of diverse groups are measured for what matters to them, they show strengths that are hidden by the conventional tests.

> "Intelligence tests work perversely to increase social and economic barriers"

Perhaps surprisingly, the dominant intelligence tests and their proxies don't even necessarily measure particularly well those aspects of analytical reasoning relevant to broader kinds of success, such as research in science, technology, engineering and mathematics. When we assessed students for their abilities at generating alternative scientific hypotheses, designing experiments, drawing scientific conclusions and related skills, the students' scores on different tests of scientific reasoning correlated with each other, but didn't consistently correlate with scores on US university admissions and abstract-reasoning tests.

More generally, the characteristics of real-world problems are very different from the characteristics of problems on standardised tests (see "Real-world problems...", left). IQ works best for solving problems that follow familiar or easily learned patterns. It doesn't work so well for the complex, highly novel, high-stakes, often emotionally charged problems we frequently face – how to balance the demands of individual liberty and public health in the covid-19 pandemic, for example, or how best to motivate action on global climate change and the other environmental challenges we face. As UN secretary-general António Guterres said last month, humanity is waging a suicidal war on the natural world. That is hardly the product of intelligent thinking.

So how do we fix things? Put simply, by embracing the idea that intelligence is about adaptation. Sometimes we change ourselves to suit the environment, sometimes we shape our environment to suit ourselves, and sometimes we find a new environment when our current environment isn't working out. We need to nurture the adaptive intelligence that is best suited to identifying the need for such changes and developing the strategies for carrying them out. ›

IVA ZIMOVA/PANOS PICTURES

MEASURING ADAPTIVE INTELLIGENCE

Adaptive intelligence is relevant to solving complex problems in the real world. It consists of four main skill sets: creative thinking, analytical thinking, practical thinking and wisdom (see main story). Questions designed to test adaptive intelligence look very different from the narrowly focused questions characteristic of IQ tests and many standardised tests used to determine schooling and career opportunities, but good performance on such tests can be a better indicator of potential and future success than conventional academic tests.

Example question 1

Social conflict

"Qora and Tamlin, two countries in the Middle East, are having a serious clash. The Taron river flows in the direction from Qora to Tamlin. Tamlin claims that Qora is diverting more than its fair share of the water from the river. It is getting ready to go to war over this precious resource. What should the two countries do?"

Example of a strong answer – one that seeks (a) a common good; (b) by balancing participants' interests and larger collective interests; (c) over the long and short term; (d) through the infusion of positive ethical values:

"Qora and Tamlin need outside help to resolve their differences regarding the river water. They should each appoint a commission of people who are water experts from their own country. These people should be responsible for choosing top experts to form a five-person panel. One expert should be from Qora, one from Tamlin and three from outside with no allegiance to either country. Qora and Tamlin should agree in advance to abide by the panel's recommendation. The deliberations of the panel should be held in secret to reduce external attempts to influence it, and the panel should be provided with any resources it needs to make a decision. The panel should propose a solution and vote on it, with a majority decision accepted as the final solution to the problem. There should be no right of appeal of this decision."

Example question 2

Personal conflict

"Richard and Jennifer broke up. They both left you text messages saying that they want to talk to you about what happened. You know they both will want you to take their side. What should you do?"

Example of a strong answer:

"I would talk to both Richard and Jennifer. I would tell them that I consider them both dear friends. I also would explain, and ask them to understand, that I hope to stay friends with both of them, support both of them and help them reach their goals, whether separately or, if they decide to get back together again, jointly. I would ask them how I can help them in any way at all that doesn't involve my hurting the other. I would tell them I'm there for them and they should call on me for support any time."

In general, adaptive intelligence consists of four kinds of skills we use to adapt to, shape and select environments. There are creative skills, which we use to generate relatively novel and somehow useful or meaningful ideas: you can't change a situation you find yourself in if you can't creatively imagine what you want it to become. There are broad-based analytical skills, which we use to ascertain whether our ideas, and those of others, are any good: what is and isn't working in the situation we find ourselves in. Then there are practical skills we use to implement our ideas and persuade others of their value, to achieve change in our situation. Finally, there are wisdom-based skills that help to ensure that our ideas contribute towards achieving a common good, both in the short term and the long term, by balancing our own, others' and higher-level interests.

Collective wisdom

The drive to develop and deliver a covid-19 vaccine gives an example of where all these skills come into play. Creative thinking was needed to come up with the new mRNA-based vaccines that have proved successful. Analytical skills are needed to ensure that the vaccine trials are scientifically rigorous and the data from them properly interpreted. Practical abilities are needed to upscale the work of the research scientists and produce billions of doses of vaccine.

And then comes the wisdom part. Decision-makers need to have the wisdom to recognise that there will be many people with other interests – people who are afraid of the vaccine, people who are generally anti-vaccine, people who object for political, religious or ideological reasons – and to develop strategies to convince them of the need to get themselves vaccinated for the common good. We all need to have the wisdom skills to recognise the benefits, to ourselves and others, if we all vaccinate ourselves, as vaccines become available.

All this can be taught and learned. If we broaden our conception of intelligence and pay more attention to nurturing the elements of adaptive intelligence in all of us, we will stop needlessly wasting talent and also broaden the pool of skills available to us to find constructive solutions to such problems. My research shows that students taught in ways that help them to capitalise on their creative and practical strengths, and also to compensate for or correct weaknesses, often perform better than do students who are taught in a way that favours only those with good memory and analytical skills.

Instead of teaching and testing students on arcane problems, the emphasis needs to be on realistic problems. So, rather than an appropriate test question in mathematics being to recall the formula for an exponential curve and calculate quantities from a given exponential curve, it might be to describe what an exponential curve looks like, and sketch out the problems that can arise from an exponential growth curve in a given context. Or in the social sciences, instead of asking a student to recall the essential points of such-and-such a theory, problems need to test the full range of creative, analytical and practical skills (see "Measuring adaptive intelligence", left).

This isn't airy-fairy, touchy-feely stuff. Tests of creative, practical and wisdom-based skills are just as good, if not better, at measuring things relevant for success in the real world as conventional IQ-based tests. Tests of practical intelligence, for example, predict various kinds of job success as well as conventional intelligence tests, even though success on one type of test correlates only minimally with success on the other type.

Meanwhile, adding creative, practical and wisdom-based skills to university admissions tests increases the accuracy of predictions of both academic and extracurricular success over those provided by conventional tests. In one study my colleagues and I conducted in US universities with widely differing levels of selectivity and kinds of students, such tests predicted first-year grades almost twice as well as standard admissions tests. They also decreased differences between socially defined racial and ethnic groups.

REUTERS/FRANCIS MASCARENHAS

Tackling climate change requires problem-solving for the common good

"An obsession with individual success has blinded us to the damage we are causing to our collective well-being"

It is way past time to let go of a narrow, antiquated and self-serving notion of what it means to be intelligent. The stakes couldn't be higher. Our current ideas have created a "tragedy of the commons", whereby privileged people's obsession with their own individual success and that of their children has blinded many people to the damage we are causing to our collective well-being. We need to think of intelligence as having positive collective goals, not just individual ones. The dinosaurs lasted on Earth for 165 million years. If we don't change our notions about what it means to be adaptively intelligent, we may not come anywhere close to that. We will have runaway global climate change, pandemics, pollution and the confrontations among people these problems will cause. We won't need a heavenly body to do us in. We will have done it to ourselves. ▮

Robert J. Sternberg is at Cornell University in Ithaca, New York. His book, *Adaptive Intelligence: Surviving and thriving in times of uncertainty*, will be published in February

PETE REYNOLDS

Taming CRISPR

The powerful gene-editing technique will transform medicine – if we can control it. Now we may have a way, finds **Gege Li**

THERE is a technology that could tackle some of life's most pressing problems, from disease to malnutrition. It could fix medical conditions such as cystic fibrosis and sickle cell anaemia simply by changing a bit of genetic code. It could eliminate malaria by making male mosquitoes infertile, or wipe out pests that destroy crops. And it could modify other organisms to increase their usefulness, helping to create foods that are tastier and more nutritious.

This is the promise of CRISPR, a biochemical tool at the forefront of a gene-editing revolution. Produced naturally by bacteria, CRISPR has gained rock-star status among scientists in the decade since its extraordinary potential was first recognised, and it is already starting to live up to the promise. But behind all the excitement lurk some dark questions. What if the editing goes wrong? What if it has undesired effects? What if we can't stop it? Without a means to keep CRISPR on target and halt it in its tracks when needed, gene editing could have disastrous consequences – both for human health and for the planet.

What we need is an off-switch, one that can be used at will. Researchers around the world have spent years trying to find one, largely by investigating various biochemical solutions. However, it turns out that the answer may be right under our noses. In an evolutionary face-off between CRISPR-producing bacteria and the viruses that infect them, nature has already designed anti-CRISPR. The challenge now is to harness this evolved off-switch to our own ends and usher in the golden age that gene editing promises.

Viruses, such as the one that causes covid-19, don't just pose a threat to humans – they attack all living organisms, including bacteria. In the ancient bacteria-virus rivalry, CRISPR is one of the weapons bacteria have evolved to combat bacteriophages, the name given to viruses that infect them (see "Evolutionary arms race", page 44).

CRISPR forms part of many bacterial genomes. It is made up of repeating DNA sequences interspersed with fragments of genetic code left behind by phages from past viral attacks. When a phage invades again, the bacterium makes RNA copies of these CRISPR regions. These bits of genetic material then hook up with a particular protein, an enzyme called Cas. They latch on to matching sequences in the invading virus's genome, and the accompanying Cas protein snips the viral DNA strand, destroying the phage. In effect, CRISPR works as a sort of genetic memory of past viral attacks that confers immunity against future ones.

Elegant editing

Given the system's simplicity and elegance, it is perhaps unsurprising that researchers eventually spotted CRISPR's potential as a gene-editing tool. The discovery won a Nobel prize in 2020 for biochemist Jennifer Doudna at the University of California, Berkeley, and Emmanuelle Charpentier, now director of the Max Planck Unit for the Science of Pathogens in Germany. In research published in 2012, they presented a CRISPR system that contained genetic sequences of their choice, rather than ones from phages, along with a Cas enzyme called Cas9. With this tool, biologists can home in on a specific DNA sequence and make a cut at a precise location. This allows them to disable a target gene or excise a faulty one and replace it with a working version.

CRISPR-Cas9 has since been used successfully many times to genetically edit cells in the lab. But for it to be an effective medical therapy, it must be delivered directly to cells in the human body either physically, such as by injection, or with a vector, usually an engineered virus that encodes the desired genes. In 2020, a team in the US achieved this for the first time, injecting CRISPR into the eyes of someone with an inherited form of blindness caused by a single mutation. Precisely targeting other parts of the body is harder, however. The issue is how to get CRISPR only to the cells of interest, while also ensuring that enough editing takes place in them to see the changes you want. With vectors "there is no 'magic bullet' – it's a bit of a shotgun approach", says molecular biologist Erik Sontheimer at the University of Massachusetts Medical School. This is where concern begins to creep in.

Many scientists worry about the consequences if gene editing is left unchecked. "Expression of Cas9 in the wrong place, or for too long, is going to be very dangerous," says microbiologist Alan Davidson at the University of Toronto, Canada. The main problem is that CRISPR can zero in on sequences that are similar to, but ›

Evolutionary arms race

The defence mechanism that bacteria have evolved in response to the viruses that infect them is ingenious. Known as CRISPR, it consists of two elements: a stretch of DNA that can target viruses the bacteria has encountered and an enzyme that then chops up the invaders. This ability to target and destroy has brought CRISPR to the attention of researchers aiming to develop gene editing (see main story). However, in the natural world, CRISPR's power seems to be waning. Some bacteria-infecting viruses have evolved a protein-based counter-attack called anti-CRISPR – and it is almost always successful.

It is a bit of an evolutionary puzzle why natural selection keeps CRISPR going in bacteria that meet resistance from anti-CRISPR. One possible explanation is that CRISPR has acquired other useful functions. For example, it seems to help some bacteria form biofilms – diverse communities of microbes that have many advantages for the survival of their inhabitants. In addition, some bacteria use CRISPR to help regulate the expression of their genes. It may also have other uses yet to be discovered.

Another reason bacteria maintain CRISPR is that it is still effective against viruses with anti-CRISPR in certain circumstances. The most important factor appears to be the relative size of the virus and host populations. The CRISPR system takes energy to run, but its big advantage is that it can respond rapidly. So, when bacteria are under attack from just a few viruses, CRISPR can eliminate them before they proliferate and activate their anti-CRISPR, saving the microbes from having to expend too much energy.

Never-ending battle

It probably took thousands of years for bacteria to evolve CRISPR. "It requires huge genetic innovation," says Edze Westra at the University of Exeter, UK, who studies the evolutionary ecology of bacterial immunity. Yet, its evolutionary future is uncertain. All we can be sure of is that, in the arms race for survival, bacteria will continue to evolve innovative defences against viruses and viruses will evolve ways to fight back.

PETER MARLOW/MAGNUM PHOTOS

not an exact match for, its target, and Cas9 is then able to cut such sequences. As a result, there is a risk that, while being used to treat a genetic disease, CRISPR-Cas9 could cause harmful changes elsewhere in a person's genome – so-called off-target edits.

Beyond medical uses, the consequences of uncontrolled gene editing are equally concerning. In an application called a gene drive, CRISPR-Cas9 can be used to boost the prevalence of certain genes in a population by editing them to increase their chances of being passed on to the next generation. A gene drive could be used to great effect: to eradicate a vector-borne disease such as malaria, for example, by promoting a gene that makes male mosquitoes infertile or one that prevents females from biting. But there is a danger that such genetically edited organisms might run amok in the environment with unintended consequences.

Take back control

We clearly need a way to more closely control CRISPR-Cas9. That is where anti-CRISPR comes in. CRISPR has been found lurking in the genomes of half of all sequenced bacteria. However, some phages have evolved their own system to fight back.

Their defence consists of small proteins called anti-CRISPRs (Acrs) encoded in their genome. When a phage infects a bacterium, it injects its genetic material and then hijacks the host's genetic machinery to make copies of its own genes. The Acr genes are among the first to be expressed, which means that anti-CRISPR can get straight to work to block the bacteria's CRISPR response. It uses a variety of mechanisms, including attaching directly to the Cas enzyme and preventing CRISPR-Cas from binding to DNA.

Anti-CRISPR was discovered by accident in 2012, just as the CRISPR gene-editing revolution was taking off. Working in Davidson's lab, microbiologist Joseph Bondy-Denomy was surprised to find that phages infecting a pneumonia-causing bacterium

OHSU/KRISTYNA WENTZ-GRAFF

weren't being destroyed by the microbe's CRISPR system. Looking more closely, he discovered that the virus had genes capable of inactivating the bacteria's defence. At first, Bondy-Denomy didn't realise the magnitude of his discovery. Back then, no one was thinking about the problem of keeping CRISPR-Cas9 under control, let alone ways to do so. Nevertheless, he continued studying Acrs, finding them in a range of other phages. For a while, he and his colleagues had the field to themselves.

“We need a way to control gene editing – that is where anti-CRISPR comes in”

Anti-malaria measures may be redundant one day thanks to CRISPR gene editing (above)

The first operation using CRISPR in a human was carried out in 2020 (left)

In 2016, Bondy-Denomy and his colleagues found Acrs capable of disabling the Cas9 enzyme, the one used in the vast majority of gene-editing studies. By then, he had his own lab at the University of California, San Francisco. His former colleague April Pawluk discovered this same protein, AcrIIA4, simultaneously. Now CRISPR researchers did take notice. With the problem of control widely recognised, they began to pile in to anti-CRISPR research. Within months, a team including Doudna had delivered AcrIIA4 into human cells along with CRISPR-Cas9, allowing them to limit gene editing to a brief period, so minimising the problem of off-target edits. Timing when the Acr was administered provided another layer of control, allowing them to switch off Cas9 either abruptly or gradually.

There is still much to discover about Acr proteins, but their potential to regulate gene editing is clear. “It’s a very exciting time to think about this Acr strategy as one option – or even the premier option,” says Bondy-Denomy. “What it gives you, is the ability to have a genetic off-switch encoded with Cas9.”

That has significant advantages over other possible approaches. For a start, it would minimise the number of therapies patients are exposed to compared with using a separate drug to inhibit Cas9. It also means you can be sure that Cas9 and AcrIIA4 are in the same place at the same time. And it can give you more control to stop and start gene editing by allowing the activity of the two proteins to be toggled back and forth – potentially by using light. Already, one group has engineered a version of AcrIIA4 that can be turned on and off by shining light onto it, a technique known as optogenetics.

On target

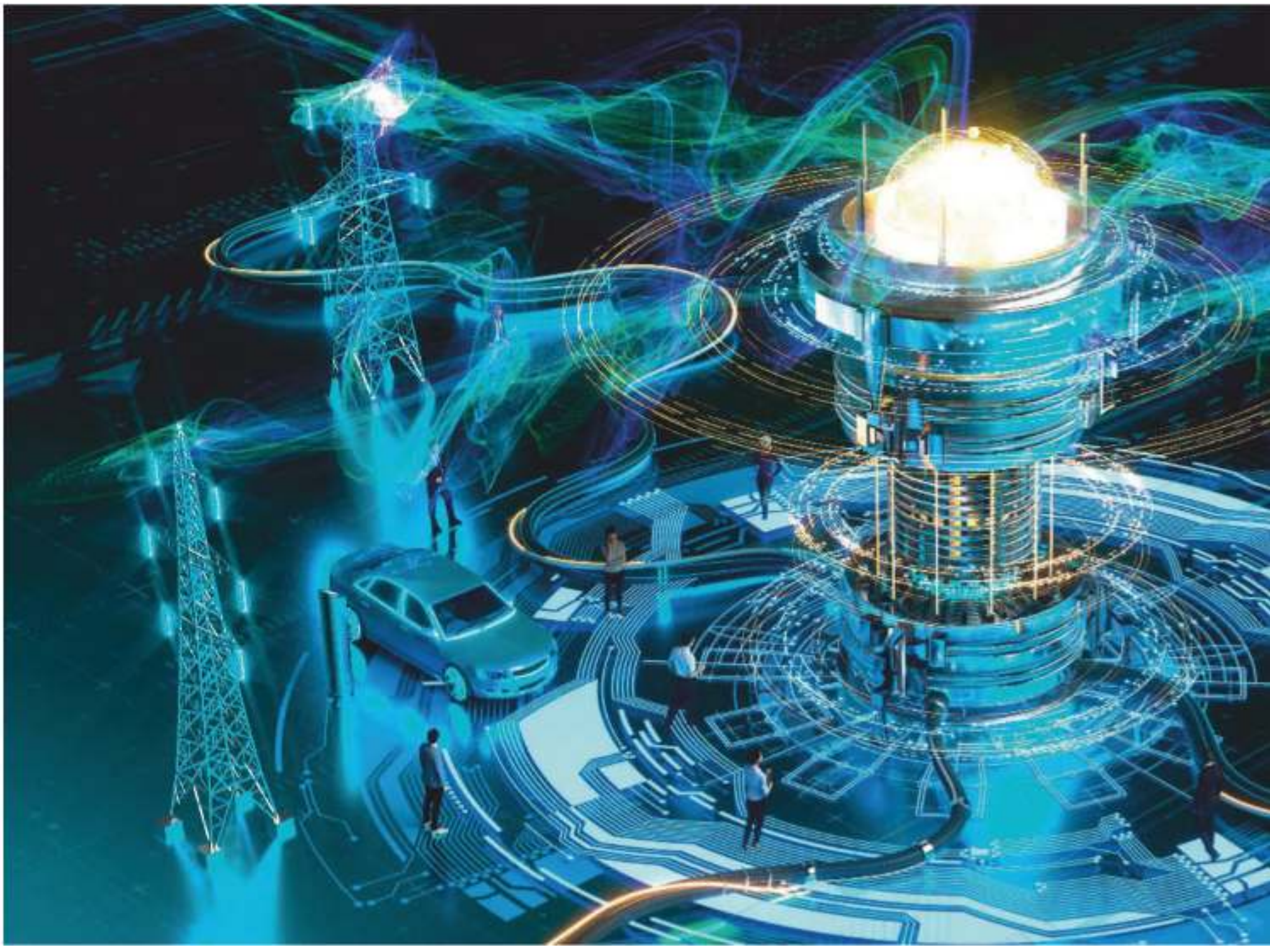
Anti-CRISPR might even help solve the problem of getting gene editing to occur only in certain cells. By tinkering with Acrs, it is possible to produce CRISPR-Cas9-Acr complexes that are permanently off in non-target parts of an organism. Sontheimer’s team demonstrated this in the first successful study of anti-CRISPR in a living organism. The researchers created an Acr that was active unless it was in the presence of a snippet of RNA found only in liver cells. They then added this to CRISPR-Cas9 so that gene editing occurred only in a mouse’s liver. Such an approach could potentially be used in any organ that contains a unique RNA molecule.

Combining Acrs with CRISPR offers long-term benefits too. Viral vectors are currently the most common method for getting CRISPR-Cas9 genes into cells, but these then remain there indefinitely because they become incorporated into the cell’s DNA. As a result, there is a risk that, somewhere down the line, Cas9 will somehow become active again and make undesired edits in the genome. This can be prevented if the gene-editing sequence also contains an off-switch.

Progress with anti-CRISPR has been remarkably rapid, but huge questions remain. One is whether it is safe to administer Acrs to people. “I don’t think that they have any risks that aren’t present with using CRISPR or, in fact, any foreign proteins that you would introduce into people,” says Davidson. Nevertheless, both Acrs and CRISPR-Cas9 are of non-human origin so could generate an immune response that would inactivate them and might cause damaging inflammation. Cas9 has already been seen to generate antibodies in mice. However, Acrs are around 100 times smaller than Cas9, which means they stand less chance of being recognised by any antibodies that might be produced in response to them. Bondy-Denomy thinks that adding Acrs is unlikely to make things any worse.

The biggest challenge will be making anti-CRISPR work in practice. To control gene editing using Acrs, we need to find ways to deliver them to the right place inside the body and reliably control them once they are there. We aren’t capable of that yet. “We’re still just scratching the surface,” says Davidson. That is hardly surprising, given that this idea is just a few years old. Bondy-Denomy, for one, believes it will happen one day. But to make the life-saving potential of CRISPR a reality, anti-CRISPR needs to generate the same level of interest and creative research as its nemesis. “It’s really important to get it on everybody’s radar,” says Bondy-Denomy. ▮

Gege Li is a freelance science writer and was working as an intern at *New Scientist* when she wrote this article



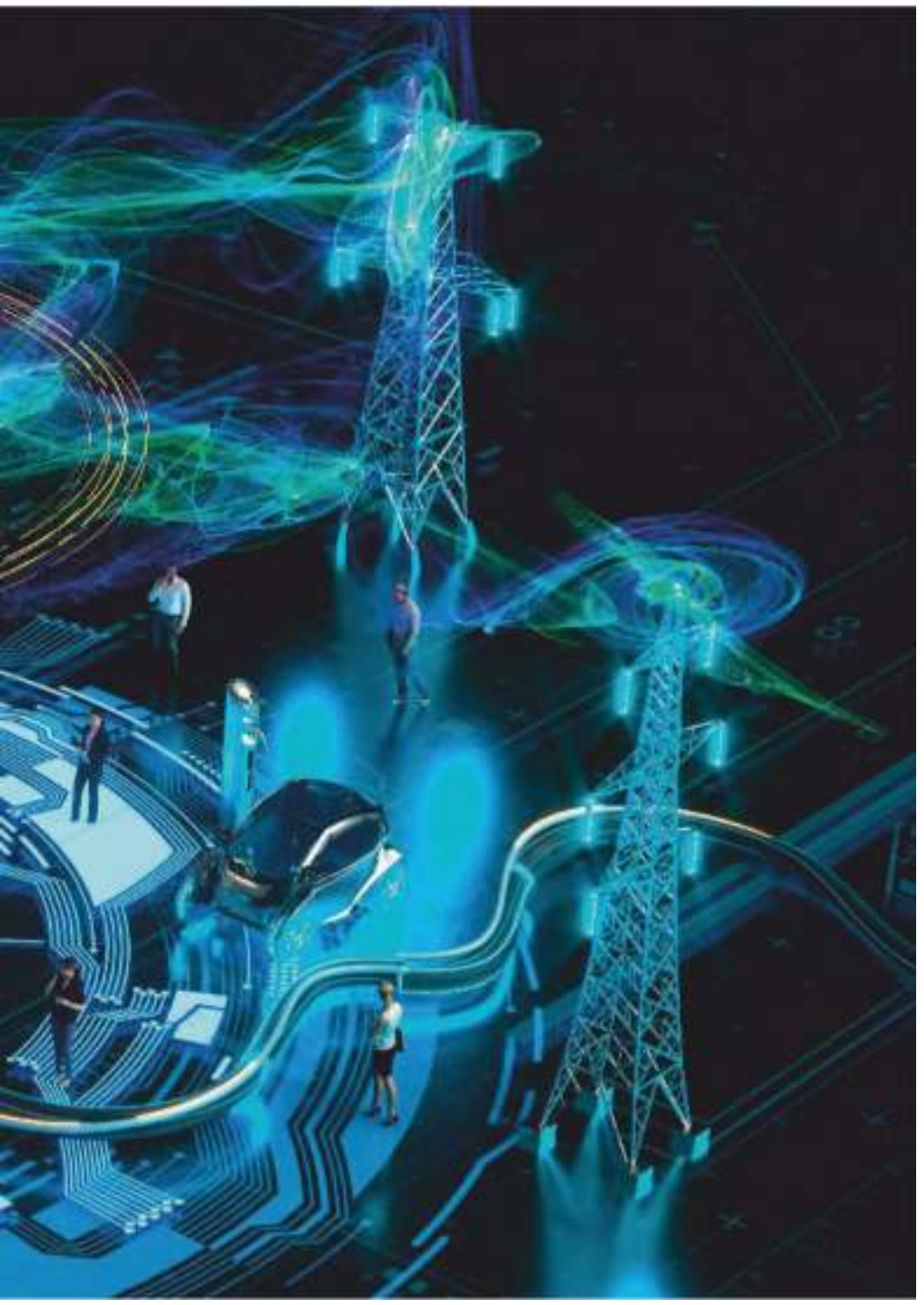
SPOOKY POOKA

Superconductors are hot (again)

It's been a long time coming, but materials that conduct electricity without losing any of it could finally be emerging from the cold, says **Michael Brooks**

THEY called it the "Woodstock of physics". The hastily convened evening session of the American Physical Society meeting in the New York Hilton hotel on 18 March 1987 was supposed to last for just a few hours. In the event, some 1800 physicists crammed into a space made for 1100, with thousands more watching on TV screens outside. The session eventually broke up at 3.15 am, with many people lingering until beyond dawn. The news made front pages around the world. In New York, meeting participants were feted on the street.

The reason for the unlikely euphoria was a sudden slew of breakthroughs in superconductivity. Superconductors are materials that can transport electrons, and



therefore electrical power, entirely without resistance – unlike the lossy conducting metals that wire up our electrified society, or the semiconductors within our computers. Making a practical superconductor would presage a revolution in how we make, store and transport energy – just what we need in today's era of accelerating climate change.

More than 33 years on, that revolution is still pending. Just lately, though, there have been rumblings of renewed optimism. Theory and experiment are coming together to provide new avenues towards superconductors. Not only that, it seems that we might already have made a superconductor that works at close to room temperature – the ultimate target of this

"We might have made a superconductor that works at close to room temperature"

realm of physics. Until now, we have been fumbling around in the dark in our search for working superconductors. Suddenly, we are seeing glimmers of light.

This has been a long time coming, even before the false dawn of 1987. It was in 1911 that Dutch physicist Heike Kamerlingh Onnes discovered that mercury wire lost all electrical resistance at an extremely frosty 4.2 kelvin, or 4.2 degrees above absolute zero (-273.15°C), the lowest temperature possible. The next year, tin and lead were discovered to become superconductors, at 3.8K and 7.2K, respectively, followed by other metals, often as alloys such as niobium-tin.

Onwards and upwards

This is known as low-temperature, or "conventional" superconductivity. As Nobel prizewinning research in the 1950s finally showed, it occurs because conducting electrons team up into so-called Cooper pairs, which use quantum properties to evade the normal barriers to their free movement through a solid. This pairing is caused by the influence of phonons – vibrations in the lattice of atoms that make up a solid. These vibrations get disrupted at higher temperatures. Until recently at least, conventional superconductors worked only below 40K or so, meaning they had to be cooled using expensive liquid helium.

What got the world so excited in 1987 was the discovery of materials that became superconducting at temperatures above 100K. This was a huge leap because they required only relatively cheap and accessible cooling with liquid nitrogen, which works down to 77K. Research teams quickly refined these new copper-oxide, or "cuprate", superconductors by experimenting with various recipes of elements in different proportions. By 1993, they had pushed their maximum superconducting temperature up to 133K or -140°C, a little under halfway from absolute zero to room temperature, which is typically taken as 293K or 20°C. ›

How will superconductors change the world?

Being able to conduct electricity without resistance at room temperature would be a game changer in everyday life. Something like 10 per cent of electrical power is lost in long-distance, high-voltage cables, so making them out of superconductors would be an immediate big win. We would also be able to store energy in superconducting circuits, allowing us to keep cheaply generated power from renewable sources until it is needed.

By making our energy systems more efficient, superconductors would reduce greenhouse gas emissions, helping slow climate change. In applications such as motors and generators, they would offer a significant improvement in the power-to-weight ratio, boosting the efficiency of electric vehicles, for example. And the strong magnetic fields that will be needed to confine the hot plasma in future nuclear fusion reactors will only be sustainable with the high current density that superconductors provide.

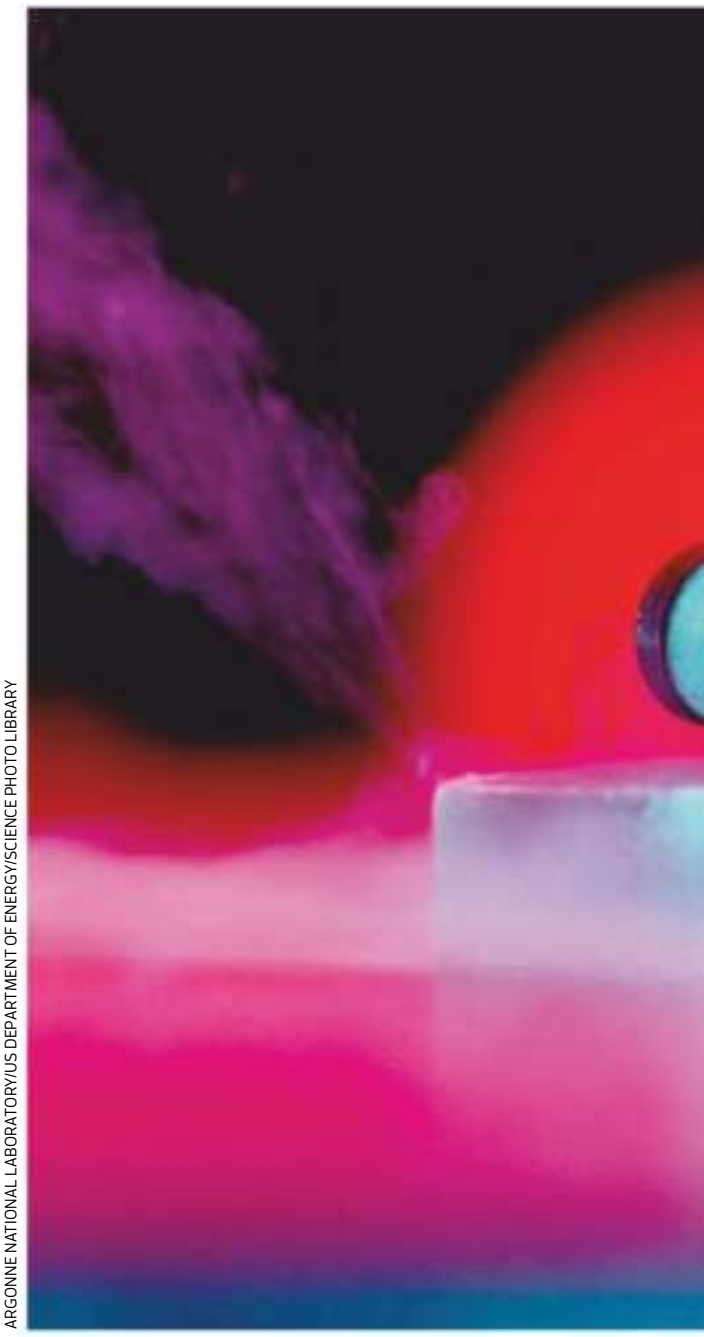
What about magnetically levitating trains, you might ask? These have been a much-vaunted application of the strong magnetic fields that superconductors provide. In truth, though, you can get a train to float above its tracks, and hurtle along friction-free, using standard magnets. The infrastructure costs for this kind of track are already eye-watering enough for most governments to demur, without adding expensive superconductors.

Frustratingly, however, that was it. Unlike with conventional superconductors, we don't know what's going on inside these higher-temperature superconductors to make them lose their electrical resistance. We suspect that they form Cooper pairs directly, without phonons, but that is only an educated guess. Without knowing for sure, the only way to improve the recipes for these materials is by tinkering and crossing fingers.

There are also practical issues with the cuprate superconductors. They aren't ductile metals that you can draw out into thin wires, but brittle ceramics. They are expensive to manufacture, easily "poisoned" by contamination with stray elements and superconduct only within a single crystal. This means they are no good if you want, say, to make electricity transmission cables (see "How will superconductors change the world?", left). "That means you have to try to make a crystal that is a kilometre long," says Susie Speller, who researches superconductor applications at the University of Oxford.

Cuprate wires of bismuth strontium calcium copper oxide, known as BSCCO (pronounced "bisco"), get round some of these problems. But this material is "prohibitively expensive" for most applications, says Speller. Besides only working below particular temperatures, other superconductors require high pressures or low intensity magnetic fields to function. Promising-looking iron-based superconductors discovered in 2008 also proved too brittle to easily turn into wires. "The materials science has held back the applications of these materials because they are so difficult to work with," says Speller.

The high density of the current in superconductors creates strong magnetic fields, so they have found niche applications. These include the magnets that steer particles at the Large Hadron Collider at the CERN particle physics laboratory near Geneva, Switzerland, and within hospital MRI scanners, which use the magnetic fields to look at tissue structures within the body. But these superconducting magnets typically use niobium-tin alloys cooled with liquid helium

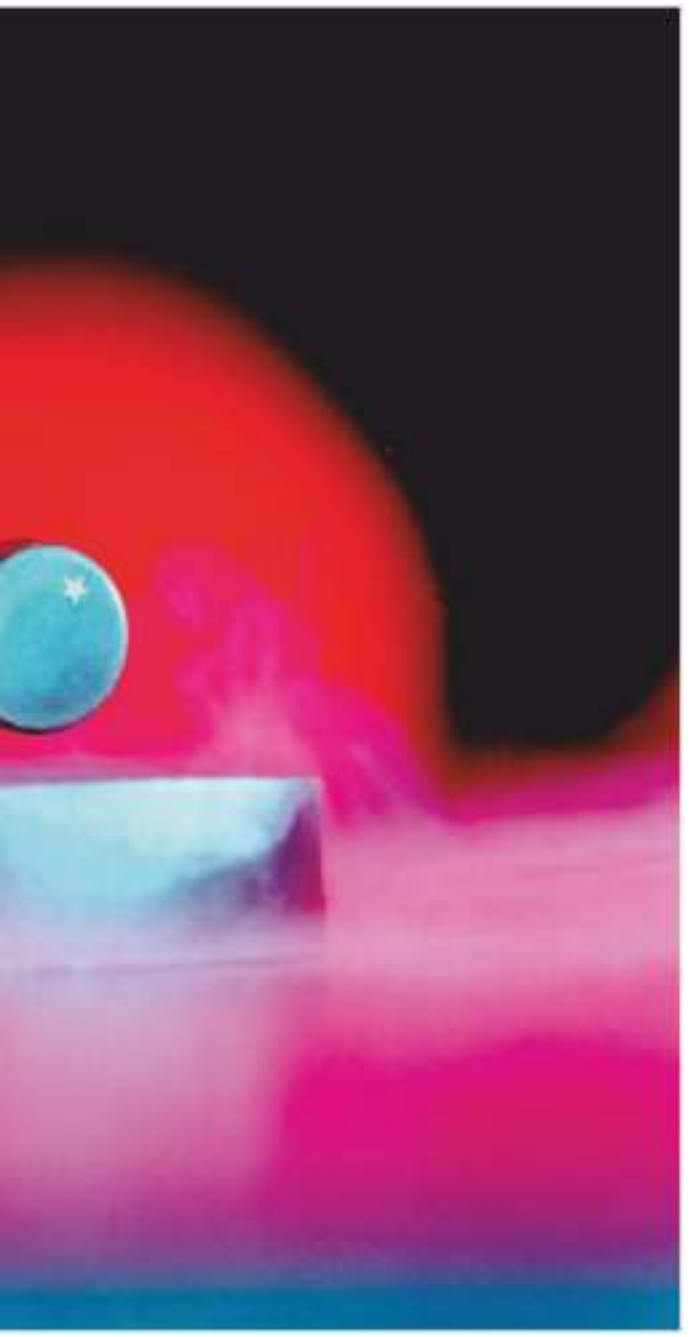


ARGONNE NATIONAL LABORATORY/US DEPARTMENT OF ENERGY/SCIENCE PHOTO LIBRARY

to 4K or lower. The lack of wider applications is disappointing, to say the least.

Today's fresh optimism comes courtesy of two breakthroughs. One concerns graphene, the much-feted supermaterial made of atom-thick sheets of carbon. In 2018, researchers led by Pablo Jarillo-Herrero at the Massachusetts Institute of Technology showed that putting two sheets of graphene together and introducing a twist makes it superconduct. That happens only at 1.7K, but, crucially, the superconductivity seems to mimic the way it works in cuprates.

In 2020, Artem Mishchenko at the University of Manchester, UK, revealed another carbon-based material that mimics cuprate superconductivity, rhombohedral graphite. "It's potentially interesting as a model system to help us understand high-temperature superconductors," says Mishchenko.



The strong magnetic fields from some superconductors can levitate objects

> **“Theory, computation and experiments all came together to make the breakthrough”**

But it is a result published late last year that has provoked the most excitement. It too was a long time coming. Back in 1968, Neil Ashcroft at Cornell University in New York showed that if hydrogen could be turned into a solid, it should contain superconducting Cooper pairs. Ashcroft continued his theoretical studies for decades, and in 2004 showed the same should be true of hydrogen-containing compounds known as hydrides under conditions such as extreme pressures, perhaps even at room temperature.

That was a clue, but no more. To make a material superconduct “we’ve learned that you’ve got to have a number of different elements sitting in the right place in the crystal, in exactly the right proportions”, says Speller. That means going through a whole periodic table of elements. “It’s looking for a needle in a haystack – unless you’ve got a strategy for where to look.”

That is where computing muscle comes in. In 2006, Chris Pickard, a materials scientist at the University of Cambridge, showed it was possible to speed the search by putting the theoretical frameworks for a range of materials – including the hydrides – into a free and easy-to-use software package called Ab initio Randomised Structure Searching, or AIRSS. This enables theorists to explore the internal structure of a solid, and analyse how its electrons would behave and what kind of electron-phonon coupling it would experience at particular temperatures, for instance. That won’t tell you the best superconducting material, but it does tell you whether the material you are looking at could be a good one. “The computations are faster and less expensive than doing experiments,” says Eva Zurek, a theorist at the State University of New York at Buffalo.

That approach has been a game changer, says experimentalist Mikhail Eremets at the Max Planck Institute for Chemistry in Mainz, Germany. “Just using intuition doesn’t work: it’s very difficult to predict which material will be favourable,” he says. In 2015, Eremets took hints from the software to achieve superconductivity in hydrogen sulphide at 203.5K by squeezing it until it was at 155 gigapascals (GPa), more than 1.5 million times the atmospheric pressure at Earth’s surface.

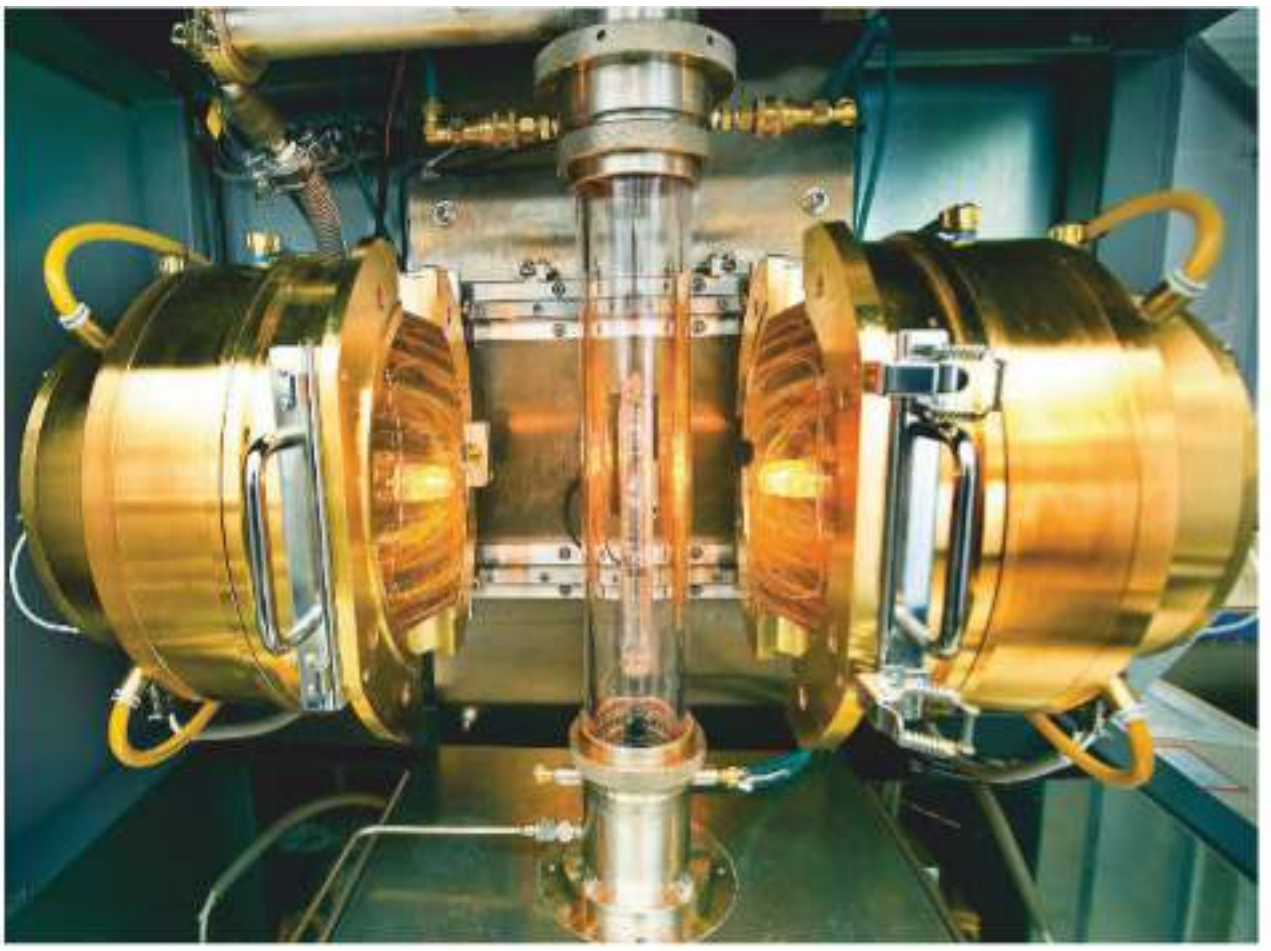
Following that lead, in October last year, Ranga Dias at the University of Rochester in New York and his colleagues created a material that superconducts at 287K, or 14°C. Assuming it is winter, and the central heating has been off, that is pretty much room temperature – the first time superconductivity has been achieved at anything like this temperature.

Dias and his team made their material superconduct by crushing it between two diamonds, achieving a pressure of 267 GPa – akin to that found near Earth’s core. That is highly impractical. But crucially it seems likely, says Dias, that the material becomes a superconductor through the conventional Cooper pair mechanism.

Proof of principle

If so, it is the long-sought proof that conventional superconductivity is possible at room temperature, meaning we can use well-developed models to look for materials whose properties can tick all the boxes necessary to make a practical room-temperature superconductor. “Theory, computation and experiment all came together in the right place and at the right time for this breakthrough to happen,” says Pickard. “These results demonstrate that we have the theoretical and computational tools to do that search.”

The focus of theorists now is on directing experimentalists towards similar materials with a structure that means they will superconduct at low enough pressures and high enough temperatures, while having desirable physical properties such as ductility or malleability. Only a few research groups can achieve the kinds of pressures that Dias managed, but attaining pressures below around 100 GPa doesn’t need the specialised equipment he used. If theorists can point to structures that might superconduct at ›



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Superconducting crystals are grown in an infrared furnace at Brookhaven National Laboratory in New York state

100 GPa or lower, "we suddenly open it up to a much wider experimental community that can test and refine and optimise the materials", says Pickard. He already has a paper out that predicts a 0°C superconducting transition temperature for a material that requires just 100 GPa of pressure.

There is a further stumbling block to feeding the results of Dias's experiments back into the models, though: nobody knows quite what his team made.

Dias aped Eremets's techniques – he says that if there is a Nobel prize for this work, Eremets should get it – but squeezed together a witch's brew of carbon, hydrogen and sulphur. No one can tell exactly how those atoms bonded together at high pressure, and the material doesn't respond to the usual X-ray diffraction imaging technique used to see what is going on inside at the atomic level: hydrogen is such a light element that its diffraction is too small to see. "We're trying to develop new techniques," says Dias. "As of now, we are sort of blind."

If we can understand the structure and the mechanics of how high pressures might create a Cooper-pair interaction, we may be able to start doing it at lower pressure. One hope is that the material is "metastable" and won't fall apart when the pressure is released. Diamond is an example of a metastable material: it is created when carbon atoms are subjected to extremely high pressures, but once it has formed you can remove the pressure and it doesn't revert to its previous form.

Cool ideas

Metastability isn't easy to check: the experiments to squeeze materials to induce superconductivity generally crank up the pressure until the diamond breaks, mixing with the sample, and you can't just reverse the process. David Johnston, who researches superconductivity at Iowa State University, isn't convinced that any Cooper-pair interaction present would survive a return to low pressures. "I don't see any hope of room-temperature superconductivity from that interaction at ambient pressure," he says.

Zurek reckons further developments might need to be led by a theory that starts with mathematics, not a compound that just happens to have some of the properties we are looking for. That might lead us in a completely different direction. If we can understand what allowed superconductivity to exist at room temperature in Dias's experiment, we could apply that insight to conventional superconductors such as niobium-titanium and magnesium diboride.

These are useful, useable materials, and we don't necessarily need to lift their transition temperature above that of liquid nitrogen. That is a point people often miss, says Pickard. "Sometimes it can be hard to get people excited about that – they want to get to room temperature," he says. But to start the superconducting revolution, we just need a "good enough" material that is relatively cheap, can easily be drawn out to form wires and works at liquid-nitrogen temperatures.

That would be enough, for instance, to make cheaper MRI scanners, widening their availability for medical diagnostics and studies of the human brain. The same is true of using superconductors in electricity transmission. "Needing to cool using liquid nitrogen is not a showstopper for power lines," says Speller. The current within superconducting wires is so dense that high-voltage transmission cables could be much thinner than normal. It is "pretty easy", she says, to make vacuum-flask-style jackets for them to stop liquid nitrogen from boiling off too fast.

What has changed in the past couple of years is that we have theory, computation and experiment feeding off each other to find a material that ticks those boxes. That can only be good, says Pickard. "The more people that can have different ideas, the more chance that someone, somewhere, will find the needle in the haystack." This time round there may not be Woodstock-style euphoria, but with the hard graft now becoming easier, the superconducting revolution really could be within our grasp. ▮

Michael Brooks is a consultant for *New Scientist*. His latest book is *Hollywood Wants to Kill You: The peculiar science of death in the movies*

The back pages

Stargazing at home

Hunting the Hexagon

Six bright stars make a special hexagon in the night sky from now until March. **Abigail Beall** reveals how to spot them

Abigail Beall is a science writer in Leeds, UK. She is the author of *The Art of Urban Astronomy*
@abbybeall

What you need

Clear night skies
Binoculars (optional)
A telescope (optional)

Stargazing at home appears every four weeks

Next week
Science of cooking

BETWEEN December and March, there is something special for stargazers in most of the world to watch out for. You will be able to see a pattern of stars, or asterism, made up of six bright stars. It is called the Winter Hexagon or Winter Circle in the northern hemisphere, or the Summer Hexagon or Summer Circle in the southern hemisphere.

Each of these stars is the brightest in their constellation. The asterism can be seen from anywhere except the most southern parts of New Zealand, Chile and Argentina and further south. Depending on where you are in the world, its orientation with the horizon will change, but the pattern of the stars with respect to each other will stay the same.

In previous columns, I have revealed how to find Orion and its brightest star, Rigel. Rigel makes one corner of the hexagon. You can find the hexagon's next two stars by extending Orion's belt. In one direction, you will find Sirius, the brightest star in the night sky. It will be low in the horizon in the northern hemisphere and higher in the southern hemisphere. Go in the other direction, and you will get to a bright star in Taurus called Aldebaran, the next point.

To find the other stars in the asterism, start by looking for Pollux, in the constellation Gemini. Draw a line from Rigel, through Orion's Belt and keep going, past the red bright star Betelgeuse and on until you see two bright stars close together. These are Castor and Pollux, the twin stars in Gemini. The brightest of these, Pollux, is another point on the hexagon.

JEFF DAI / SCIENCE PHOTO LIBRARY

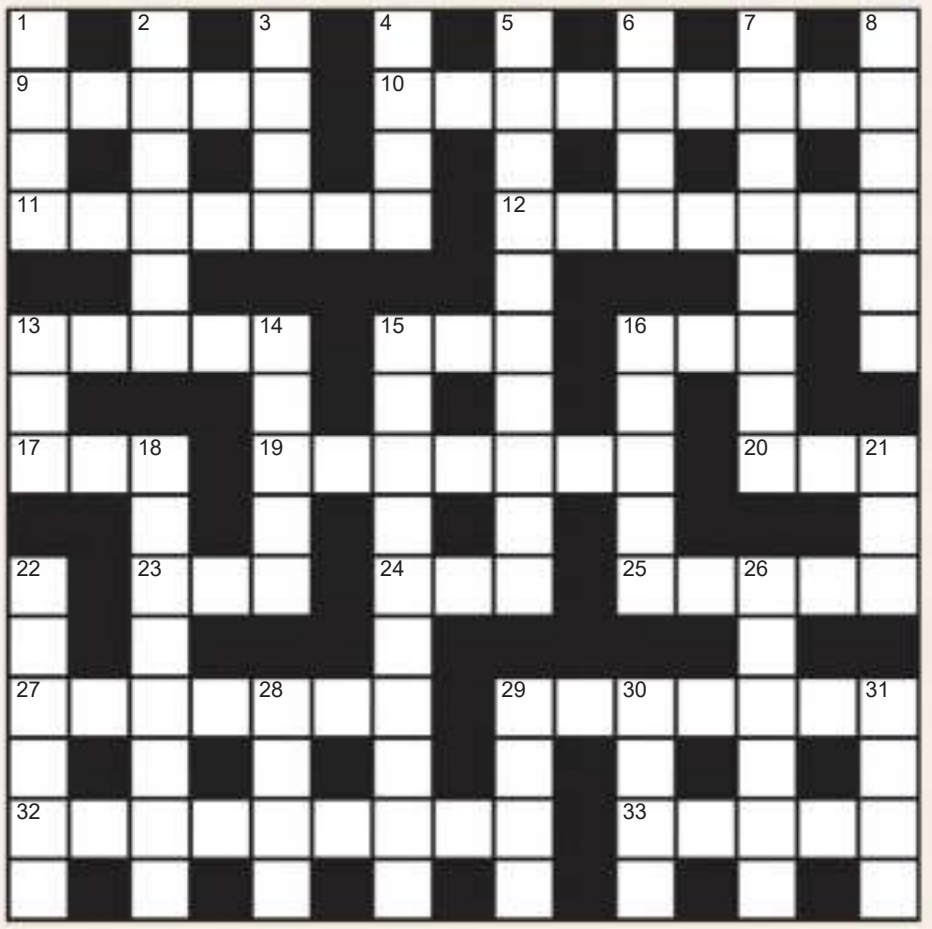
It should be easy to fill in the gaps where the remaining two corners of the hexagon lie. If you look between Sirius and Pollux you will see a bright star, called Procyon,in the constellation Canis Minor. Follow the lines of the hexagon round to look for a star shining brightly opposite where Sirius sits. This is the final star in the hexagon, Capella, in the constellation of Auriga.

In the southern hemisphere, you can extend this asterism to include another star, called Canopus. This star is in the constellation Carina. It is the second brightest star in the night sky after Sirius, and you can find it by drawing a line from Canopus to Sirius then continuing it until you see a bright star.

Now we have them all: starting from Rigel and going clockwise, the hexagon's stars are Sirius, Procyon, Pollux, Capella and Aldebaran. There are different ways to remember their names, but I think of it as the RSPPCA, the Royal Society for the Protection of People who Care about Asterisms. If you find the two stars beginning with P hard to recall, remember Procyon is in Canis Minor and Sirius is in Canis Major, and the two dog constellations are loyally next to each other.

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

Quick crossword #74 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

9 Higher, superior (5)
10 90° north (5,4)
11 20th-century Dutch astronomer (3,4)
12 ___ number, used to label or identify (7)
13 Leg joints (5)
15 Unspecified ordinal numeral (3)
16 Period, age (3)
17 Woodworking tool (3)
19 Of memory, able to precisely recall an image (7)
20 1000 hertz (3)
23 Animal doctor (3)
24 Public transport vehicle (3)
25 Illuminated (3,2)
27 "There is no such thing as a ___" – Mark Twain (3,4)
29 Acetylsalicylic acid (7)
32 Arctic bird of prey (9)
33 Siblings from the same pregnancy (5)

DOWN

1 ___ Khalifa, Dubai skyscraper (4)
2 Marine life forms in the phylum Porifera (6)
3 Georg von ___, German wireless pioneer (4)
4 Small wading bird (4)
5 Inflammation in the lung (10)
6 Metabolic panel (4)
7 Perambulation first undertaken by Neil Armstrong (8)
8 Involuntary response to stimulus (6)
13 Carnivorous parrot of New Zealand (3)
14 Perspiration (5)
15 Soft-bodied marine mollusc (10)
16 Microsoft spreadsheet software (5)
18 Cable carrying a flow of current (4,4)
21 Fastening device formerly known as a clamp locker (3)
22 Ancient non-flowering plant (6)
26 Asphalt lake (3,3)
28 Air or water resistance (4)
29 Skin condition (4)
30 Hierarchy expressing a location in a file system (4)
31 John ___, mathematician and economics Nobel laureate (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #84

1 What name is given to a kind of modified berry with a thick rind and segments of juicy pulp, such as oranges and kumquats?

2 In biology, Cope's rule is the tendency of organisms to evolve in what way over time?

3 What is Pele's hair?

4 Pando, a clonal colony of around 47,000 genetically identical trees in Utah, is thought to be the heaviest known organism. What kind of tree is it made up of?

5 Comet Tempel-Tuttle is associated with which meteor shower?

Answers on page 55

Puzzle
set by Rob Eastaway

#96 Inside the box

Can you join the 36 dots below using 10 straight lines, with your pen never leaving the paper and no lines going outside the grid? At least one line must pass through each dot and no devious rule-bending is required. You will find lots of ways to do it with 11 lines, but 10 is much more of a challenge.

PS This puzzle forces you inside the box, but its solution is related to the classic four-line, nine-dot problem that was the origin of the cliché "thinking outside the box".

Answer next week

Now is the time

Buddhists recommend living in the present moment. How long is this gap between the past and the future?

Talia Morris
Cape Tribulation, Queensland, Australia
As someone who has practised Buddhist-inspired meditation for three years, I can answer the question of how long the gap is between past and future with some confidence.

In a very real sense, neither the past nor the future exists – the past is composed of memories, and the future of hopes, fears and expectations. Only the now is real, there is no gap between past and future.

As viewed by the person meditating, "now" is both infinitesimally small and infinitely large because it is possible to use techniques like following a simple bodily sensation, such as breathing, to – at least temporarily – disregard

"The present moment is a psychological illusion based on events of the past and predictions about the future"

mental intrusions. Ignoring memories, worries and random thoughts lets someone focus on simply being present for as long (or as little) as they desire.

If done successfully, meditation can have the interesting effect of telescoping time so that 10 or 15 minutes can feel like a few seconds.

Will Kemp
Wagait Beach, Northern Territory, Australia
While I understand the psychological benefits of being "in the moment", I think the present is grossly overrated. No sooner has it come than it is gone.

The most important part of the present is what you will remember later, possibly in decades to come. The past is important because you can enjoy the memories you have of it, and the future is important because without it, what you do in the present is irrelevant.

The present doesn't really exist, except in future memories.

Pete Lloyd
Torremolinos, Spain
I once worked in an office with air conditioning that cycled on and off. When the fan stopped, I would become aware of the noise it had been making – which, up to that point, I had been ignoring.

The change in sound made me aware of what I had been hearing for about the last second or so. As far as my hearing is concerned, my present is about 1.5 seconds long.

Hillary Shaw
Newport, Shropshire, UK
For a non-physicist Buddhist, the gap between past and future might be around 150 milliseconds, reckoned to be the speed of human thought.

For a quantum Buddhist, however, this gap may be much smaller. The shortest measurable distance in the universe is the Planck length: about 1.6×10^{-35} metres. Light will traverse this length in around 5.4×10^{-44} seconds, making that the shortest time measurable.

However, there may be even shorter lengths. A black hole Buddhist must allow for the possibility of the singularity at the heart of a black hole being infinitely small. At this point, conceptions of time and space break down, making the past-future gap precisely 0 seconds.

In this case, there is no present.

Tim Lewis
Narberth, Pembrokeshire, UK
It can take up to a second for the human brain to process information about the immediate environment, so all that we experience is already in the past.

Neither for Buddhists nor for anyone else can there be such a thing as being "in the present".

Chris Arnold
Darlington, Western Australia
Consider time as running along a timeline arrow where there is no gap, only a future and a past separated by an infinitesimally narrow boundary. The future flows into the past across this boundary.

In this model, the present is an interval that we, for convenience, overlay on the timeline.

Chris Daniel
Glan Conwy, Conwy, UK
It depends. The faster you are moving, the more time slows down, and if you are on the event horizon of a black hole, time stops.

In *The Order of Time*, Carlo Rovelli describes time as a light cone converging from the past to a point representing perhaps nanoseconds of the present, then diverging again into an ever-widening cone of the future.

It can take milliseconds for sensations such as touch, sound or light to register with our brains, but 2 or 3 seconds are required for the brain to make sense of these inputs in order to experience the moment of "now".

The present is therefore a psychological illusion based on events of the past and predictions about the future.

DAVID TIPLING PHOTO LIBRARY/ALAMY

This week's new questions

Escape from the sun **How far would you have to travel away from the sun for it to no longer be the brightest object you could see?** ***Jim Loft****, Swansea, UK*

Bird banter **Many birds are able to remember and mimic sequences of sounds they hear, including human speech. What evolutionary advantage does this skill give them?** ***Mick Groves****, Oxhill, Warwickshire, UK*

What are the advantages of being able to mimic sequences of sounds?

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Tom Gauld
for New Scientist

NIGEL COATSWORTH

Rainbow riot

I have seen many double rainbows, but can you get triple or quadruple ones? If so, where are the best places to see them? What is the maximum number that could occur at the same time? (continued)

Nigel Coatsworth
Dudleston Heath, Shropshire, UK
What wasn't mentioned previously were the extra rainbows that can appear inside the arc of the primary bow, known as supernumerary rainbows. I was fortunate to glimpse one at a Devon motorway service station in August 2011 (pictured).

When light is reflected within a raindrop, it is dispersed into its constituent colours. A double reflection, which is what creates the primary bow, spreads the colours out further. However, unless the raindrops are exactly the same size, the dispersed patterns smear out and only the primary one is seen.

The day that I saw a supernumerary rainbow was clearly an exceptional one, where the raindrops were the same size, so the dispersed patterns reinforced one another and revealed two strong bows and a third faint supernumerary one.

I just happened to be in the right place at the right time. I had never seen one before and haven't seen one since.

Guy Cox
St Albans,
New South Wales, Australia
Something that I have never seen reported before is what I call a "stormbow", which seems to be a rainbow in the salt spray from storm waves.

Going potty

If plants and trees can communicate via their root system, do they get lonely in pots? (continued)

Nikki Walter
University of Nottingham, UK
Let's consider the opposite of "loneliness" in plants by thinking about the relationships they form.

A well-known plant-bacteria relationship is between leguminous plants and bacteria in their nodules. When soil is rich in nitrogen (something that bacteria in the nodules "fix" from the air into a form usable to the plant), the plant shuns the relationship with the bacteria. You could say that a plant only wants to make friends when it needs something.

Plants, like most of nature, are usually only acting in their own interests. Keeping another tree alive via underground fungal networks, as trees do, benefits the plant, as a forest is more likely to survive than a tree on its own. Give a potted plant what it wants and it probably won't get too lonely! ▮

Answers

Quick quiz #84 *Answers*

1 Hesperidium.

2 To increase in size.

3 Thin strands of volcanic glass, named after the Hawaiian goddess of volcanoes.

4 Quaking aspen (*Populus tremuloides*).

5 The Leonids.

Cryptic crossword #48 *Answers*

ACROSS 1 Skip, **3** Midnight, **8** Audubon, **10** Umami, **11** Prehistoric, **13** Apache, **15** On edge, **17** Resolutions, **20** Hyena, **21** Forceps, **22** Smocking, **23** Hasp

DOWN 1 Snap peas, **2** Indie, **4** Innate, **5** Neutron star, **6** Glanced, **7** Trig, **9** Bright spark, **12** Messes up, **14** Agree to, **16** Olefin, **18** Omega, **19** Ohms

#95 Catch up *Solution*

Player A can be sure of winning by starting with stack 3. At the end of the game, the combined heights of the towers will be 15, so if either player reaches a height of at least 8, they are guaranteed to win. If A plays 3, either B includes 5 in their first move (by playing 1, 5 or 2, 5 or 5 alone), in which case A can win by playing 1, 4 or 2, 4; or B doesn't include 5, in which case A plays 5 next move and wins. If A plays 1, 2, 4 or 5 as a first move, B has a response that can guarantee they win.

The last word (again)

Many thanks to those who wrote in response to our division of the world into magazine-forwards and (Feedback's favoured) magazine-backwards readers (19/26 December 2020). Robin Shipp confesses to taking things even further, reading our individual items in reverse order, thereby sometimes missing the point of running jokes.

Robin, if you're reading this week, nice to have you with us and it's a pleasure to devote our sign-off item to you. Our apologies that none of the preceding items followed on from one another, but at least you have the consolation that we are all, column-forwards and column-backwards readers, now just as confused as each other.

Me and my spoon

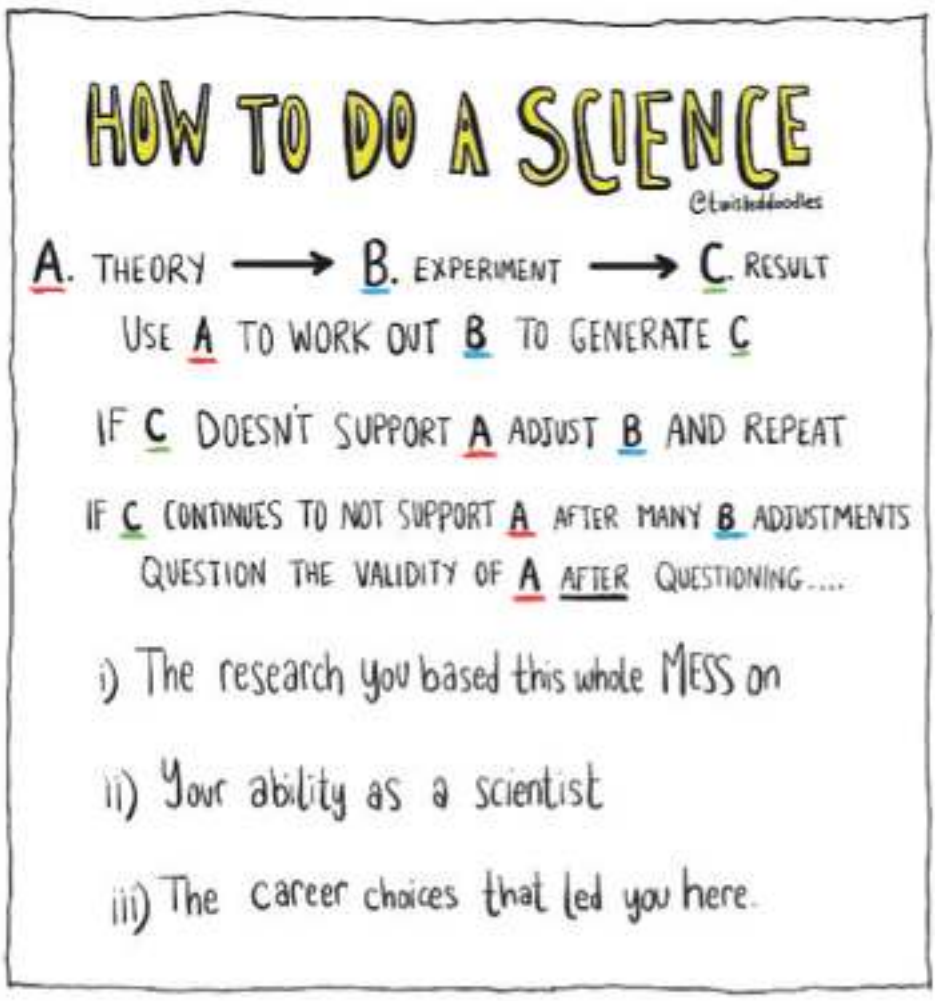
Onwards and... downwards. As the roving albatross is to the high seas, so the humble teaspoon is to the office kitchen: its mysterious comings and goings are the subject of myth and legend, and much academic research. We need hardly remind you, dear readers, of that seminal paper from 2005 which established that the half-life of a teaspoon in the communal tea rooms of the Macfarlane Burnet Institute for Medical Research and Public Health in Melbourne was 42 days.

The latest instalment in the saga comes courtesy of a paper in *The Medical Journal of Australia* sent to us by reader Lyndal Thorburn. It is by Mark Mattiussi at the Royal Brisbane and Women's Hospital and his colleagues – clearly, cutlery-related passions run particularly high in Australia – and is entitled "What the forks? A longitudinal quality improvement study tracking cutlery numbers in a public teaching and research hospital staff tearoom".

In the equivalent of ringing an albatross with a radio receiver, only not, the team introduced 18 forks and 18 teaspoons to a communal cutlery drawer, each furnished with a red nail varnish dot. During a seven-week observation period, six spoons went missing, compared with only one fork. In a previously unobserved phenomenon, the overall number of knives and forks in the drawer went up, presumably because the passive-aggressively marked spoons shamed the light-fingered into returning half-inched wares.

As to the deeper question "where the fork did all the spoons go?", that remains as deep a mystery as what happened to that other sock. Hastily hiding our emergency stash under a pile of tea-stained correspondence, we point by way of diversion to our suggestion a few years back that quantum teleportation might play a part: could the disappearing teaspoons be the same ones that mysteriously appear at the bottom of every washing-up bowl when you pour out the water? Now that really would be a research project.

Twisteddoodles *for New Scientist*



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The weight of W(h)ales

"If we assume that the annual rate of teaspoon loss per employee can be applied to the entire workforce of the city of Melbourne (about 2.5 million), an estimated 18 million teaspoons are going missing in Melbourne each year. Laid end to end, these lost teaspoons would cover over 2700 km – the length of the entire coastline of Mozambique – and weigh over 360 metric tons – the approximate weight of four adult blue whales."

We append this quote from the 2005 research merely to note that Mozambique isn't the only place blessed with around 2700 km of sea views. This was a golden opportunity to express something in terms of both Wales and whales.

On the button

As a brief interlude, responding to our question last week of how many belly buttons there are in a 10-minute walk, John Dobson suggests "a very good estimate is one per person undertaking the walk". Very good, John – but how many people fit into a 10-minute walk?

Put your clothes on

Welcome, column-backwards readers. To perplex you straight off, the cutlery research actually took second place in *The Medical Journal of Australia*'s annual Christmas research competition. The golden stethoscope went to David Chapman and Cindy Thamrin at the Woolcock Institute of Medical Research in Sydney for looking into factors affecting the productivity of Australian medical researchers during the covid-19 pandemic, apart from unfocused cutlery rage.

The list of most frequent causes of interruptions to teleconferencing meetings will be familiar to many: internet connectivity (61 per cent of respondents), children (42 per cent) and other household members (40 per cent). One person reported an interruption by a sleepwalker, although the researchers observe "it is unclear whether this was during a daytime nap or a night meeting".

The headline findings of the study may be summarised as: having young children at home while trying to work depresses productivity, but doesn't affect mental health. Wearing pyjamas while working, on the other hand, has no effect on productivity, but does correlate with more frequent reporting of a decline in mental health. This finding tallies, the researchers suggest, with earlier studies showing improvements in the mental health of hospital patients when encouraged to change into day clothes.

Feedback's elegant silken pyjamas are supremely comfortable, that's our excuse. But we're going to have to find another excuse for why we squeeze out just this one measly column a week.

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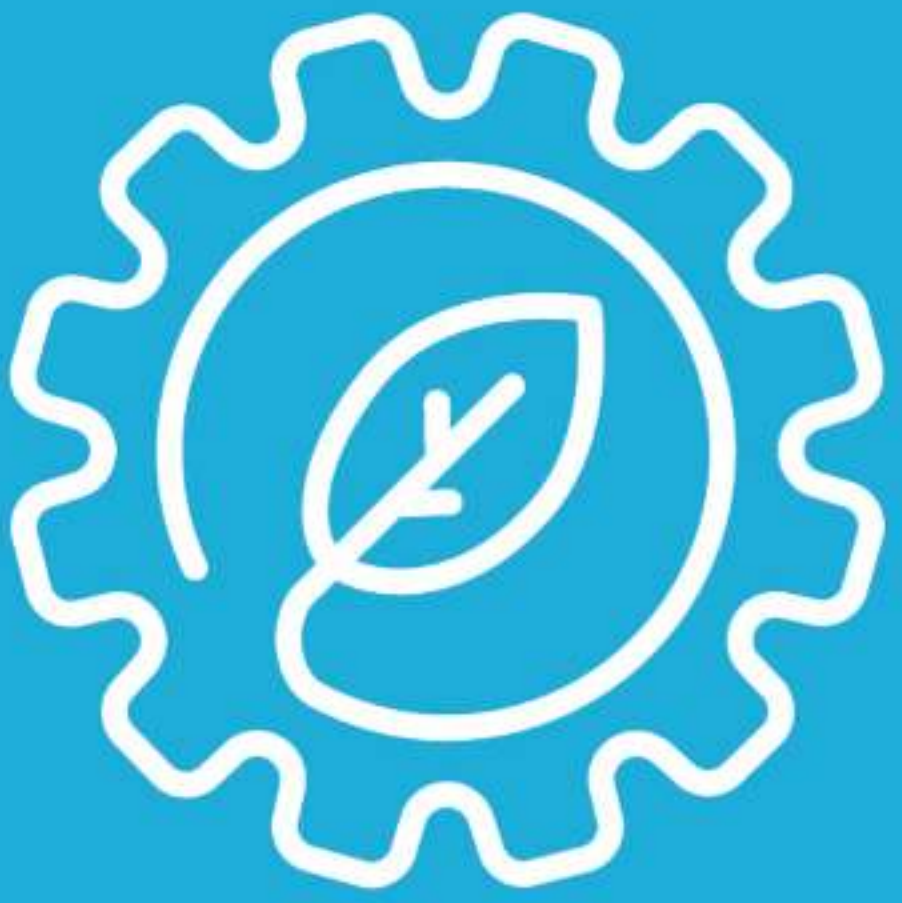

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