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New Scientist

WEEKLY 22 May 2021

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This week's issue

On the cover

Vol 250 No 3335
Cover image: Quentin Monge

44 Features

"Nature was using mechanical bonds long before we humans came on the scene"

News

Views

OZGURDONMAZ/GETTY IMAGES

Features

The back pages

Elsewhere on New Scientist

Academy

Your immune system and how to boost it

As we live through a pandemic, understanding the immune system has never been so important. This new offering from New Scientist Academy will provide you with a vital primer on how your body's defences work, when they change and what you can do to keep the system healthy. This course will be released in June but you can pre-purchase now and save £50. Book a place or find out more online.

newscientist.com/immune-course

Podcast

Weekly

This week, the team looks at vaccine booster shots to keep on top of the coronavirus and how they could work. Also on the pod: how measuring time makes the universe more disordered; neuroscientist David Eagleman on the marvels of brain plasticity; and why it is a special year for cicadas.

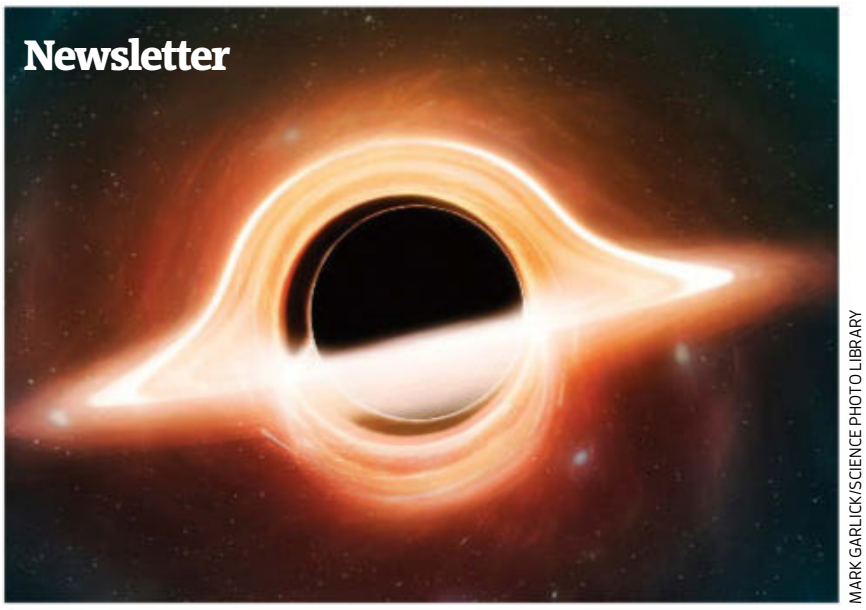
newscientist.com/podcasts

Online

Covid-19 daily briefing

All the latest, most crucial coverage of the pandemic, with links to our best news, features and interviews. Updated each day at 6pm BST.

newscientist.com/coronavirus-latest



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Event horizon Space-time gets taken to extremes at black holes

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Shot in the arm Is it time to think about covid-19 vaccine boosters?

Newsletter

Launchpad

A weekly dose of the latest space news delivered free to your inbox. This week, reporter Leah Crane explains how to think about space-time, the brain-twisting concept that flowed out of Albert Einstein's revolutionary theory of general relativity.

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Video

Science with Sam

In this week's video explainer, Sam Wong asks: why do cats go crazy for catnip? If your cat turns from elegant hunter to drooling ball of fluff at the merest whiff of the stuff, then this one is for you. Don't forget to subscribe to our channel to catch every episode.

youtube.com/newscientist

Newsletter

"Until the 20th century, people thought space and time were separate. Then came relativity"

Puzzle

The latest in our popular series of puzzles features the near side of the moon and the missions that have landed there. With 1000 pieces, this one should keep you going for a while. Available to buy now.

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YEMEN EMERGENCY APPEAL

MEDECINS SANS FRONTIERES
DOCTORS WITHOUT BORDERS

MSF anaesthetist Lenka Červeňová and her team care for a four-year-old boy after surgery in Dhi As-Sufal hospital in Yemen's Ibb province. Photograph © Majd Aljunaid/MSF

ALISON CRIADO-PEREZ

MSF NURSE

The conflict in Yemen is now in its sixth year. In Marib, in central Yemen, nearly three million people have been displaced from their homes and are living in makeshift camps close to the frontline. Pregnant women and children are in desperate need of medical care.

"When we arrived in Marib, we found the local hospitals overwhelmed by the sheer number of people and by an influx of war-wounded. Around 2.7 million people are in the province now, many of them displaced from their homes elsewhere and looking for a safe haven.

People were living in makeshift shelters made of plastic and metal sheets. There were no latrines, just pits dug in the ground outside the tents. People were very worried about their health, about the risk of disease, about not having enough food. We were very concerned about the health of mothers and children, and pregnant women were a major worry too.

Over the next month, our small team worked around the clock to set up clinics providing basic healthcare and to supply hospitals that were struggling. Getting medicines to this part of Yemen wasn't easy. Supplies often had to cross frontlines. One of our trucks carrying antibiotics, medicines and other supplies was hijacked. It was an incredibly difficult environment to work in.

"As the frontline approaches Marib city, people sheltering in the area may find themselves with no place else to go."

Along with general healthcare, we provided routine vaccinations for children and offered antenatal and postnatal care. We saw a lot of pregnant women and children and were able to refer pregnant women with complications to larger hospitals for emergency caesareans. It made a real difference.

The day we started working in a rural hospital near the frontline, a woman came in with a breech delivery who was having real difficulty. Our midwife assisted and everything went well. But who knows what would have happened to that woman if the hospital wasn't there.

A DESPERATE SITUATION

Since I left, many more people have come to the area. But Marib is no longer a safe place to be. In recent weeks, the frontlines have moved into the province, causing large numbers of injuries and forcing thousands more people to flee their homes. As the frontline approaches Marib city, we are concerned that people sheltering in the area may find themselves with no place else to go.

After six years of conflict, the situation is desperate. These people need our help now more than ever."

WHAT IS HAPPENING IN YEMEN?

Yemen is in the midst of civil war. After six years of conflict, the medical and humanitarian situation in Yemen continues to deteriorate. Poverty is widespread, malnutrition is on the rise and people are confronted by the daily threat of violence.

Pregnant women struggle to access medical care.

Infant and maternal mortality are on the rise as mothers and children bear the brunt of an increasingly brutal conflict.

MSF teams are providing urgent medical care to people caught up in this crisis. We work in 12 hospitals and health centres and support more than 20 hospitals and health facilities across the country.

We provide medical support in emergency rooms, maternity wards and outpatient departments, conduct surgeries, and run mobile clinics in rural towns and villages. The situation remains desperate. **We need your help now more than ever**.

Thank you.

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100555

Take vaccines global

Vaccinating everyone is the best way to reduce the risk of further variants emerging

IN THE long term, the future is looking bright. Several coronavirus vaccines are proving far more effective than we dared hope, and while some aren't as effective against new variants, most do still work.

In the short term, however, things may get worse before they get better. Despite many countries, including the UK, starting to return to "normality" with the relaxing of restrictions, we now have another dangerous new variant – B.1.617.2, first detected in India – to contend with. It might be even better at spreading than the B.1.1.7 variant from the UK (see page 7).

Even the UK, which has given at least one vaccine dose to more than half its adult population, may not have vaccinated enough people to prevent another wave of cases, although it has, hopefully, vaccinated enough vulnerable people to prevent another major wave of hospitalisations and deaths. Most countries are in a much worse position. Globally, just 9 per cent of people have had at least one dose, and in lower-income countries the proportion is closer to zero.

Many people will die because higher-income countries are vaccinating their entire populations rather than sharing doses once they have vaccinated the most vulnerable. Worse, some have stockpiles of unused doses building up. The US has an estimated 70 million doses sitting on shelves, which is more than the international initiative for distributing vaccines fairly, COVAX, has distributed to all the countries in the scheme so far (see page 8).

> "A variant that evades existing vaccines will cost a lot more than vaccinating the world"

Experts say that as manufacturing rapidly ramps up, the US could share its excess now without any risk of running out. As *New Scientist* went to press, President Joe Biden had promised to send 20 million vaccine doses abroad.

Higher-income countries need to share more money too. Another $45 billion or so is needed to achieve global vaccination – small change compared with the $5 to 10 trillion cost of the pandemic. This money isn't charity. Ensuring the whole world is vaccinated is the best way to reduce the risk of further dangerous variants emerging. A variant that evades existing vaccines will cost a lot more than $45 billion, quite apart from the human toll. ■

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Two people hug each other on 17 May at Roller Nation in London

Variant of concern

Caution needed in the UK

Has lockdown been eased too soon in the UK considering the surge in cases of a coronavirus variant from India? **Graham Lawton** reports

ON 17 MAY, many people in the UK regained some of the freedoms surrendered to the coronavirus pandemic. But there are concerns that the relaxation has come too soon, with B.1.617.2 – a variant first identified in India – set to become the dominant strain in England over the coming week.

England, Wales and most of Scotland have now proceeded in line with step three of the UK government's plan for easing lockdown. That means most businesses can fully reopen, including pubs and restaurants, entertainment venues, museums, galleries and gyms. People can welcome others into their homes, and the ban on foreign travel has been lifted to some extent.

However, Prime Minister Boris Johnson urged caution and said that B.1.617.2 "could pose a serious disruption to our progress". A complete lifting of England's restrictions, currently pencilled in for 21 June, may be delayed.

Some scientists think that step three may already be a step too far. Jeremy Farrar, director of Wellcome and a member of the Scientific Advisory Group for Emergencies (SAGE), told BBC Radio 4 that he wouldn't be meeting people indoors just yet.

The key question is whether vaccination has "decoupled" infection from severe illness, he said, which would mean that a rise in infections doesn't lead to a surge of hospitalisations, deaths and long covid. "To be honest, we don't know that today," he said, and warned that if B.1.617.2 proves to be resistant to vaccines, the relaxation may have to be reversed.

In February, the UK government set itself four tests that must be passed in order to continue on the planned pathway for easing of restrictions in England. The fourth of these is "assessment of the risks is not fundamentally changed by new Variants of Concern".

According to Kit Yates at the University of Bath, UK, who is a member of the alternative Independent SAGE group, this test is "potentially failing". B.1.617.2 is booming in many parts of the UK, he says.

According to modelling done by SAGE, a variant that is more transmissible or substantially escapes immunity could lead to a surge of hospitalisations even bigger than the UK's second wave in January, which at its peak was seeing more than 50,000 new infections every day.

Most scientists agree that B.1.617.2 is more transmissible, says Yates, "although it hasn't been entirely confirmed yet. The good news is that there's no firm evidence that vaccines don't work against it."

> **"The B.1.617.2 variant first identified in India could pose a serious disruption to our progress"**

UK health secretary Matt Hancock said on 16 May that "new, very early" lab data from the University of Oxford suggested that the vaccines work against B.1.617.2. The university confirmed the existence of the data, but said it couldn't give further details.

There is laboratory evidence that B.1.617.1, a closely related variant, can evade immunity to some extent, says Christina Pagel of University College London (UCL) and Independent SAGE.

In response to the threat, the UK government said it would shorten the gap between the first and second doses of vaccine from 12 weeks to eight weeks for people over the age of 50 and for those who are clinically vulnerable.

But Anthony Costello at UCL says that what was needed was a functioning test-and-trace system and regional powers to impose measures such as local lockdowns. The response in England has been too centralised, he says.

The Scottish government decided that restrictions wouldn't be relaxed in Glasgow because of concerns over B.1.617.2, and in Moray after a surge in cases there. Northern Ireland will review its restrictions on 10 June. ■

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

Vaccine equity

How to share vaccines

Vaccines can help end the pandemic, but with dangerous variants and limited supplies, how do you protect people fairly? **Michael Le Page** and **Layal Liverpool** report

THE covid-19 pandemic has entered a dangerous new phase, with new variants spreading widely and overwhelming healthcare systems in some countries, such as India. Vaccines promise to bring an end to the pandemic, but with supplies still severely limited, many believe we need to think more wisely about how best to use the doses we have.

"Our vaccinations should go to those that are most vulnerable, in most urgent need and where they can make the most difference," says Krishna Udayakumar at Duke University in North Carolina.

That isn't what is happening. High-income countries have bought the vast majority of vaccine doses made so far, and the small amount being distributed by the global scheme set up by the World Health Organization (WHO) and others, known as COVAX, are initially being allocated per head of population.

"COVAX is purely based on pro-rata distribution models, which is a very good place to start, but can't be the only consideration," says Udayakumar.

What's more, not only are those high-income countries not sharing the vaccines they have bought with other countries equitably, many are sitting on stockpiles that won't get used immediately and which those countries might not need at all.

"We don't want these doses sitting in these countries for even a day," says Jenny Ottenhoff at ONE, an international charity campaigning to eradicate poverty and preventable diseases. "There's way too many people around the world that need to be vaccinated."

The US alone has more vaccine doses sitting unused than have been distributed via COVAX. According to Unicef, COVAX will deliver its 65 millionth dose this week (see "How is COVAX distributing vaccines?", right). "We have around 60 million doses sitting in refrigerators at the state level. The federal has more," says Ali Mokdad at the University of Washington in Seattle. Udayakumar estimates that the US may have 70 million doses unused. "This is, in my opinion, criminal," says Mokdad. "We should start sharing. There are people dying out there."

Globally, around 9 per cent of the world's 8 billion people have had at least one vaccine dose, which many regard as an amazing achievement in just six months.

But there are huge differences between countries. A few, including Israel and the UK, have given more than half their populations at least one dose of a covid-19 vaccine. Some others, including the US and Chile, are approaching half. However, no country in Africa has given a vaccine to more than 2 per cent of its population.

Brazil and India – both battling devastating outbreaks – have given at least one dose to 15 and 10 per cent of their populations respectively. Both are slightly above the world average, meaning they have vaccinated more people than if all doses had been globally distributed on a per head of population basis. This is because both are manufacturing vaccines locally, and Brazil also began buying extra doses this year.

The Serum Institute of India was meant to be the main supplier of vaccines to COVAX, but as the country's infection rate soared, the Indian government temporarily suspended vaccine

REUTERS/MONICAH MWANGI

People queue to receive a vaccine provided through COVAX in Nairobi, Kenya

9%
of the world's 8 billion people have had one dose of vaccine

100,000
vaccine doses donated to COVAX by France

70 million
vaccine doses may be sitting unused in the US

exports, leaving COVAX short.

COVAX has yet to distribute enough doses to get close to its initial aim of 3 per cent vaccination in all countries. Meanwhile, Israel, the UK, the US and to a lesser extent countries in the EU are well on their way to vaccinating their entire populations.

The aim of high-income countries, even if not openly stated, is to use vaccination to eliminate the coronavirus within their borders, says Antoine Flahault at the Institute of Global Health in Geneva. That is, to try to pass the herd immunity threshold and stop the virus spreading.

Reducing mortality

By contrast, the focus of COVAX is on preventing deaths and severe cases. "Countries should focus initially on reducing mortality and protecting the health system," states the document on fair allocation by COVAX drawn up by the WHO in September.

If high-income countries gave away vaccine doses once they have vaccinated the most vulnerable groups, instead of keeping enough and more for their entire populations, many deaths could be avoided, suggests a model created last year by Alessandro Vespignani at Northeastern University in Boston and his colleagues. It concluded that global deaths would be halved in a cooperative scenario compared with richer countries keeping most vaccines to themselves. The team is updating the model and plans to publish these findings shortly.

But high-income countries aren't sharing in this way. In fact, some, including the UK, are now ordering additional booster shots, which will prevent other countries receiving more first doses.

Is there a better way of using the few doses that COVAX has? One option, for instance, would be distributing doses according to the proportion of vulnerable people in a country and the current threat level. That is what COVAX plans to do once 20 per cent of people in all countries have been vaccinated.

But we are still far from this point, and changing the plan now would be difficult as countries that signed up to COVAX did so on the agreement that doses would be allocated per head of population.

What's more, according to a source who didn't want to be named, the single biggest issue with equitable distribution isn't getting vaccines to countries but what happens after they arrive. The WHO has set out priorities for who should be vaccinated first when supplies are limited, which are similar to those used by high-income countries in their roll-outs. If doses for fewer than 10 per cent of a population are available,

> **"The US alone has more vaccine doses sitting unused than have been distributed via COVAX"**

healthcare workers at high risk and older people should be prioritised. If there are enough doses for up to 20 per cent of a population, the next in line should be people at risk because of other health problems and groups who are especially vulnerable, such as refugees or other people who are homeless.

Many low-income countries, however, don't have the infrastructure to contact older and more vulnerable people, or to get them to vaccination centres. A high proportion of people are digitally illiterate, so can't enrol via websites. As a result, jabs are being given to whoever can get to mass vaccination centres rather than to those who are supposed to get them.

India has changed its plan of vaccinating front-line workers and those over the age of 45 and is now vaccinating everyone over 18, with up to half of doses being supplied via the private sector. This could work if it had enough supplies, says Udayakumar, but in practice could lead to more inequity. "To open up eligibility ›

How is COVAX distributing vaccines?

Countries followed two main routes to get hold of vaccines. Some dealt directly with vaccine companies. Others signed up to a global initiative to fairly distribute vaccines, called COVAX. Some are doing both.

Countries that can afford it pay COVAX for the doses they get via the scheme, while others get them free, funded by donations. Broadly, higher-income countries buy vaccines while lower-income countries rely on COVAX.

There are some exceptions. South Korea initially relied on COVAX, choosing to wait its turn. But after public criticism, it started buying vaccines directly.

The initial aim of COVAX is to ensure first 3 per cent, then 20 per cent, of everyone in the world gets vaccinated, a proportion that will cover the most vulnerable. The World Health Organization (WHO) wanted higher-income countries to start sharing doses once they reached the 20 per cent threshold, but this hasn't happened.

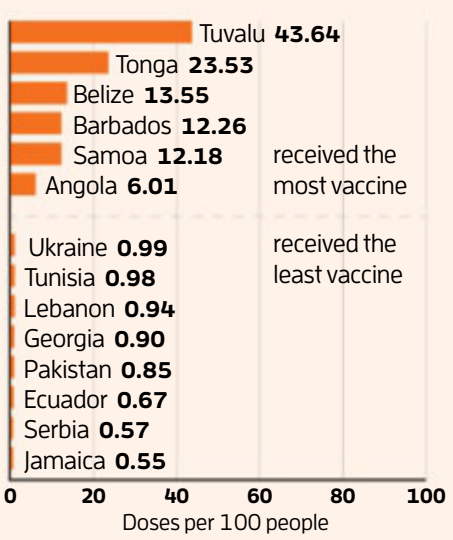
COVAX allocates doses in proportion to each country's population size. However, most haven't yet been allocated enough to cover even a tenth of their populations, with just a few, such as Tuvalu – population 12,000 – getting up to 44 per 100 people.

Actual deliveries are even scarcer. As of 10 May, COVAX had shipped just 58 million doses to 122 countries. It had hoped to ship 240 million by the end of May. A halt to vaccine exports by India amid its second wave of infections has contributed significantly to the delay.

Of the 78 countries for which figures are available, Tuvalu is the only one to get all its allocated doses. Only six countries have received enough doses to fully vaccinate 3 per cent of their population.

Higher-income countries aren't donating funds either. On 3 May, the WHO said the initiative that includes COVAX has a $19 billion shortfall.

Of the 122* countries that requested vaccines through COVAX, most have received fewer than six per 100 people from the scheme



*78 OF THE 122 COUNTRIES HAD DATA AVAILABLE ON THE COVAX VACCINE ROLL-OUT PAGE OF THE GAVI WEBSITE AS OF 11 MAY

to 900 million people when there are 70 to 80 million doses a month of capacity creates an even worse mismatch between demand and supply," he says. "There's a path for people who can afford vaccines to get it more quickly as opposed to those who might benefit most."

Another option for boosting coverage with limited supplies would be to delay the second dose of a vaccine, as the UK has done. But this can't be done with all vaccines. SinoVac, for example, was found to be just 3 per cent effective at preventing infection after a first dose in Chile.

"Doses donated from countries with excess supply will be an important part of the solution"

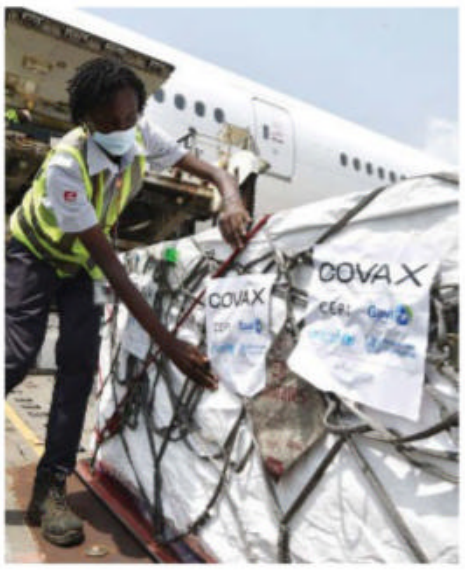
Even with more effective vaccines, a recent study suggests a delay is best done with people under 65, which isn't the stage of roll-out most countries are at yet. And Mokdad thinks it is a bad idea because delaying the second dose will increase the risk of the virus mutating to evade vaccines.

The shortfall in COVAX supplies means that many people aren't getting the second dose within the planned window. So this delay is happening whether it is desirable or not.

Another way to use doses more efficiently would be to give only one dose to people who have previously been infected, as studies show this provides substantial protection. This is impractical, though, as it would involve providing antibody tests to detect prior infection.

There have been some positive steps forward. First, the US recently gave its backing to a proposed waiver of intellectual property rights for covid-19 vaccines (see "Would an IP waiver boost supplies?", below). Although controversial, such a waiver could result in a boost to vaccine supplies in the long run.

Second, a few countries are starting to share vaccines. France recently became the first to donate doses from its domestic supply, providing an initial 100,000 doses to COVAX that the scheme allocated to Mauritania. Norway and New Zealand are donating doses that they had been allocated and paid for via COVAX back to the scheme. And as *New Scientist* went to press, President Joe Biden announced that the US will send at least 20 million covid-19 vaccine doses abroad by the end of June.



SIA KAMBOU/AFP VIA GETTY IMAGES

A delivery of covid-19 vaccine arrives in Abidjan, Ivory Coast

"Given the limited supply environment in the near term, doses donated from countries with excess supply... will be an important part of the solution for getting rapid, equitable access globally," said a spokesperson for Gavi, one of the organisations behind COVAX.

Finally, there is growing evidence that several of the vaccines are much more effective than we hoped – so much so that Flahault thinks the international community should start talking about whether we could eradicate the SARS-CoV-2 virus in the same way as smallpox, which was officially eradicated in 1980 through vaccination alone.

"I am in favour of opening discussions at an international level regarding the possibility of eradication," he says. "I am not entirely sure eradication is achievable for covid but maybe it is."

However, in the short term, things could get worse before they get better, warns Udayakumar. More dangerous variants are emerging, much of the world has reached pandemic fatigue, there are more and more humanitarian crises and we have yet to produce enough vaccine to meet global needs. "I think it is a very dangerous period of time over the coming months," he says. ■

Would an IP waiver boost supplies?

"These extraordinary times... call for extraordinary measures," tweeted US trade representative Katherine Tai, as she threw the country's backing behind a waiver of intellectual property rights for covid-19 vaccines.

The announcement earlier this month turbocharged an idea pushed by India, South Africa and many campaigners: that lifting IP protections on covid-19 vaccines would boost supplies by allowing the vaccines to be made in greater numbers, in more countries.

There has, however, already been strong opposition to the idea. "IP rights weren't the practical problem to scaling up global vaccine production," said the UK Bioindustry Association in a statement. The trade body's members include Pfizer and AstraZeneca.

The response is unsurprising. A World Health Organization-backed plan to scale up vaccine supplies, the Covid-19 Technology Access Pool (C-TAP), was launched a year ago. Companies were encouraged to waive IP on core products and share knowledge to help other firms produce vaccines. It was roundly snubbed by vaccine manufacturers.

Arguments against a waiver include the suggestion that it wouldn't disclose enough information for other firms to make the product, that there aren't enough manufacturing facilities or raw materials, and that quality assurance would be difficult. "It won't result in manufacturing vaccines faster in the following months," says Zoltán Kis at Imperial College London. "[But] it might lead to producing more vaccines in a year's time."

If a waiver is agreed, the impact looks distant. In the short term, the US government's stance has made C-TAP, in which manufacturers may have been able to set some of the terms for how they share their IP, look like a much more attractive prospect. Adam Vaughan

New vaccine

Cuba bids to vaccinate all citizens with home-grown shots

Luke Taylor

CUBA has begun a mass vaccination campaign against the coronavirus using a vaccine it has developed that hasn't yet completed large-scale human trials. The country has five covid-19 vaccines in development, with two in such phase III trials.

It is the smallest country to develop a promising vaccine candidate, and the only one in Central or South America to do so. Its ambition is to immunise its entire population with the vaccines – and with no doses of other shots on order, there is everything to lose.

Cuba began rolling out its Abdala vaccine in Havana on 12 May, with phase III trials still running. The country's Ministry of Public Health approved emergency use of the vaccine as a "public health intervention" that will eventually reach 1.7 million people.

The ministry has justified the roll-out based on the growing number of cases in the country and deems the vaccine to be safe based on trials so far.

Abdala and another vaccine, Soberana 02, which is also in phase III trials, are already being rolled out to 145,000 healthcare workers and researchers as part of a similar intervention to test the vaccine in high-risk populations.

YAMIL LAGE/AFP VIA GETTY IMAGES

People wait to receive the Abdala covid-19 vaccine in Havana, Cuba

Welcome boost

A successful vaccine could lift Cuba out of its worst economic and health crisis in decades. It has reported more than 125,500 cases of covid-19 and 814 deaths. The toll is relatively small for the region, but cases have surged to more than 1000 a day since airports were reopened last November. There are even suggestions that a vaccine could be offered to tourists to entice them to return, as they are a vital source of revenue for the socialist nation that is under US sanctions.

Other countries in the region are looking to Cuba too, as covid-19 cases continue to surge. Argentina, Bolivia, Honduras and Mexico are discussing the possibility of procuring or manufacturing Cuban vaccines. Venezuela is trialling the Abdala vaccine and hopes to produce 4 million doses.

The Abdala and Soberana 02 vaccines appear to be "very safe" as no severe adverse reactions were reported in phase II trials and because they are based on pre-existing vaccine technology, says Amilcar Perez Riverol at São Paulo State University in Brazil.

Phase III trials of Soberana 02 began in Havana on 8 March, and Abdala's began on 22 March in Santiago de Cuba, Guantánamo and the province of Granma. Both trials are expected to have results between the end of May and July.

A phase II trial of Soberana 02 showed that it generated neutralising antibodies against the SARS-CoV-2 coronavirus in 81 per cent of people who were given two doses, four weeks apart. Adding a third dose of a different vaccine, Soberana Plus, increased this to 96 per cent.

"You hope in phase II to have the same levels of neutralising antibodies that you see in infected people who overcome the infection and the disease, and the data [shows] this is happening for both," says Perez Riverol. "I'm pretty optimistic."

Neither Abdala nor Soberana 02 needs specialist refrigeration, but people may need to be given three doses of them.

That the 11-million-strong island is the leader in the regional vaccine race has raised some eyebrows, but Cuba has a strong reputation for vaccinology, says Helen Yaffe at the University of Glasgow, UK, who studies Cuba's biotech history.

Cuba has eliminated five diseases through vaccination: polio, diphtheria, measles, rubella and whooping cough. Every year, it exports hundreds of millions of vaccine doses to more than 40 countries. Its biotech sector, which was set up by former president Fidel Castro, receives plenty of investment and is based on a collaborative model directed at public need rather than profit. "The different institutes don't compete for resources and information, they share them and coordinate between themselves," says Yaffe.

If Cuba succeeds in its efforts, it could bring much relief to the wider region, which is facing a scarcity of jabs while reporting 1 in 3 global covid-19 deaths. On 1 May, it was announced that there would be delays to manufacturing the Oxford/AstraZeneca vaccine in Central and South America.

However, if Cuba's vaccines aren't approved, or aren't effective, it would be a disaster. Cuba isn't engaged in negotiations with international pharmaceutical companies or with COVAX, a scheme co-led by the World Health Organization to help all nations who sign up to acquire vaccines (see page 8).

1.7 million

Number of people in Cuba who will receive its Abdala vaccine

Dagmar García Rivera at the Finlay Vaccine Institute in Cuba, which developed Soberana 02, is confident that the high-risk strategy will pay off. "Betting on the development of our own vaccines rather than buying them was a strategic decision supported by the scientific and technological development of the Cuban biotechnology industry, and at the moment, we are on the way to prove that it was a wise one," she says. ■

Solar system

Europa's secret lakes may host life

One of Jupiter's moons could have large, habitable bubbles of liquid water near its icy surface

Jonathan O'Callaghan

POCKETS of liquid water trapped in the thick ice shell of Jupiter's moon Europa may be shorter-lived than previously thought, but they may still be present and potential habitats for life.

Europa, the fourth-largest moon of Jupiter, is believed to have a liquid water ocean buried tens of kilometres under its frozen surface. This water may be in contact with an ocean floor that provides the necessary mix of materials for life to arise. Previous research suggested that parts of the icy shell might also be liquid, in pockets of water 10 kilometres or so wide that sit much closer to the surface, perhaps only a kilometre down.

Chase Chivers at the Georgia Institute of Technology in Atlanta and his colleagues have modelled these pockets in greater detail, finding that while they might be shorter-lived than thought, they are still promising locations for life (*JGR Planets*, doi.org/gcdk).

"We find that they last for tens of thousands of years" before they refreeze, says Chivers. Previous research suggested they would last hundreds of thousands of years.

Evidence for the pockets comes from images taken by NASA's Galileo spacecraft in the 1990s and 2000s. It spotted pits and markings called lenticulae on the surface of Europa, some of which appear dark in colour – thought to be linked to salt that keeps water liquid in subsurface pockets. These features suggest that water pockets are still present today, says Chivers, possibly hundreds of them. They may be a result of the ocean seeping into the icy crust or portions of the crust itself melting.

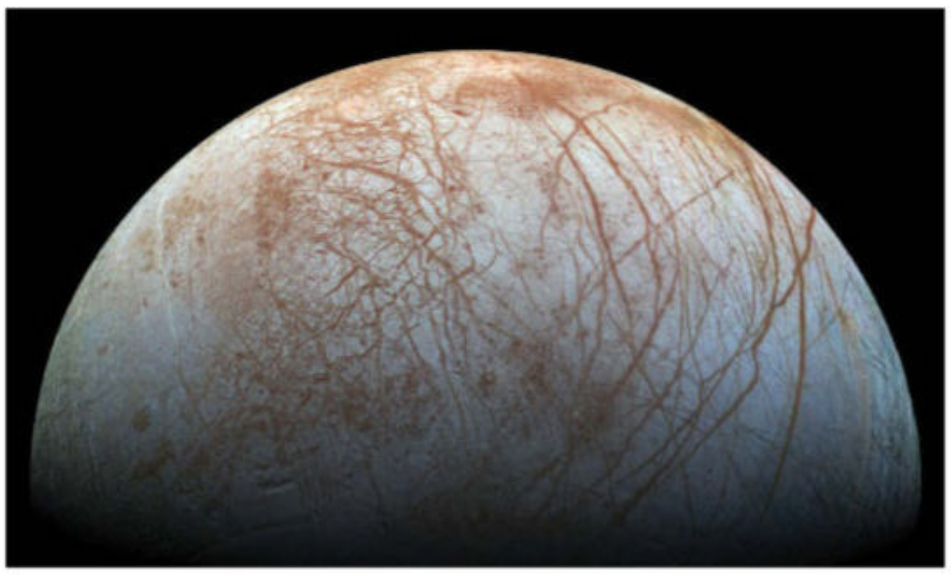
"We think there is still shallow water under some of these features," says Chivers. Some may even erupt onto the surface as plumes, which were previously thought to come directly from Europa's subsurface ocean.

If these pockets do exist, they could be potential habitats for life, says Mark Fox-Powell at the Open University in the UK. "If there is life in the subsurface ocean, and it gets incorporated into the ice shell and later remelted, that could kick-start a community," he says. But once the pockets refreeze, that life would become trapped. "It's a doomed community."

The pockets are close enough to the surface that they may be detectable by upcoming missions such as NASA's Europa Clipper spacecraft, scheduled to launch in 2024 and arrive in 2030. The craft will fly by and use a radar to peer beneath the surface. It also has a dust analyser that could detect material from one of these pockets – perhaps even microbial life itself – if it were to pass through a plume linked to one.

Steve Vance at NASA's Jet Propulsion Laboratory in California says having evidence of liquid water so close to the surface would be "really intriguing". If these pockets do exist, they would be a much shallower target to perhaps directly sample with a future lander mission on Europa, says Vance. "Drilling through a kilometre of ice sounds a lot easier than drilling through 5 or more kilometres." ■

Europa is covered in a thick shell of ice, but life might lurk below



NASA/JPL-CALTECH/SETI INSTITUTE

Animal behaviour

Female mice that lose a partner are wary of a new one

FEMALE mice that mate for life seem to take longer to get over the loss of their partner than male mice. The females are slower to begin a sexual relationship with a new partner – perhaps because life experience has taught them that a new male might not be able to stick around and help care for pups.

California mice (*Peromyscus californicus*) form lifelong relationships with a partner, sharing a nest and parenting duties. But if the partner dies or disappears, the bereaved mouse often finds a new life partner and reproduces.

Amber Valentino at Saint Joseph's University in Pennsylvania and her colleagues found that this process happens more quickly if the bereaved mouse is male. The researchers examined the birth records of 59 California mouse couples in their labs in which one was a virgin and the other had lost a partner within the preceding 24 hours, usually because of death from natural causes.

The team found that roughly 85 per cent of the couples had a litter of pups – a similar success rate to that the researchers reported in a connected experiment involving 525 virgin-virgin mouse couples.

However, the pups typically arrived sooner when it was the male getting a new partner. Bereaved males entered a sexual relationship with a virgin female just as fast as they did with their first partner, and pups were born on average 55 days after the first meeting.

When it was a bereaved female mouse being offered a virgin partner, though, pups were born on average 65 days after the adult mice first met (*Behavioural Processes*, doi.org/gcgm).

The team thinks females wait longer than males because their reproductive investment is greater, through pregnancy and nursing.

"We suspect their decision to go ahead and have pups with another male takes longer based on the previous experiences they have faced," says Valentino. ■

"Females may wait longer than males to take a new partner because their investment is greater"

Christa Lesté-Lasserre

On the hunt for platypus DNA in Australia's waterways

Decked out in wellies, **Donna Lu** went searching for traces of one of the world's strangest creatures

"PLATYPUS and fish are all shedding DNA into the water – it can be skin cells, hair cells, scales," says ecologist Josh Griffiths. "A lot of it is actually urine and faeces – which, next time you're swimming in the river, is probably not a great picture."

There are a few chuckles from the dozen or so members of the Moorabool Catchment Landcare Group, who have joined Griffiths at a park in Ballan, a town in Victoria, Australia, north-west of Melbourne.

Griffiths works for EnviroDNA, a company that detects DNA from environmental samples in order to monitor animal populations. In partnership with Odonata, a biodiversity non-profit, the team is hoping to map the whereabouts of platypuses in Victorian waterways. Group members have volunteered their Saturday morning to join the search.

Expecting dreary weather, everyone is dressed accordingly – rain jackets and wellies abound – but it turns out to be a brilliant autumn morning. In the trees surrounding us, crows caw as Griffiths explains the programme for the day and gives a short safety briefing. "Look out for snakes and stings – so typical outdoor issues," he says, and because we are all Australian, nobody bats an eyelid.

Our job today is to take samples from the Moorabool river, which is flowing at around 10 per cent of its usual volume. There are 18 sampling sites. People are assigned three or four sites each and given printed satellite maps with marked locations, as well as testing kits in bright blue fabric lunch boxes.

Though most of us are wearing waterproof shoes, we are told not to get into the water if possible. This is partly to avoid disturbing sediment in the water, which can clog up the fine sampling filter, and partly to avoid contaminating the water with anything that may be on our boots, like dog faeces.

MOORABOOL CATCHMENT LANDCARE GROUP

Volunteers learn how to take environmental DNA samples

Environmental DNA (eDNA) moves with the flow of water, travelling between 100 metres and 1 kilometre, says Griffiths. If any sample tests positive, it means there are platypuses upstream.

Logging their locations is increasingly important. Platypuses are found on the eastern mainland of Australia and in Tasmania. The animal is classified by the International Union for Conservation of Nature as a near-threatened species, and populations have declined in recent decades.

Research from the University of New South Wales concluded in November that platypus habitat has shrunk by 200,000 square kilometres in the past 30 years – an area roughly the size of England and Scotland combined.

In January, the government of the state of Victoria listed the animal as a threatened species for the first time. The platypus is also officially endangered in South Australia. Major threats include vegetation clearing and urbanisation. "Because they're dependent on aquatic ecosystems, essentially every time we modify our rivers, that's going to have an impact," says Griffiths.

Farley Connelly, who also works at EnviroDNA, demonstrates how to take samples, drawing up creek water through a large syringe and pushing it through a fine filter in a thin spurt. Gradually, the filter browns with collected matter.

The group scatters, driving off to take two samples at each of their assigned sites. The samples will eventually be tested in the lab with a platypus-specific probe, which binds to any platypus mitochondrial DNA present.

Platypuses are nocturnal and hard to spot, but DNA sampling can track them

Two samples of eDNA can detect the presence of a platypus with an accuracy of 97 per cent, says Griffiths. The testing process seems simple – essentially just water collection – but it has changed the way in which platypus populations are monitored, he says.

Platypuses have home ranges of 1 to 2 kilometres and tend to be solitary animals, meaning that population surveys have historically been hard to carry out.

Because of their low density, Griffiths believes that mapping platypus whereabouts is a more practical measure of population health than quantifying numbers of animals at individual locations. In the past, he has done overnight trapping surveys, which involves a laborious process of setting and checking nets every few hours for the nocturnal creatures. "They're not easy to spot," says Griffiths, which somewhat alleviates my disappointment at not managing to see one today.

200,000

Area of platypus habitat lost in the last 30 years, in square kilometres

The team is planning to launch a Victoria-wide citizen science mapping project later in the year, sampling during platypus breeding season between August and October.

The hope is that by identifying waterways that platypuses historically inhabited but are now scarce in, the team may be able to develop programmes to increase populations, such as boosting water flows during dry summer months. ■

Medicine

Nose swab could point to early Parkinson's disease

Clare Wilson

SIGNS of Parkinson's disease could be detected in the nose years before people develop more obvious symptoms of the condition.

The finding could lead to the development of a nasal swab test for the disorder, similar to ones used for coronavirus testing, and may shed light on its causes, says Werner Poewe at the Medical University of Innsbruck in Austria.

Parkinson's disease is a condition involving tremors and difficulties in moving that usually starts in later life. It is caused by the death of brain cells that make a signalling molecule called dopamine. These cells die because of the build-up of a faulty version of a protein called alpha-synuclein. When some synucleins become wrongly folded, this spreads to others, like a row of dominoes toppling.

44%

of people with an early sign of Parkinson's had misfolded proteins in their nose

In the past few years, there has been growing evidence that synucleins can sometimes start becoming misfolded in the gut and this spreads up to the brain through long nerve fibres. But a nasal origin has also been suspected because many people with Parkinson's disease have a reduced sense of smell, which often begins years before their movement problems.

Poewe's team looked for misfolded synucleins in the noses of 63 people who had another early sign of Parkinson's, a sleep disorder where people start acting out their dreams, which is caused by the loss of the usual brain mechanism that keeps us motionless during sleep. The researchers took samples of the cells at the top of people's nasal cavities with a swab.

They found that 44 per cent of people with the sleep disorder had misfolded synucleins in their noses. This compared with 46 per cent in another group of 41 people with confirmed Parkinson's disease and 10 per cent of 59 people of a similar age who didn't have the condition (*Brain*, doi.org/gjtd99).

Those who tested positive through the swab but who hadn't been diagnosed with Parkinson's disease could also be in the early stages of the condition, says Poewe.

People with the sleep disorder who tested positive also had more severe loss of smell, suggesting that problems with faulty synucleins are indeed the cause of this symptom.

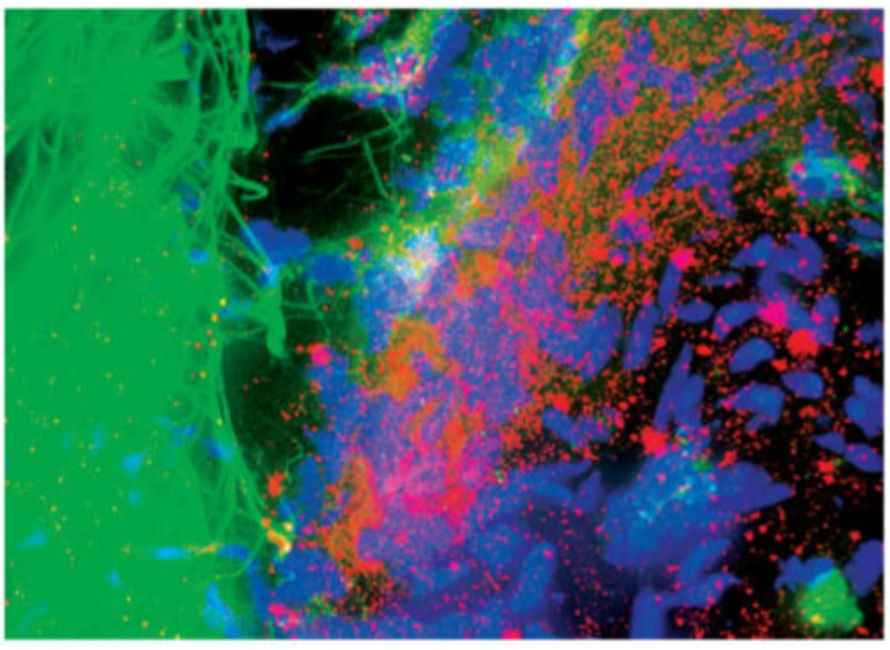
One idea is that synucleins start becoming wrongly folded in the nose in some people and in the gut in others, and then this spreads to the brain, says Poewe. Alternatively, synucleins could start misfolding in multiple sites in the nervous system.

Prevent misfolding

Several medicines aimed at stopping misfolded synucleins from spreading to other nerve cells are in development. If they prove effective, a nasal swab would be an easier test than the current way of checking for faulty synucleins, which is to take a sample of cerebrospinal fluid from the spine, says Poewe. "This is the least invasive obtainable tissue to test," he says.

"Early diagnosis is going to be important in the future when we have better drugs," says Alfonso De Simone at Imperial College London. "The later you get diagnosed, the more damage you will have to your neurons."

Creutzfeldt-Jakob disease, a much rarer brain disorder that is also caused by protein misfolding, can already be diagnosed by collecting nerve cells from the top of the nasal cavity. ■



MYA C. SCHIESS, ROGER BICK, UT MEDICAL SCHOOL/SPL

Misfolded synuclein (red) degrades neurons (blue)

Animal behaviour

Whale sharks gulp in air to float vertically while eating

Christa Lesté-Lasserre

WHALE sharks can suspend themselves in an upright position despite having a body density that is greater than that of seawater. A study of captive whale sharks suggests this may be due to air they take in as they feed.

SIMON PIERCE/ALAMY

When sucking in their food, whale sharks also take in air

Scientists have previously observed whale sharks (*Rhincodon typus*) feeding vertically in the wild. They use slow fin movements to stay in place, but occasionally remain still without sinking or tipping to the side, says Taketeru Tomita at the Okinawa Churashima Foundation Research Center in Japan.

Tomita's team found that whale sharks in an aquarium didn't have to move all the time to stay upright. Fascinated, the team realised that the animals would suck in air from the surface while consuming prey. When they stopped taking in air, they would sink.

The group estimated the body volume, mass and density of two sharks, then equipped one with underwater ultrasound equipment. This detected air in the shark's gill cavities when it was feeding vertically, but not at other times.

Using this data, the group created a mathematical model to determine how much air the whale shark would need to stay vertically afloat and immobile. In theory, about 0.2 cubic metres of air would provide enough buoyancy for each of the study sharks, says Tomita (*Zoology*, doi.org/gcdf). Considering the size of the sharks' mouths, the animals could easily suck in that much air each time they feed. ■

Physics

Searching for the earliest black holes

Some black holes may have formed just after the big bang – have we detected them?

Leah Crane

WE MAY have already seen black holes from the dawn of the universe, known as primordial black holes. The Laser Interferometer Gravitational-Wave Observatory (LIGO) in the US and the Virgo observatory in Italy have detected 47 pairs of black holes slamming into one another, and a statistical study suggests that nearly one-third of them may be primordial.

Black holes are thought to form via several mechanisms. The main way is by a huge star collapsing in on itself, forming what is called an astrophysical black hole. Some black holes are too large to have formed that way, so they probably come from the mergers of smaller black holes. And primordial black holes may have formed in the early universe from dense clouds of plasma, but as yet we have no direct evidence for their existence.

"When we get a black hole observation from LIGO, it does not come with a label that tells us how it was formed, it just comes with a mass and a spin," says Salvatore Vitale at the Massachusetts Institute of Technology. Vitale and his colleagues have done a statistical analysis of data from LIGO and Virgo that was informed by data from three leading models for the formation of astrophysical black holes, as well as a model of primordial black hole formation.

Their analysis concluded that the observatories have collected so much gravitational wave data that all of the formation models are likely to be correct. This includes the idea that some observations are from primordial black holes (arxiv.org/abs/2105.03349).

"Typically in this kind of analysis, you're punished because of Occam's razor for making things more complex and adding more models," says Nelson Christensen at the Nice Observatory in France. "So the fact that they added primordial black holes and that had the highest probability is interesting."

The analysis suggests that about 27 per cent of the LIGO and Virgo black holes could be primordial. "When I started this, I was expecting we would not find any significant level of support for primordial black holes," says Vitale. "I got surprised."

However, because this result relies on theoretical models, it isn't proof that primordial black holes exist. Those models are the best we have right now, but they aren't guaranteed to be correct.

"The result is not definitive: it is not a 'hard proof', it is more of a change in our expectations in light of the new data," says Francesca Vidotto at the University of Western Ontario in Canada. "But such a change is important." It could lead astrophysicists and cosmologists to build more sophisticated models for black hole formation, both for astrophysical and primordial black holes, she says.

One of LIGO's gravitational wave observatories is in Livingston, Louisiana

CALTECH/MIT/LIGO LAB

If some of these black holes are primordial, they could be a crucial window into our early universe and may even make up part of the mysterious dark matter that holds galaxies together. But either way, this result is a hint that our understanding of black holes is incomplete. "Even if these are only astrophysical black holes, there's clearly something involved in their formation beyond what has been assumed so far," says Jane MacGibbon at the University of North Florida.

The next step is to build better models and get more data from LIGO and Virgo. The observatories, along with the Kamioka Gravitational Wave Detector in Japan, are expected to turn on again in 2022. "We need more [data], and we will get more," says Christensen. ■

Internet culture

Emoji meanings may morph as time goes by

THE meaning of emojis can change depending on the context in which they are used and when they have been posted, according to the first study of their use over time.

Alexander Robertson at the University of Edinburgh, UK, and his colleagues tracked how emojis were used on Twitter between 2012 and 2018. They checked 1.7 billion tweets to see if they contained an emoji, with duplicate content and non-English tweets filtered out. They analysed them with models that recognise the semantics of how words are used based on others around them. This allowed them to attribute meanings to emojis and note changes to those meanings.

"We found patterns we would also find in words," says Robertson. Just as words change meaning through usage, so do emojis. "You have seasonality in emojis," he says. For instance, the maple leaf emoji was most used in exchanges about autumn during those months, while for the rest of the year it became a substitute for mentions of cannabis.

The four emojis that changed meaning most over the study period were fingers pointing left, right and down, and a fist bump. For example, the fist bump changed from signifying a willingness to fight to expressing support for movements such as Black Lives Matter (arxiv.org/abs/2105.00846).

Effie Le Moignan at Newcastle University, UK, says the work is a valuable contribution, but that the findings have limitations. She says this doesn't generalise beyond Twitter, and says social media and linguistic experts could help parse the data in more detail.

"Language use online is flexible and evolving. 'Tea' has changed to mean gossip in online vernacular"

"If you map to closest words, the pairings may remain matched, but language use online is also flexible and evolving," she says. For example, "tea" has evolved to mean gossip in online vernacular. Seeing a word next to an emoji "does not guarantee in the weird world of the internet the meaning didn't alter over the time you collected data", she says. ■

Chris Stokel-Walker

Climate change

The methane mystery

Levels of a powerful greenhouse gas are rising strangely fast, and no one knows why, reports **Adam Vaughan**

IN A University of Colorado lab, near a furnace running at 1100°C and machines adorned with *Star Trek* posters, lie rows of metal flasks holding clues to the cause of an alarming rise in a powerful greenhouse gas. They contain samples of air from around the world that Sylvia Michel's team of methane detectives analyse to reveal whether the gas came from burning fossil fuels and wood, or from wetlands and cow guts.

The work isn't merely academic. Pinpointing the sources of the methane has become an urgent task: the gas may be shorter-lived than carbon dioxide, but its warming effect is 28 times more potent and atmospheric concentrations of it have resumed climbing inexorably upwards since 2007, after seeming to plateau in the early 2000s. We still aren't sure why.

Worryingly, according to preliminary data released this month, last year, methane levels made their biggest annual jump, by 14.7 parts per billion, since records started in 1983. "2020's increase was double the 2007 growth. It's even higher than the early 1980s, when the gas industry was going crazy. It's really scary," says Euan Nisbet at Royal Holloway London. It is possible the coronavirus pandemic had a role, but this is still being investigated.

Whatever the cause, methane levels have raced ahead of most climate scientists' scenarios. Even new modelling for a landmark report by the Intergovernmental Panel on Climate Change, due out in August, predicts that methane concentrations will start to fall this year, says Martin Manning at the Victoria University of Wellington, New Zealand. But that isn't happening in reality.

Since the pre-industrial period, methane has contributed about 16 per cent of global warming. Tackling it matters if we want to avert catastrophic climate change. "In the long-term, we absolutely must reduce CO_2 emissions. However, on shorter timescales, of 25 years, methane is a really potent greenhouse. It provides a huge lever for near-term climate [change] and is really one of the best ways of keeping temperature rises below 1.5°C," says Alex Turner at the University of Washington in Seattle, referring to the 2015 Paris Agreement's tougher goal.

PLAINPICTURE/JAN HÅKAN DAHLSTRÖM

Livestock, particularly cows, are a major source of methane

Fixing the problem requires knowing what is driving the surge. Methane in the atmosphere can be traced back to a thermogenic source – the burning of methane locked up in fossil fuels – a pyrogenic one, such as burning wood, or a biogenic one, meaning microbes in wetlands, rice paddies, livestock, permafrost and landfill sites. Michel's team is analysing the ratio of two isotopes of carbon in methane samples to pinpoint the sources.

Some research has blamed the US fracking boom, which coincided with the rise in methane. However, the methane in air flasks that Michel's lab has sampled in recent years has less carbon-13 and more carbon-12, implying the growth is from microbial sources such as wetlands and agriculture. "Fossil fuels are definitely part of the picture. But it's hard to explain our data without having an increase in biogenic methane," says Michel.

Michel's spectrometers can't tell us whether the source is more cows, or wetlands behaving differently. However, big annual swings in methane levels, like 2020's, are unlikely to be due to anthropogenic sources, be it cattle or fossil fuel extraction, says Ed Dlugokencky at the US National Oceanic and Atmospheric Administration.

14.7

2020 increase in methane levels in parts per billion

Wetland emissions vary widely depending on temperature and rainfall. Wetlands in the tropics, such as northern Zambia and the Amazon, appear to be behind the increase, says Nisbet, who has analysed air samples from these regions. "The tropics are getting warmer and wetter," he says.

Microbes produce more methane when it is warmer, which raises fears of a "climate feedback", where warming begets more warming because higher temperatures make wetlands emit more of the powerful greenhouse gas. "What if subtle changes to temperature and precipitation are increasing natural emissions of methane?" says Dlugokencky.

"That would be consistent with the observed isotopic signals. It would also complicate the challenge of reducing greenhouse emissions to stabilise the climate."

Last year was one of the three warmest years on record, so methane-belching wetlands could partly explain 2020's record methane jump. Another possibility, which Turner is investigating, is that the big falls in nitrogen oxide air pollution caused by covid-19 lockdowns had the knock-on effect of reducing levels of hydroxyl radicals in the atmosphere. Nitrogen oxides play a role in the formation of this molecule, which removes methane from the atmosphere. "My guess is that it's a combination of both human-caused and natural factors," says Turner.

"2020's increase in methane was double the 2007 growth. It's really scary"

In the face of possible climate feedbacks and accelerating growth, methane can look like an impossible roadblock to reaching the Paris climate goals. But there is an upside. "It's in many ways easier to do something about methane than CO_2 and N_2O [nitrous oxide, the third main greenhouse gas]," says Drew Shindell at Duke University in North Carolina.

Most N_2O comes from fertiliser used for growing crops, while burning CO_2 is so entangled in our economies that eliminating it is slow and difficult. Moreover, CO_2's long-lived nature means, even if emissions stopped today, we wouldn't see a halt in rising temperatures for many decades.

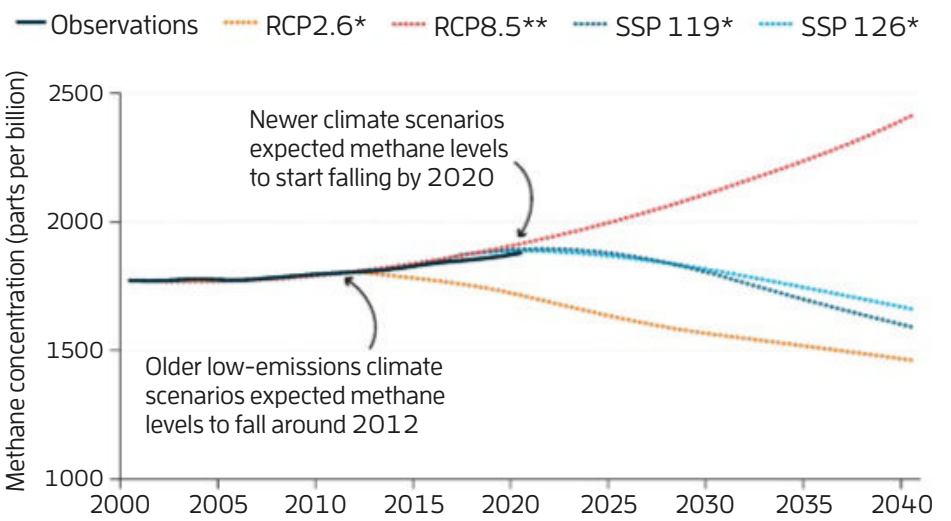
By comparison, reducing methane could make a big difference to temperatures quickly. A report by Shindell for the United Nations Environment Programme (UNEP) found that a 45 per cent cut in methane emissions by 2030 would avoid nearly 0.3°C of warming by the 2040s. Another recent paper concluded that pursuing only the easiest methane cuts could avoid 0.25°C of warming by 2100.

About half of our methane emissions come from the fossil fuel industry – oil, coal and gas – while the other half is from agriculture and waste sites, says Marielle Saunois at the Laboratory for Sciences of Climate and Environment in France. Saunois, who runs the Global Methane Budget report, says there is little sign of serious action to cut methane emissions yet. "But there is hope," she says. A quick fix would be countries banning uncovered landfills as the European Union has done, she says.

Finding leaks in oil and gas pipes and wells could greatly reduce emissions, says Turner. And we don't have to focus on all oil and gas fields, but mainly the industry's "superemitters".

Atmospheric methane levels are still climbing

The concentration of methane in the atmosphere (solid black line) is continuing to stay above what all but the highest old emissions scenario projected (orange/red lines show projections of older climate scenarios, blue lines show newer scenarios)



SOURCE: MICHAEL MANNING / NOAA *LOW EMISSIONS ** HIGH EMISSIONS

Just 1 per cent of the industry's methane sources accounts for 30 per cent of its emissions, says Turner. Moreover, about 40 to 45 per cent of methane abatement has no net cost, because firms can sell the gas instead, according to the International Energy Agency.

There are signs that big firms are taking the issue more seriously than smaller ones. BP, ExxonMobil and others have methane leak-reduction targets for 2025. The problem is in 2019 these firms accounted for less than 2 million tonnes of the 75 million tonnes of methane the industry emitted.

Stronger regulation is coming. The EU will flesh out its methane strategy later this year, and the US senate last month approved President Joe Biden's decision to reverse methane deregulation under Donald Trump. Our ability to spot methane leaks from space is also rapidly improving, thanks to a flurry of new satellites (see "Methane eyes in the sky", left).

There are other benefits to reducing methane levels: Shindell's UNEP report found each million-tonne cut in methane prevents about 1430 annual premature deaths from ozone air pollution globally.

As Dlugokencky says, many ways of cutting methane emissions from the fossil fuel industry – including a shift to renewable energy and electric cars – would also have the benefit of reducing enemy number one: CO_2 emissions. We just need to get on with it. ■

Methane eyes in the sky

Canada-based firm GHGSat launched its first methane-tracking satellite in 2016, followed by a higher resolution one in 2020. A new version launched in January this year can detect methane plumes 100 times smaller than some other satellites can.

That level of detail matters, so companies can be advised about specific methane plumes on sites with kilometres of pipelines. GHGSat spotted a massive plume in Turkmenistan, pumping out the same amount of methane as a major gas leak near Los Angeles in 2015-16. After a paper on the plume was published, authorities in Turkmenistan were contacted and emissions dropped to zero.

More eyes in space are coming. The Environmental Defense Fund, a US non-profit group, is due to launch its own satellite next year to find methane hotspots. Another US non-profit organisation, Carbon Mapper, plans a group of satellites to monitor methane. Software is also being used to make older, low-resolution satellites better at detecting leaks, such as with the European Space Agency's Sentinel-5.

DE AGOSTINI/GETTY IMAGES

Archaeology

Foreign fighters helped the ancient Greeks to wage war

THE ancient Greeks relied on help from non-Greek mercenaries when it came to fighting their enemies, suggests an analysis of bodies in 2500-year-old mass graves.

The western Mediterranean witnessed several conflicts between about 2600 and 2300 years ago as Greek-led city states fought the Carthaginians. Some of this was documented by contemporary Greek writers, including Herodotus, but his accounts could be biased.

In particular, Herodotus suggests that in 480 BC, in the first Battle of Himera, local soldiers had aid from other Greek allies and successfully defeated the Carthaginians. But during a second battle, in 409 BC, the local soldiers went unaided and the city (pictured) fell.

Following the discovery of eight mass graves associated with the battles of Himera, it is now possible to check Herodotus's account.

Katherine Reinberger at the University of Georgia and her colleagues analysed strontium and oxygen isotopes from teeth of 62 individuals in the mass graves, which can reveal whether someone was born and raised locally or not.

This showed that the accounts weren't entirely accurate: the isotope evidence suggests that many of the non-Himeran soldiers weren't actually Greek, but came from across the Mediterranean (*PLoS One*, doi.org/gcf5).

The team thinks such accounts downplayed the involvement of foreign mercenaries in order to create a more Greek-centric narrative and align the victory of the first battle with Greek successes against other forces. Krista Charles

Medicine

Life-saving oxygen could be given anally

PIPING an oxygen-rich liquid through the anus could be a lifesaver. A new treatment for failing lungs that involves this has been successfully tested in pigs.

People with low blood oxygen levels may be treated in intensive care by being put on a ventilator, which blows air into their lungs. But this usually requires sedation and can injure delicate lung tissue.

Takanori Takebe at the Tokyo Medical and Dental University wondered if people could absorb oxygen through their intestines, which some freshwater fish do. In mammals, the rectum has a thin membrane that allows certain compounds into the bloodstream.

Takebe's team tested the idea on pigs by giving them enemas of perfluorocarbon, a fluid that can hold a lot of oxygen. Such fluids have been investigated as a way of breathing liquid, and are already used to help protect the lungs of premature babies, so are likely to be non-toxic when used in this novel way, says Takebe.

The researchers anaesthetised four pigs and put them on a ventilator at a lower breathing rate than normal, so their blood oxygen levels fell. When they gave two of the pigs enemas of the oxygenated fluid, replaced once an hour, their blood oxygen levels rose significantly. The same happened when the fluid was delivered by a tube surgically inserted into the rectums of the other two pigs (*Med*, doi.org/gcgn).

If the same happened in people, it would be enough to provide a medical benefit, says Takebe. He thinks this could be especially useful in low-income countries with few intensive care facilities.

One problem is that gut function may be impaired in people sick enough to need such care, which can cause diarrhoea, says Stephen Brett at Imperial College London. **Clare Wilson**

Marine biology

Genes reveal secrets of surviving the deep

ADAPTATIONS that help a snailfish survive in the crushing depths of the Pacific Ocean have been identified. It has extra genes for repairing its DNA and for making a chemical that stabilises essential proteins in high pressure waters.

The species was found in 2017 in the Yap Trench in the western Pacific at a depth of 6903 metres. Tentatively called the Yap hadal snailfish, it was at depths where it is dark, the water is cold, food is scarce and the pressure intense.

MU Y ET AL., 2021, PLOS GENETICS

To find out how it survives, researchers led by Xinhua Chen at Fujian Agriculture and Forestry University in Fuzhou, China, sequenced its genome. They found that it has extra copies of genes involved in DNA repair. Some DNA repair genes also contained mutations that would alter the proteins they coded for – although it is unclear if or how this is helpful for life at depth.

It also had five copies of a gene crucial for the production of trimethylamine N-oxide (TMAO), a chemical that stabilises proteins and may protect them from damage by the intense pressure. In line with this, the snailfish's muscle tissue had elevated levels of TMAO compared with zebrafish that live in shallower waters.

The Yap hadal snailfish has lost many olfactory receptor genes, possibly because its deep-sea diet is very repetitive (*PLoS Genetics*, doi.org/gcgh). **Michael Marshall**

Really brief

ANTON WROBLEWSKI

Big mammals hit the beach even earlier

An extensive set of fossilised footprints shows that large mammals were gathering by the sea 9 million years earlier than we thought. Some of the 58-million-year-old tracks were made by the now extinct hippo-like *Coryphodon*, depicted above (*Scientific Reports*, doi.org/gcc5).

AI mimics our errors to refine keyboards

A new AI mimics how people type on their smartphones – including making typos. The AI replicates human typing behaviour so well it may become a tool designers could deploy to judge our receptivity to new keyboard designs, said researchers at the virtual CHI conference last week.

Some coral might survive warming

Some corals can swap the algae inside their tissues for strains that are more heat tolerant – and these coral species have a better chance of surviving global climate change, according to a model applied to nearly 2000 reefs worldwide (*Nature Climate Change*, DOI: 10.1038/s41558-021-01037-2).

Technology

Interface lets man type just by thinking

A NEURAL network can interpret brain signals from a person who is imagining that they are writing and convert them into text. The method works accurately at 90 characters per minute.

That is more than twice the record for typing with head or eye-tracking systems, which are hard on users as they are all-consuming, says Jaimie Henderson at Stanford University in California.

To solve this problem, he and his team implanted two sensor arrays just under the surface of the brain of a 65-year-old man who has a spinal cord injury. Each array was able to detect signals from around 100 neurons.

As the man imagined writing letters and words on a piece of paper, the signals were fed to a neural network. With the two arrays monitoring around 200 neurons, there were enough clues in the data for the neural network to build a reliable interpretation of brain signals.

Often a neural network is trained with thousands of pieces of example data, but in this case that wasn't practical. Instead, the team took examples of signals from the man's brain while writing certain letters and generated extra examples with random noise added to build a synthetic data set.

The model the team created won't translate to another person as the neural network is trained only on data from one individual.

Using this system, the man was able to type at 90 characters per minute, near the average of people his age when using a smartphone, which is 115 characters (*Nature*, doi.org/gjz4x9). **Matthew Sparkes**

Physics

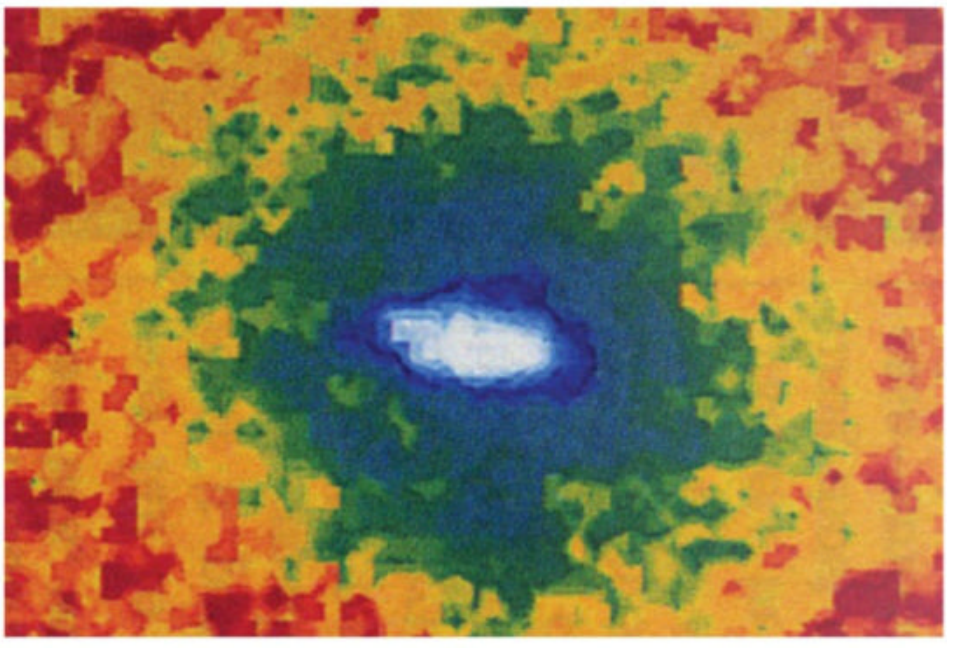


PHOTO RESEARCHERS/SCIENCE HISTORY IMAGES/ALAMY

Squeeze particles into a tight space and they capture light

CLOUDS of atoms can hide their light. When an atom moves to a lower-energy state, it emits a particle of light called a photon. But this process can be delayed and photons trapped in a dense cloud of atoms. This may eventually prove useful for quantum devices that communicate using light.

When an atom absorbs a photon, exciting it to a higher-energy state, it will always release that photon and return to its initial state in about the same amount of time. When this is delayed, it is called subradiance.

Igor Ferrier-Barbut at the University of Paris-Saclay in France and his team induced subradiance in clouds of 300 to 5000 rubidium atoms by compressing them into a space less than 3 micrometres across. The team then shot pulses of light at the cloud to excite the atoms. Because the atoms are so close together, they can essentially pass the photon back and forth within the cloud.

The team repeated this tens of thousands of times, measuring how long it took for the photons to be released from the cloud. It took up to about 150 nanoseconds – about six times longer than it does for a single rubidium atom to release a photon (*Physical Review X*, doi.org/gjx4qt). Leah Crane

Climate change

Global warming is damaging cave art

DEGRADATION of prehistoric rock art in Indonesia may be picking up pace due to climate change.

The Maros-Pangkep karst, a cave complex in Indonesia, contains paintings that are between 20,000 and 45,000 years old. Anecdotal reports suggest that the paintings have been degrading at an accelerated rate. To investigate, Jillian Huntley at Griffith University in Australia and her colleagues analysed flakes of rock at 11 cave sites in Maros-Pangkep.

They found a high level of sulphur in the rock at all 11 sites, as well as a build-up of calcium sulphate and sodium chloride at three sites. These salts occur naturally in the rock and form crystals in a process called salt efflorescence, which often happens in wet environments.

The crystals expand and contract with temperature and humidity. This can lead rock to flake and fragment, damaging any art painted on the surface.

The team suggests the growing severity and frequency of El Niño-induced droughts – due to climate change – as well as monsoon-related moisture have created the ideal conditions to accelerate the degradation of the art (*Scientific Reports*, doi.org/gcgs). **Donna Lu**

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Chris Impey is a University Distinguished Professor of Astronomy and Associate Dean of the College of Science at the University of Arizona. He has over 180 refereed publications on observational cosmology, galaxies, and quasars, and his research has been supported by $20 million in NASA and NSF grants.

Fiona Panther is a research associate at The University of Western Australia in Perth. She is a physicist and mathematician with an interest in astronomy and software development. Her expertise is primarily in microphysical astronomy: how processes that occur on the atomic and subatomic scale can influence what we observe on galactic and cosmological scales.

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Penny Lewis is a sleep scientist and professor of psychology at Cardiff University. She has coined the term sleep engineering to capture the spirit of her lab's work. She explores ingenious ways to enhance memory, disarm negative emotions, and combat cognitive decline through ageing during sleep. Her book, *The Secret World of Sleep* explores the latest research into the night time brain to understand the real benefits of sleep.

Sophie Scott is professor of cognitive neuroscience at University College London. As head of the speech communication group, her research focuses on how our brains process the information in speech and voices, and how our brains control the production of our voice. Her work also explores individual differences in speech perception and plasticity in speech perception, both of which are important factors for people with cochlear implants.

Anil Seth is professor of cognitive and computational neuroscience at the University of Sussex. His research seeks to understand the biological basis of consciousness by bringing together research across neuroscience, mathematics, computer science, psychology, philosophy and psychiatry.

Find out more
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Comment

Machine churning

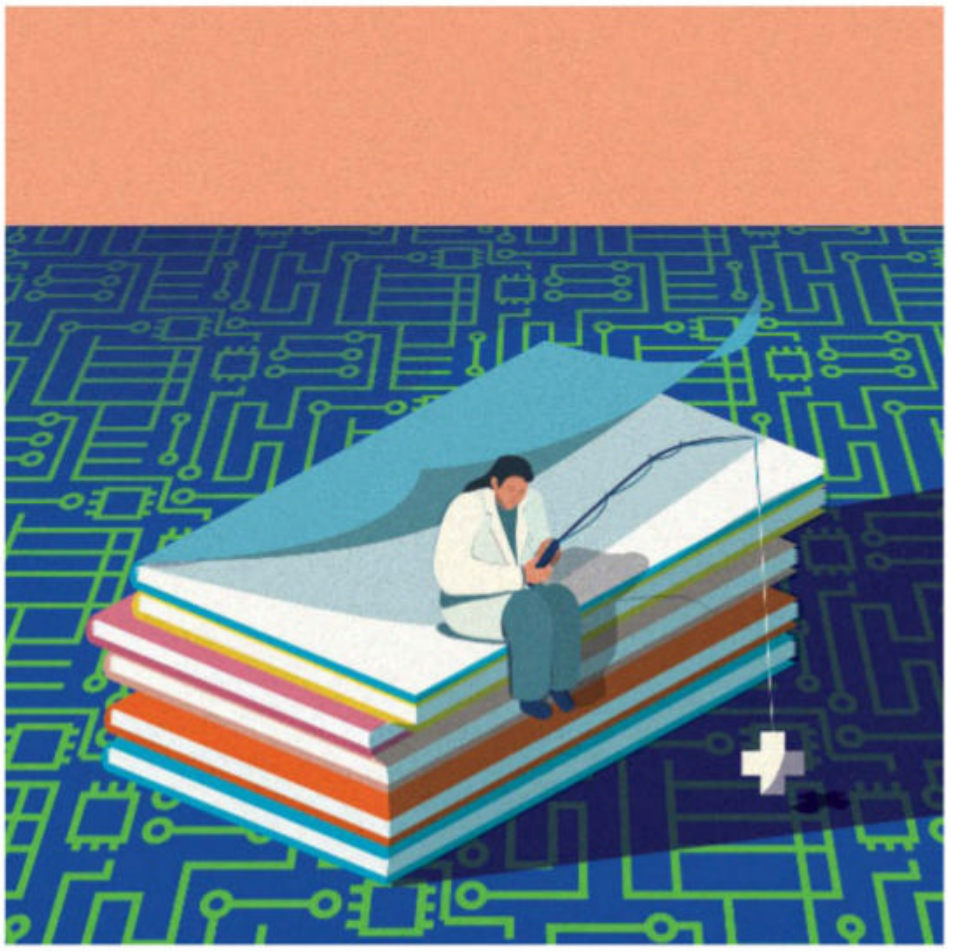
Attempts to use artificial intelligence to diagnose covid-19 have so far been unsuccessful, says **Michael Roberts**

IS THERE no problem artificial intelligence can't tackle? Methods such as deep learning are finding uses in everything from algorithms that recommend what you should purchase next to ones that predict someone's voting habits. The result is that AI has developed a somewhat mystical reputation as a tool that can digest many different types of data and accurately predict many different outcomes, an ability that could be of particular use for solving previously impenetrable problems within healthcare.

However, AI is no panacea. Too often, it is turned to too quickly and in an impulsive way, resulting in claims that it works when it doesn't. This has become increasingly apparent during the covid-19 pandemic, as many AI researchers try their hand at healthcare – without much success.

It is no wonder many people think healthcare is a promising area for AI as hospitals generate lots of data, which deep learning relies on. The partnership has already borne fruit, with AI systems able to help identify cancer earlier and better predict which treatments people will respond to.

In the initial stages of the pandemic, there was a deluge of publications attempting to do the same for covid-19. In particular, there are hundreds of papers claiming that machine-learning techniques can use chest scans to quickly diagnose covid-19 and to accurately predict how patients will fare.



MICHELLE D'URBANO

My colleagues and I looked at every such paper that was published between 1 January 2020 and 3 October 2020 and found that none of them produced tools that would be good enough to use in a clinical setting (*Nature Machine Intelligence*, doi.org/gjkjvw). Something has gone seriously wrong when more than 300 papers are published that have no practical benefit.

Our review found that there were often issues at every stage of the development of the tools mentioned in the literature. The papers themselves often didn't include enough detail to reproduce their results.

Another issue was that many of the papers introduced significant biases with the data collection method, the development of the machine-learning system or the analysis of the results. For example, a significant proportion of systems designed to diagnose covid-19 from chest X-rays were trained on adults with covid-19 and children without it, so their algorithms were more likely to be detecting whether an X-ray came from an adult or a child than if that person had covid-19.

Though authors may have been motivated by the desire to develop models that could help people, in their haste, many of the publications didn't take into account how, or whether, these models could pass regulation requirements to be used in practice.

The papers also suffer from publication bias towards positive results. For example, imagine a theoretical research group that carefully develops a machine-learning model to predict covid-19 from a chest X-ray and it finds that this doesn't outperform standard tests for the illness. This finding isn't of interest to many journals and is hard to communicate. It is far easier to develop a model with poor rigour that gives excellent performance and publish this.

While machine learning has great promise to find solutions for many healthcare problems, it must be done just as carefully as when we develop other tools in healthcare.

If we take as much care in developing machine-learning models as we do with clinical trials, there is no reason why these algorithms won't become part of routine clinical use and help us all push towards the ideal of more personalised treatment pathways. But there is no rushing that. ■

Michael Roberts is part of the Cambridge Image Analysis group at the University of Cambridge

#FactsMatter

Do negative-calorie foods exist? There is a persistent claim that eating celery burns more calories than it contains, but the truth is a little more complicated, writes **James Wong**

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

James's week

What I'm reading
This isn't exactly reading, but I am currently hooked on the podcast A History of the World in 100 Objects.

What I'm watching
Last Stand For Our Forests – Fairy Creek, *a short film about the felling of one of the last old-growth temperate rainforests on Vancouver Island in Canada.*

What I'm working on
I am just about to do an interview on the ecology of hedgerows for BBC Radio 4.

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

IN OUR world of constant information bombardment, there are so many conflicting claims about food out there that it can often be hard to sift fact from fiction. Sometimes you hear an idea being proclaimed as incontrovertible truth almost as often as you hear the exact same one being resoundingly debunked by scientists.

Yet when it comes to a topic as complex as diet, could this often be because both claims have some merit depending on the context? I think looking at one long-enduring dieting belief – that you burn more calories digesting celery than it contains – is a useful way of answering this question.

This is a piece of received wisdom that I have been hearing since I was a kid. Indeed, it is intuitively plausible given the extremely small number of calories that celery contains and how much chewing is involved to crack open its fibre-lined cells and access their contents.

So I was fascinated to learn that the idea that celery was a "negative-calorie" food had been scientifically investigated by a team at Oxford Brookes University in the UK back in 2012. The researchers served a group of women a typical 100-gram portion of the fresh stems, then closely measured their calorie expenditure at specific intervals using an ingenious "ventilated hood" system that calculated their bodies' energy usage by measuring the carbon dioxide they exhaled.

Crunching the numbers, the team found that although digesting, assimilating and storing the energy from the veg did, on average, burn more than 85 per cent of the calories that the celery contained, there was indeed a small surplus.

How much is a 15 per cent surplus from 100 grams of celery? A ridiculously tiny amount: just 2 whole calories. However, it is still technically a surplus. Case closed, right?

Well, here's the thing: in reality, humans don't live off celery alone. We don't even tend to eat it on its own, but as part of meals containing all sorts of other ingredients. We also know that foods with a low calorie density, particularly those that contain loads of water and fibre, can measurably increase satiety.

So, in the context of wider diet, could foods like celery fill us up faster, resulting in a reduction in our consumption of more calorie-dense food, cutting overall calorie intake? Well, looking at the evidence so far, the answer seems to be: probably.

> **"Humans tend to eat a similar weight of food each day, irrespective of the number of calories it contains"**

According to a study published in the *Journal of the Academy of Nutrition and Dietetics*, for example, serving up a large starter salad to a group of volunteers saw them eat significantly smaller portions when presented with a massive, all-you-can-eat buffet of pasta. How much smaller? Well, there was as much as a 12 per cent reduction in calories consumed, even when those contained in the salad were factored in.

On average, this clocked in a saving of up to 100 calories in a single meal. Although extrapolating too much from the limited data is fraught with difficulty, if this sort of calorie cut could be replicated, it would constitute a significant 300-calorie saving per day.

This isn't just the findings of a single study either. One experiment at the University of Pennsylvania found that eating a single apple before lunch could slash the total calories people ate in a meal by 15 per cent. That is an impressive reduction of an average of 187 calories, more than is found in a can of soft drink.

It is fair to say that both of these trials were short term and included only a limited number of participants, but similar results have been echoed by a number of other studies investigating foods with low-calorie densities, like vegetable soup and pears, suggesting a consistent pattern.

This points to a curious phenomenon surrounding appetite regulation and our eating behaviour. Humans tend to eat a similar weight of food each day, irrespective of the number of calories it contains. To me, this is a fascinating quirk of how our bodies regulate our appetite, one that may offer key insights into weight management.

In the concluding words of one such study by researchers at Pennsylvania State University: "This approach may facilitate weight loss because it emphasizes positive messages rather than negative, restrictive messages."

So, while even extremely low-calorie, high-fibre foods like celery don't contain magical negative calories when tested in isolation, when viewed in the more accurate, real-world context of how we actually eat, it seems that this could indeed be a reasonable label. So could the difference between fact and fiction in simple scientific measures sometimes just be the frame of reference used in the definition? I think so. ■

Day of the cicada

Photographer **Carolyn Kaster**
Agency **AP/Shutterstock**

THIS remarkable image shows just one of the trillions of cicadas starting to emerge in 15 US states after 17 years underground. Carolyn Kaster's photo captures an adult insect shedding its old skin on the bark of an oak tree in Maryland, before it goes in search of a mate.

More than 3000 cicada species have been described worldwide. Most have a yearly life cycle, but seven species in the US belonging to the *Magicicada* genus remain underground as nymphs for 13 or 17 years before emerging, a process called periodical brooding. The only other two species of cicada to do this are found in Fiji and India.

This year, insects from a group called Brood X – which is made up of three species – will emerge in the eastern US in their trillions. It is one of 15 broods in the country, and last appeared in 2004 (see photo below). Cicadas from Brood X have already been spotted in Georgia, Maryland and Virginia. After mating, females lay their eggs in the stems of woody plants.

Remaining underground for so long may make it harder for predators to remember where to find the insects, giving the next generation a survival advantage when they eventually emerge.

Gege Li

GENE KRITSKY

Editor's pick

Nature isn't less natural just because we are in it

8 May, p 24

From Ralph Timms, Nocton, Lincolnshire, UK

Claiming that there was once a time when nature was in a perfect, "pristine pre-industrial state", as mentioned in Graham Lawton's column on ecocide, is a fallacy.

A preference for one environment or species over another is purely a human judgement; evolution has no inclination for, say, an English bluebell over a Spanish bluebell, or English farmland over the forests that were cleared to create it.

The concept of pristine nature seems reliant on the idea that our species isn't the result of natural causes or evolution like every other organism on the planet, but a deus ex machina that sits outside nature and interferes with it. The dams we build are as "natural" as those that a beaver makes, and both can result in good and bad consequences.

All isn't doom and gloom in a world influenced by humans, as ecologist Chris Thomas writes in *Inheritors of the Earth*. He says that our influence is actually leading to an acceleration of new species.

Lockdown keeps the pantry close to hand

8 May, p 10

From Sam Edge, Ringwood, Hampshire, UK

You report a study claiming that decreased physical activity during the first covid-19 lockdown in England may lead to increased obesity. But I have recently read several convincing articles in *New Scientist* showing evidence that there is little correlation between exercise and weight change when measuring over periods longer than a month or two.

If obesity is the phenomenon of interest, the researchers would do better collecting data on weight change from their subjects. I wouldn't be surprised to find an increase, but I suspect that boredom and displacement activity leading to increased "grazing" from the pantry is more likely to be the cause.

Another way to improve your metacognition

8 May, p 36

From Tim Johnson, London, UK

Reading Stephen Fleming's article on self-reflection, I realised there is at least one training exercise that might improve metacognition – the ability to think about our own thinking – that millions of people do every day: crosswords.

How well does your answer fit the clue? Is it the right length? Does it match the existing letters? We get quick feedback on the correctness of our ideas, which Fleming suggests should give us "heightened metacognitive sensitivity". I wonder whether regular crossworders do better on metacognitive tests.

Underwater archaeology is a wave well worth riding

17 April, p 44

From Peter Robbins, London, UK

You report rising interest in the archaeology of seabeds that were once land. Another reason to think coastal areas would be rich in possible finds is the idea that food supplies were effectively static in these areas. Unlike forests or open plains, where hunter-gatherers would have had to be constantly following game, seafood can be found on beaches and under rocks at any time of the year.

Although this would mean that the early humans living by the sea, maybe in fairly large numbers, could lead sedentary lives, it might also mean that they had to be called upon to defend their coastal "asset" from other groups.

If that was the case, it might also indicate that these were the first people to develop social hierarchies and a warrior caste, and the first to have the time and means to develop arts and crafts. It might also have allowed contagious diseases to evolve in more unsanitary conditions.

Quantum theory equation is far from unacceptable

Letters, 10 April

From Peter Holness, Hertford, UK

Regarding Brian Reffin Smith's letter reducing to absurdity the equation cited by Carlo Rovelli in his take on quantum theory. The equation doesn't deserve ridicule. It is no more controversial than the theory it is part of. Physicists used and accepted such "non-commuting" equations long before Rovelli was born.

The platypus's glow may be an accident

8 May, p 41

From Martin Pitt, Leeds, UK

In your look at the platypus, you write that its "pelt glows in UV light, which makes no sense for a nocturnal animal".

It only makes no sense if you assume the fluorescence is the function, not just a consequence of a complex chemical structure for some other purpose, perhaps waterproofing. It is like supposing that the only purpose of haemoglobin is to make blood red.

My views on trees were justified after six decades

1 May, p 39

From Aroha Mahoney, Te Awamutu, New Zealand

Nearly 60 years ago, I had an argument with the curate taking our bible class. I thought the grove of silver birches outside might be conscious and able to communicate with each other; he wouldn't have a bit of it because, he told me, the bible said only humans could possibly have these attributes. I never went back to bible class. At 73, I feel vindicated after your interview with Suzanne Simard on the ways in which trees communicate and cooperate.

Extra historical notes on sweet, red watermelon

24 April, p 22

From Claire Taylor, Nottingham, UK

To add to James Wong's thoughts about the colour of watermelons historically, there is more evidence from the 14th century that the inside of the fruit was red then.

Moroccan scholar Ibn Battuta travelled throughout Eurasia. He loved his food and observed that Khwarazm, south of the Aral Sea, produced a "wonderful melon" of which "the rind is green, and the flesh is red, of extreme sweetness and firm texture" and which was sometimes dried in slices. This certainly sounds like watermelon, which is still preserved in that way.

Battle against malaria was an inspiring story

1 May, p 44

From Martin Sigrist, Newbury, Berkshire, UK

Thank you for your article about the fight to eradicate malaria. Quite apart from reporting the success in tackling that terrible disease, you included a statistic that at any time would be a source of hope, and especially now.

Anuradha Gupta's quote saying that, compared with two decades ago, we now save 8.5 million children per year from dying is quite simply the best statistic I can recall reading. The fact that this has happened in lower-income countries is all the more inspiring. Sadly, I suspect that the astonishing success in these nations has gone under the radar for many people. ■

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Rise of the digital citizen

In the 21st century, governments can and must use technology better to serve the needs of their people, argues a new book. **Karina Shah** explores

Book

Power to the Public: The promise of public interest technology
Tara Dawson McGuinness and Hana Schank
Princeton University Press

FRANKY DE MEYER/GETTY IMAGES

Not all citizens can expect an electronic vaccine status

THE question of how best to use technology to meet the everyday needs of citizens is on the agenda, especially in the US, where President Joe Biden wants to "listen to science". So far, he has embedded data experts and technologists in all his teams.

But there is a mountain to climb. "There is no solving the world's hardest problems without governments and institutions that really work for people," warn Tara Dawson McGuinness and Hana Schank in *Power to the Public*. Leaders have no prerogative to fail, the authors say.

This is a high bar: governments can and do fail their citizens. But the tricky question "why" hovers over the book. McGuinness and Schank have good credentials, though: both work for Washington DC-based think tank New America, and McGuinness was on the Biden transition team.

Written during the coronavirus pandemic, the book catalogues both recent and historical failures and successes in public policy. For example, many governments failed to offer key services in the pandemic, from reliable test-and-trace systems and vaccination scheduling to financial support to businesses during lockdowns.

Looking further back, the authors cite awful examples where public systems were designed without listening to, well, anyone much. One such was exposed in 2011 when the UK abandoned its bid to create the world's largest civilian computer system, linking National Health Service records in England. Nine years in the making and costing over £11 billion, it is seen as one of the most expensive fiascos in public sector history.

In the US, former President Barack Obama may have tweeted praise for the book, but his Affordable Care Act, which widened health insurance coverage, gets a bashing in it. In 2013, its website crashed 2 hours after launch. By the end of the day, only six people had managed to select a health insurance plan.

"Crisis Text Line knows the exact time people are most vulnerable and the emojis they use at their lowest point"

The authors also argue for a formula they think could improve things: "design informed by real human needs, the use of real-time data to guide problem solving, and a focus on delivery in order to continuously learn and improve". These ideas come from the private sector. "If Starbucks can use data to better understand when their customers want a Frappuccino, think of the endless possibilities for governments and non-profits to use these... tools."

While this is a naive analogy – after all, the wrong public policy can be measured in lives, not coffee – the authors are passionate about what they and others call public interest technology. Some of this harks back to the 1980s, when social theorists asked if tech would be better designed around people's real needs, and used for civic not surveillance purposes. Fast forward, add big data, social media, artificial intelligence and real-time systems – and look at what public interest tech can do.

Here, the authors' success stories are even more interesting. Take Crisis Text Line, a mental health organisation founded in 2013 to reach young people in crisis in the US using text messages. It offers a 24-hour service, putting texters in touch with trained counsellors. It now also operates in the UK, Canada and Ireland. In 2020, it supported about 844,000 texters.

While Crisis Text Line collects real-time data, the US's largest collection of mental health data (run by the Centers for Disease Control and Prevention, and the National Institutes of Health) comes from mental health surveys, with results out a year later. Crisis Text Line, however, knows the exact time people are most vulnerable and what emojis teenagers use at their lowest point.

But before world leaders can use these new tools, they must address something omitted from the book: the millions with no access to the simplest tech, often in low-income countries, but sometimes not far from the White House. ■

When sci-fi got too real

Has science fiction become too serious to imagine better futures? That is the worrying take-home of a festival, finds **Simon Ings**

Exhibition

European Media Art Festival, Osnabrück 2021

Exhibition runs until 30 May
Talks programme on YouTube

FOR 40 years, the European Media Art Festival (EMAF) in Osnabrück, Germany, has offered a glimpse of the best short films heading to cinemas and festivals – and recently online – in the coming year. It has been a reliable cultural barometer, too, revealing some of our deepest social anxieties and preoccupations.

But this year saw science fiction swallow the festival whole, as though the genre was becoming not just a valid way to talk about the present, but the only way.

This was the explicit message of audiovisual presentation *Planet City and the Return of Global Wilderness* by architect Liam Young, much of whose work is speculative. Part of his presentation was an early retrospective of a career spent exploring global infrastructures, what he calls "an unevenly distributed megastructure that hides in plain sight… slowly stitched together from stolen lands by planetary logistics".

Forming a powerful contrast with his past travels (through container shipping, the garment supply chain, lithium mining and other real-world adventures), Young's presentation features a utopian future in which humanity sagely withdraws "into one hyper-dense metropolis housing the entire population of the Earth".

It is the impossibility of this utopia that is Young's point. Sci-fi used to be full of such possibilities, but he argues that these days it has become our favourite way of explaining to ourselves, over and over, the disasters engulfing us and our planet. The once hopeful genre ceded ground to dystopia, leaving us "stranded in the long now… waiting for the end of the end of the world".

We have confronted the apocalypse before, of course. Marian Mayland's film essay *Michael Ironside and I* weaves between three imaginary rooms, assembled from stills and short clips from iconic sci-fi films and a TV series: *WarGames*, *Real Genius* and *seaQuest DSV*.

The rooms are uninhabited, cluttered, uncanny and cut together to create an imaginary habitation connected to the outside world via shafts and closet doors.

The *WarGames* bedroom of 1983 is in a suburban family house, while the *Real Genius* room is a 1985 California campus dorm and the bowels of *seaQuest DSV*'s room is a futuristic nuclear submarine imagined in 1993. All fold into each other to create a poignant, fictional childhood, capturing the effects of cold war thinking on sci-fi-loving adolescents.

Mayland's film, which won a German film critics' award at the festival, is exactly the sort of experimental work that EMAF has championed over the years.

Zachary Epcar's more obviously satirical *The Canyon* sees the calm pace of life in a sunny waterside housing estate turn increasingly strange, as the blissed-out, eavesdropped lines of the inhabitants ("Sometimes I come to in the glassware aisle, and I don't know how I got there") give way to the meaningless electronic gabble and vibration of phones and keyfobs.

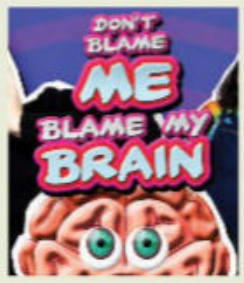
If this all sounds rather grim, even hopeless, I don't think the selection or even the works individually are to blame. I agree with Young that the problem lies in science fiction: it has ceased to be a playground and has become instead a deadly serious way of explaining our world. And that is fine – it's sci-fi growing up.

But what the artists and film-makers of EMAF have yet to find is some other way – less technocratic, perhaps, and more political and spiritual – of imagining a better future. ▮

Planet City, an impossible utopia housing all of Earth's population

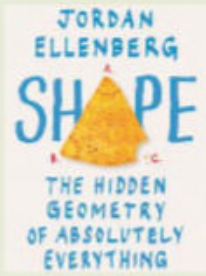
ALGAE CANALS FROM 'PLANET CITY', DIRECTED BY LIAM YOUNG, 2021.

Don't miss



Watch

Don't Blame Me, Blame My Brain is a children's show on CBBC, fuelled by unusual, out-there questions. Is it possible to catapult yourself to the moon? Or talk to dogs? Comedians Ken Cheng and Leila Navabi have answers – maybe.



Read

Shape: The hidden geometry of absolutely everything helps explain important ideas and problems, according to its author, maths whizz Jordan Ellenberg. These include everything from the spread of the coronavirus to the rise of machine learning.

Watch

Eden is the name of a city built by machines after humanity's fall in Netflix's new anime series. When two robots discover a human girl while on a routine assignment, they decide to bring her up in secret. Released on 27 May.

T-B: CBBC DON'T BLAME ME, BLAME MY BRAIN; ALLEN LANE; NETFLIX

The film column

Big neuroscience, big egos *In Silico* doesn't look slick, but it is a sharply scripted account of the backstory to an ambitious, billion-euro project to model the intricacies of the human brain – and in just 10 years, says **Simon Ings**

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

COURTESY OF SANDBOX FILMS

A virtual model of a mouse neocortex seen in *In Silico*

Film

In Silico

Noah Hutton

Available on demand in the US and Canada

Simon also recommends...

Book

The Idea of the Brain

Matthew Cobb

Profile Books

In his dazzling history of neuroscience, zoologist Matthew Cobb explains why the metaphors we use to think about the brain stop us understanding it.

Film

Inception

Christopher Nolan

Cobb (Leonardo DiCaprio) is out to steal from your mind in a groundbreaking sci-fi flick that gave Freudian psychoanalytic theory a jaw-dropping CGI makeover.

SHORTLY after gaining a neuroscience degree, young film-maker Noah Hutton fell into the orbit of Henry Markram, a neuroscientist based at the Swiss Federal Institute of Technology in Lausanne.

Markram models brains in all their complexity. His working assumption is that since the brain is an organ, a sufficiently good computer model ought to reveal its workings, just as "in-silico" models of kidneys, livers and hearts enrich our under standing.

The world is filled with people who seem to think in different ways. Much as we might want to understand this full diversity, no one is going to dig about in a living human. Markram hopes that a computer model will offer an ethically acceptable route.

So far, so reasonable. Except that, in 2009, Markram said he would build a working computer model of the brain in 10 years. This was during a TED talk about his Blue Brain Project (BBP), set up in 2005 to model the mouse brain.

Every year for well over a decade, Hutton interviewed Markram, his colleagues and his critics as the project expanded and the deadline shifted. Hutton's film, *In Silico*, is the result.

Markram's vision transfixed purseholders across the European Union: in 2013, he won €1 billion of public cash to set up the Human Brain Project (HBP).

Although his tenure at its Geneva headquarters didn't last long, Markram is hardly the first founder to be wrested from the controls of their institute. His BBP endures: its in-silico model of the mouse neocortex is visually astounding.

> **"It is within our power to model some organs. But the brain isn't an organ in the usual sense"**

Perhaps that is the problem. In a voice-over, Hutton says the HBP has become a special-effects house, a shrine to touchscreens and VR headsets, but lacks meaning "outside this glass and steel building in Geneva".

We have heard such criticisms before. What about how the CERN particle physics lab sucks funds from the rest of physics? There is no shortage of disgruntled junior researchers blaming it for failed grant applications. CERN, however, gets results; HBP, not so much.

The problem runs deep. It is within our power to model some organs, but the brain isn't an organ in the usual sense. By any engineering measure, it looks inefficient. A spike in the neurons can trigger the release of this neurotransmitter, except when it releases another one – or does nothing. There is bound to be some commonality in brain anatomy, but so far research shows that every brain is like a beautiful, unique snowflake.

The HBP's models generate noise, just like real brains. In the film, there is a vague mention of "emergent properties". Yet linking that noise to brain activity is an intellectual Get Out of Jail Free card if ever there was one: no one knows what this noise means, so there is no way to tell if the model is making the right noise.

Deep learning guru Terrence Sejnowski, who is based at the Salk Institute for Biological Studies in California, tells Hutton that the whole caper is a bad joke – if successful, Markram will only generate a simulation "every bit as mysterious as the brain itself".

Hutton accompanies us into the yawning gap between Markram's reasonable ambitions and the promises he makes to attract funds. It is a film made on a budget of nothing, and it isn't pretty. But Hutton makes up for all that with the sharpest of scripts. ■

Mind-altering moves

The way you move your body can change the way you think and feel, says **Caroline Williams.** Here are six ways to shift your brain into a new gear

FILTER-FEEDERS aside, humans are the only creatures that can get away with sitting around all day. As a species, we have been remarkably successful at devising ways to feed, entertain ourselves and even find mates, all while barely lifting a finger.

True, this is a sign of just how clever and adaptable we are. But there is a huge cost to our sedentary ways, not only to our bodies, but also our minds. Falling IQs and the rise in mental health conditions have both been linked to our lack of physical movement.

But the connection between movement and the brain goes deeper than you might think. A revolutionary new understanding of the mind-body connection is revealing how our thoughts and emotions don't just happen inside our heads, and that the way we move has a profound influence on how our minds operate. This opens up the possibility of using our bodies as tools to change the way we think and feel.

Evidence is starting to stack up that this is indeed the case, and it isn't all about doing more exercise. In my new book, *Move! The new science of body over mind*, I explore emerging research in evolutionary biology, physiology, neuroscience and cell biology to find out which body movements affect the mind and why.

Whatever it is that you want from your mind – more creativity, improved resilience or higher self-esteem – the evidence shows that there is a way of moving the body that can help. Here is my pick of the best ways to use your body to achieve a healthier, better-functioning mind.

SERGIO MEMBRILLAS

GET ON YOUR FEET

It isn't exactly news that walking and running help to clear the mind, but research into the reasons why these activities affect our heads suggests that different speeds provide different mental benefits.

Running or walking at a pace that feels easy to you allows the mind to wander by temporarily reducing activity in the prefrontal regions of the brain. These areas favour rational, straight-line thinking, and studies suggest that reducing their activity allows broader, more creative ideas to flow.

The effects spill over for at least 15 minutes after you have finished walking, according to researchers at Stanford University, California, who speculated that a walk before an ideas meeting could pay dividends. But there is a catch: walkers performed slightly worse in tests of straightforward, linear problem-solving compared with those who remained seated.

Intriguingly, even the gentle pressure of footfall on a slow walk has a big impact on blood flow to the brain. Studies by Dick Greene at New Mexico Highlands University in Las Vegas and his colleagues suggest that when our feet hit the ground, their arteries are compressed. This increases turbulence in the blood, providing it with an extra rush towards the brain of up to 15 per cent.

Pick up the speed to a marching pace and things get even more interesting. In Greene's experiments, the biggest boost to blood flow happened when people's step rate and heart rate synchronised at 120 steps and 120 beats per minute, hinting at a possible sweet spot. What exactly this extra blood does when it gets to the brain is unclear, but we do know that ›

exercise in general increases grey matter in the hippocampus, which is crucial for memory processing and spatial awareness.

All this makes sense if you consider that walking a lot, running a little and using our big brains to hunt and gather are what humans are built for. Anthropologist David Raichlen at the University of Southern California has said that we evolved to be "cognitively-engaged endurance athletes", so it shouldn't be surprising that our bodies are set up in a way that means moving and thinking are intertwined.

GET STRONG

If you are a millennial, you might want to avoid picking a fight with your dad. Today's men appear to be markedly weaker than their counterparts in the 1980s, according to a 2016 study in the US that measured maximum grip strength, which is a proxy for overall muscle strength. The next generation, it seems, are weaker still. A 2019 study found that 10-year-olds in England were 20 per cent weaker and had 30 per cent less muscle endurance in 2014 compared with children of the same age measured in 1998.

Sedentary lifestyles are almost certainly to blame, and it matters for our physical and mental health alike. People who are stronger in middle age have more grey matter and better memory a decade later. One explanation for this could be a hormone called osteocalcin, which is released from bones when we move against gravity in any form of weight-bearing exercise. In rodent studies, its release has been linked to the size and connectivity of the hippocampus. Studies in humans are ongoing, but there are signs that a lack of osteocalcin could be linked to age-related cognitive decline and neurodegenerative disease.

The benefits of being strong don't stop there. It has been known for many years that physical strength is linked to higher self-esteem and a feeling of being capable in all walks of life.

One explanation for why physical strength provides mental resilience is that our sense of self – and, more importantly, our sense of what we can achieve in the world – is built on the foundations of our bodily sensations. Neuroscientist and philosopher Antonio Damasio at the University of Southern California says that as well as keeping tabs on heart rate, blood pressure and blood sugar levels, our body has an unconscious sense of the health and state of our muscles and bones. This "musculoskeletal division" constantly sends messages about the strength and agility of the body's movement apparatus – the muscles, bones, tendons and ligaments that allow us to move. This then feeds into our implicit sense of what we can handle.

If that is the case, the decreasing levels of strength in modern society are troubling. It is tempting to think that this decline may even play into the epidemic of anxiety and mental health conditions that is affecting people of all ages – perhaps the message from the musculoskeletal divisions of our bodies is giving us nothing to feel confident about?

The good news is that we can update this body-mind conversation at any time. Strength training is emerging as a powerful tool to tackle depression and anxiety, even when it isn't done as part of a wider fitness programme. This doesn't have to involve going to a gym or even buying a set of dumb-bells; you can use your own body weight. Spending more time sitting on the floor, for example, is a good way to strengthen leg muscles, because at some point you have to stand up. Strong legs also boost balance and coordination, both of which are suffering in our sedentary lifestyles.

DANCE

The power of dance to bring humans together is so strong that some governments and religious groups around the world have tried to ban it at times.

It is a futile strategy. As a species, we are born to dance. Brain-imaging studies of newborns have shown that they notice if rhythmic music unexpectedly skips a beat. By the time they are 5 months old, this ability ties in with movement, too. Research shows that babies are able to move their bodies in time with music at this stage, and that the

“We are born to dance – even babies notice if rhythmic music skips a beat”

better they are at bopping along, the more they smile. Even at a tender age, moving to music seems to make us feel good.

According to studies led by Morten Kringlebach at the University of Oxford, the feel-good factor is because our brains work as prediction machines that constantly make guesses about what is likely to happen next. In this view, a regular beat is satisfying because it makes it easy to predict what is coming. Each time we are correct, we get a small hit of dopamine, a neurotransmitter involved in feelings of pleasure.

Following the beat with your body provides a second dopamine hit, and may also create the illusion that our movements are producing the beat in the first place, says music psychologist Edith Van Dyck at Ghent University in Belgium, which makes us feel powerful and in control.

Power of synchrony

As such, moving to music when we are alone can make us happy. Doing it in a room with others takes things to the next level, adding the pleasure of social bonding into the mix, too.

Experiments with toddlers have shown that they are more likely to help an adult, by picking up a dropped item for instance, after being bounced in time to music, than after they have been bounced out of time with the beat. In adults, studies have shown something similar: moving in synchrony with others makes us more likely to care about them and share with them.

One proposal for how this happens is that we usually base our sense of self on our perception of our bodies’ movements. When we synchronise with other people, this “proprioceptive” sense gets blended with information about others’ movements coming in through our additional senses in such a way that the boundaries of self and other become temporarily blurred.

The result is a state of closeness and understanding, as well as a desire to help others – which sounds like something the world could really do with right now.

BREATHE

It is the smallest of movements, and you don’t need to be fit to do it. But controlling the muscles in your chest and diaphragm can make a big difference to the way you think and feel.

Incredibly, when you regulate your breath, what you are really doing is taking charge of your brainwaves and tying them to the rate at which air travels into and out of your nose.

This link comes via sensory neurons at the top of the nose, which fire when air flows past them. Because this air contains information about the outside world, it makes sense that activity in scent-related brain regions begins to synchronise with the breathing rate, allowing information to be processed as it comes in. Recent studies, however, have shown that this synchronisation doesn’t stop there. It spreads to areas involved in assigning meaning to the information, such as memory, and those involved in planning and decision-making.

Coordinated, rhythmic activity across different regions allows the brain to share information more easily. Some researchers believe that the brain’s ability to synchronise with breath may be a fundamental feature of the way it processes information.

The easiest way to put this into practice is to close your mouth and breathe at the rate of six breaths per minute: inhaling for 5 seconds, then exhaling for 5 seconds. Breathing at this pace has been shown to be the most efficient way to fill the air sacs of the lungs, where oxygen diffuses into the blood. This can raise oxygen saturation by a couple of per cent, enough to make a small difference to brain function.

Inhaling and exhaling six times per minute has also been shown to stimulate the vagus nerve, part of the parasympathetic nervous system, which resets the body to a state of calm after stress. Intriguingly, studies of religious chanting and prayer have found that they tend to slow breathing to six breaths per minute – which may explain why people find these practices calming.

At three breaths per minute, something else happens entirely. A 2018 study led by Andrea Zaccaro of the University of Pisa, Italy, in ›

which volunteers had air wafted up their noses to simulate breathing at a rate of three inhalations per minute found that brainwaves synchronised in the low-frequency delta and theta bands, particularly in brain regions involved in emotional processing. Theta waves are associated with deep relaxation and a state of "being" rather than "thinking", a condition that was experienced by many of the study volunteers. It also felt so relaxing that some of the participants fell asleep. But if you can stay awake long enough, slow breathing is a free ticket to an altered state of consciousness, no added chemicals necessary.

"Slowing your breathing is a free ticket to an altered state of consciousness"

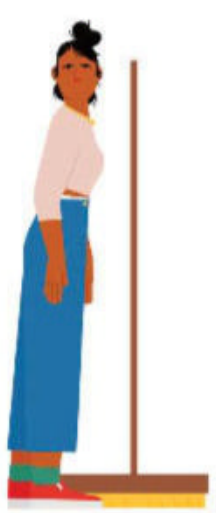
STRAIGHTEN UP

A slouched posture has long been linked to negative thinking and feelings of defeat, according to psychological research, while an upright, expanded posture brings a more positive mental attitude. Experiments also show that holding the body upright during a stressful event helps people experience less stress and recover faster.

The problem is that, until recently, there wasn't a convincing mechanism to link the physical act of holding your body upright with a positive and confident state of mind.

Intriguing new research hints at an answer. Peter Strick at Pittsburgh University in Pennsylvania stumbled on a potential explanation while tracing neural pathways that connect the brain and the adrenal glands, which are located at the top of the kidneys and are responsible for the adrenaline rush caused by acute stress. Strick and his team found that the inner part of these glands, called the adrenal medulla, is linked to regions of the brain's motor cortex, which controls voluntary movements. In turn, this neural pathway connects to the muscles of the core that stabilise the torso and support posture.

While it is too soon to be certain what information is being relayed along these routes, Strick thinks that the link could explain the stress-relieving effects of core-based exercise, such as Pilates, yoga and tai chi. Then again, all movement involves bracing the core to some extent. So however you choose to move, this pathway almost certainly comes into play at some point.



STRETCH

Stretching out stiff muscles feels good, but there seem to be some surprising additional benefits of loosening tight muscles. Emerging research suggests that stretching leads to changes in the fascia, sheets of connective tissue that wrap our muscles and allow them to slide over each other when we move.

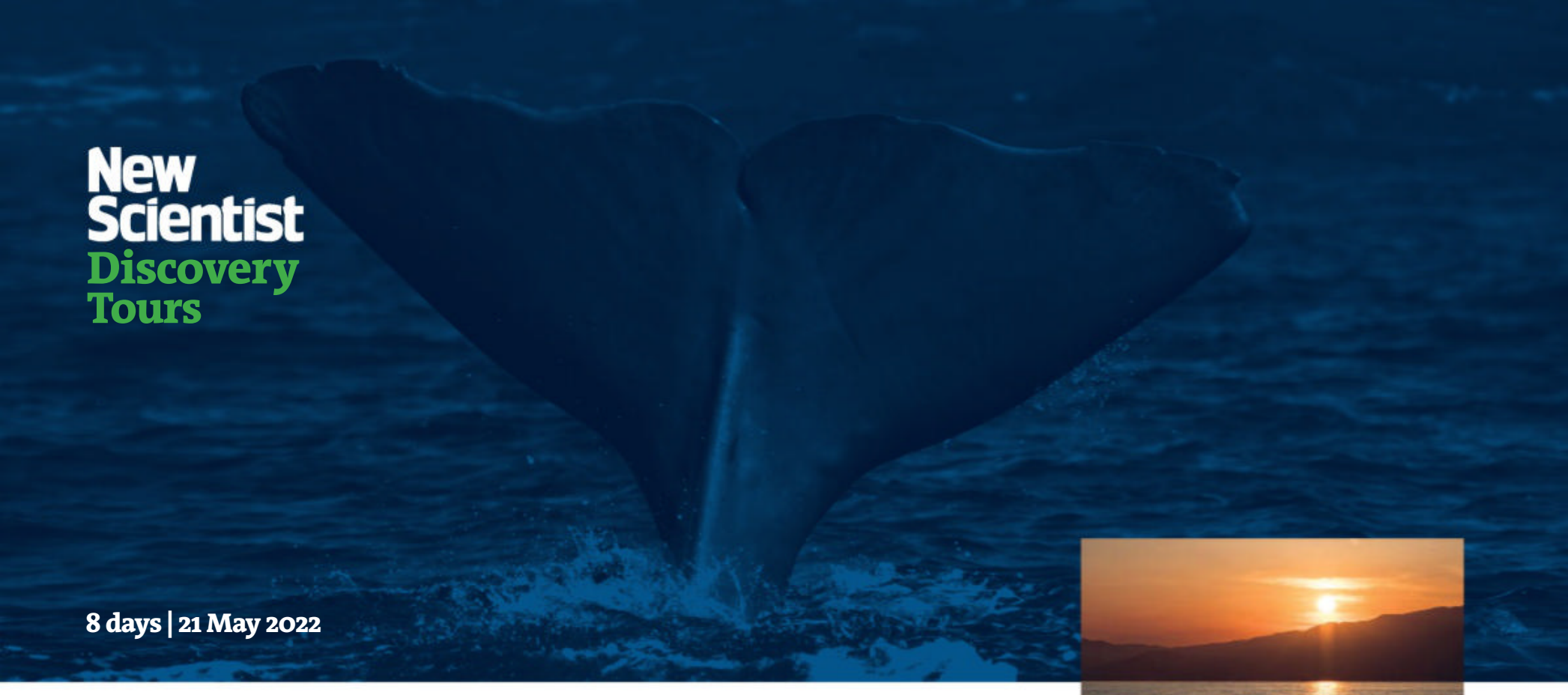
Research by Helene Langevin, then at Harvard Medical School, found that stretching rat tissue causes cells within the fascia to release adenosine triphosphate. This molecule manages levels of inflammation, which is the immune system response that ramps up in times of stress or when we have an injury or infection. In a 2016 study, Langevin and her team injected carrageenan, a substance that causes local inflammation, into rats' back muscles. Two days later, half of the rats were encouraged to stretch, while the other half weren't. The rats that stretched not only had significantly lower levels of inflammation, but also higher levels of molecules that help resolve inflammation at the cellular level.

Other studies have found that the fascia are structured like a fluid-soaked sponge that drains into the lymphatic system. This could mean that stretching helps move the body's fluids along, allowing the immune system to give these liquids a regular clean-out and deal with inflammation as it arises.

This matters for the mind because uncontrolled inflammation is linked to depression, chronic pain and fatigue. It is also exacerbated by modern lifestyles and obesity, and accelerates as we age.

Human studies into stretching and inflammation are still ongoing, but if it is confirmed that stretching and squeezing the fascia turns off inflammation after the threat has passed, it could help explain why people who do yoga and tai chi have lower levels of inflammatory markers in their blood. This could provide yet another reason to take regular breaks to stretch. ▮

Caroline Williams is author of *Move! The new science of body over mind.* To buy a copy, go to shop.newscientist.com/move



New Scientist Discovery Tours

8 days | 21 May 2022

Portugal: Marine ecosystems of the Azores

The Azores are a paradise. Lush vegetation, volcanic craters, lagoons, and picturesque towns are nestled in the rich biodiverse waters of the North Atlantic. Accompanied by a team of marine experts and marine biologist Jon Copley, you will spend time both at sea and on land surrounded by a host of different species. Spot the blue whale, the world's largest mammal, and the sperm whale, boasting the world's largest brain. Among others you may also see species such as baleen, pilot, and fin whales, bottlenose, risso, spotted and striped dolphins.

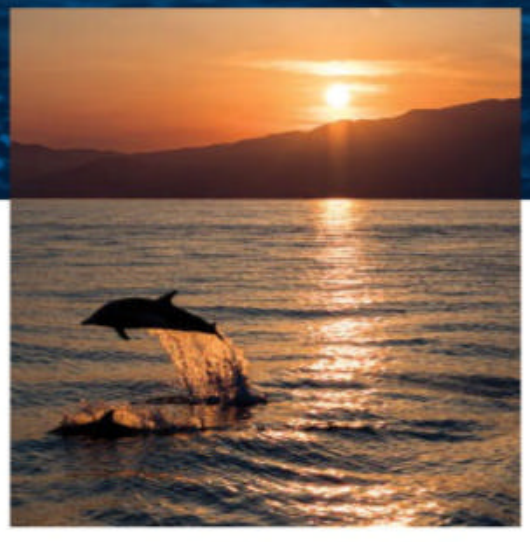
You will spend your days exploring the land and sea, learning about marine life, intelligence and ecosystems through a series of talks, as well as actively take part in whale research, the data of which is used around the world.

Highlights

- Two full days at sea with researchers from the University of Lisbon and Azores to spot whales, dolphins, turtles, and birds.
- A hands-on experience as you learn about global conservation efforts and how data is shared as you help collect and measure microplastics in the ocean as well as acoustic records of the different whales and dolphins in the nearby waters.
- Evening talks and floating seminars at sea from marine biologist and ocean explorer Jon Copley, covering behavioural ecology of sea mammals, the hydrothermal vents off the coast of the Azores and many other subjects.
- Discover the town of Sete Cidares, nestled in a 3-mile-wide volcano which is also home to both blue and green crater lakes.
- Explore many of the fascinating areas of the Sao Miguel Island, including a stop at a tea plantation and various beautiful viewpoints
- Ferry ride to Pico Island where you will enjoy a visit to a local vineyard in a UNESCO Protected Landscape, views of lagoons and volcanic cones, and a trip to the Whaler's Museum.
- Accompanied by a biologist, you will visit a local nature reserve, where you can expect to see an exceptionally large Cory's Shearwater seabird colony. With the breeding season at its peak in May, this will be an unforgettable experience.
- Explore Faial including central Caldeira and the unique lunar landscape of the Capelinhos volcano. From volcanoes to endemic forests, breath-taking lookouts, and landscapes, enjoy a series of short walks amidst the nature and culture of the Azores.

Covid-19 safety protocol includes:

- Pre-departure screening of all guests and tour leaders.
- Increased sanitisation of all accommodation and transport.
- Mandatory use of PPE where appropriate.



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'This is a terrifying, nail-biting, exciting time to be alive'

If humanity has any hope of tackling climate change, it needs to take action in this decade, sustainability researcher **Kimberly Nicholas** tells Richard Webb – and that challenges every aspect of how society works

ROCIO MONTOYA

"TO 2030. I hope we did right by you". It is an unusual dedication that appears at the front of *Under the Sky We Make: How to be human in a warming world*. But then Kimberly Nicholas, a sustainability scientist at Lund University in Sweden, has written an unusual book: a guide, she says, to living through the "decade that will define the future for both humanity and life on Earth". It is part clear-headed summary of what we know about climate change, part call to action and part personal reflection on how global warming has challenged her own views and values.

Nicholas spoke to *New Scientist* about climate science, environmental loss, the problem of finding a green date on Tinder and her challenging legacy as a turkey heiress.

Richard Webb: What's the meaning of the title *Under the Sky We Make*?

Kimberly Nicholas: It came to me when I was travelling overland to a science communication conference in Finland several years ago. I was really struck by what a momentous time we live in. We are the stewards of the very last traces of humanity's carbon budget. We're making the sky that we live under, and that our descendants will live under for many generations. We have a lot of agency and power and responsibility. I want us to make the changes we need to make a safe and beautiful sky, not the dangerous one we're making at the moment.

You summarise climate change as: "It's warming. It's us. We're sure. It's bad. We can fix it." But you also say that science won't save us. Why would a scientist say that?

I wanted to convey that science has taken us about as far as it can in the time we have. We know what the problems are, and we have most of the solutions. It worries me that sometimes there's an excessive faith in science and technology – that we can just switch from fossil fuels to clean energy and carry on exactly as before. That's not going to be enough. We need social and political and cultural changes as well as implementing scientific solutions.

The book suggests you already feel a sense of grief over the extent of the climate crisis.

I've been studying climate change since 1997. In that time, it's gone from being something that experts can see in long-term data sets to something we all are living through. In 2017, I was on the phone with my parents evacuating their home during a catastrophic wildfire in California that was made more likely and more devastating by climate change. My stomach was gripped by fear for their lives. That is so different than making calculations and plotting points on a graph.

I also quote my Lund University colleague, the conservation biologist Ola Olsson, saying "Half the wildlife in Africa has died on my watch". Much of what we do as environmental and climate scientists now is about witnessing the demise or death of what we love. That's not what I first thought I was getting into.

You also express anger, for example at the fossil-fuel industry's denialism. Is that emotional response compatible with the dispassionate role of a scientist?

I absolutely do feel angry at the injustices of climate change: that people who have done the least to cause it suffer the most, and for the injustice across generations. And there ›

is this really well-documented misinformation campaign over decades from the fossil fuel industry. I genuinely do not know how oil executives sleep at night knowing the harm that their products are causing. That is, I think, justifiable and righteous anger.

I think scientists can be human beings with emotions and also do rigorous and fair science. As a sustainability scientist, I must deliver goals that society has set, for example the Paris climate change agreement and the UN Sustainable Development Goals. The governments and the people of the world have said clearly that we want to live in a world where everyone's needs are met and well-being is prioritised, but where we also have thriving land and oceans and a stable climate.

Science tells us equally clearly that we don't live in that world today, and we're not heading for it with the decisions we're making. It's really critical that scientists who have this information speak up, point out this gap and highlight how we can do better and deliver what society has said we want.

You say that working to undo climate change can be "a crucible to create meaning in our lives". What do you mean by that?
We find things meaningful that are bigger than ourselves, that connect us with others, that are about giving more than taking, that make us part of a story and where our actions are in line with our values. Climate action really gives us the opportunity to put all those things in place. There is no more important task than stabilising the climate and ensuring a good future for all of us alive today and every human who will ever live. It's an opportunity for everyone, way beyond just scientists.

You have given up flying to scientific conferences. Isn't the flexibility that makes such decisions possible a luxury that most people can't afford?
Definitely. But the people who really need to make lifestyle changes are the people who have that luxury, like me: it's the 10 per cent of the global population who make above about $38,000 per year. Emissions are proportional to income, and we are the real high emitters who need to be changing our behaviour, not the majority who never fly, including half of people in the US and UK.

Some of my colleagues and friends have been saying they can't wait to fly away on a short break after the pandemic. How do you change an ingrained mindset of privilege?
Around flying, it's starting to change. I lead a research project called The Takeoff of Staying on the Ground, which is looking at the social movement in Sweden of people giving up flying for the sake of the climate. Here, it's reaching very close to a social tipping point where enough of the country's population is joining – around 25 per cent – to precipitate a wider change in norms. That movement is spreading to other countries, too.

You write about trying to find love on dating app Tinder as someone with deeply ingrained climate values. How did you do that without becoming an insufferable bore and turn-off?
Thank you for assuming that I'm not an insufferable, boring turn-off! It's not always easy, and there were definitely some awkward first dates where it was clear that my climate priorities and values did not mesh with those of the people I was seeing. When I met my husband, on our fourth date we went by train to Paris for 15 hours. We actually ended up liking each other a lot better at the end of it.

> "Nobody knows if we can pull this off. But what is humanly possible is what humans make possible"

Besides travel, there are other areas where we need to prioritise reducing emissions, for example in agriculture and food production. You have a problematic legacy there.
Globally, almost a quarter of greenhouse gas emissions come from agriculture, and a disproportionately large share of that comes from animal agriculture. My grandfather George helped invent an industrial-style process for making bigger turkeys where you basically feed them highly concentrated corn, soy and wheat, and turn food and clean air into greenhouse gases and an excess of nutrients in the form of animal poop.

A lot of research shows that both for health and for climate reasons, we need to shift to a more plant-based diet. And livestock need to be integrated into a wider system – for example cows grazing on grasslands that benefit from grazing for biodiversity or cultural reasons – rather than feeding animals food that could be going to people.

In general, it is cheap to buy things that are dangerous to the planet, like a plane ticket or industrial meat, and comparatively expensive to buy sustainably produced stuff. How do we change that?
One fundamental challenge is realising we need a stable climate to have a functioning economy. An economy is meant to deliver things that improve human lives. We can't measure that in terms of just GDP; we need to look at indicators like education and healthcare and social equality and democracy.

Subsidy reform is another big part of it. Some of my own work recently has been looking at the [EU] Common Agricultural Policy, showing how some subsidies increase income inequality and pay big polluters rather than the lowest-income farmers. Meanwhile, fossil fuel subsidies and the cost of the damage they cause amount to more than 6 per cent of the global economy. Recalculating the value of things so that the market price reflects their true costs is a big step to an economy that meets our needs in a sustainable way.

DAVE RUSHEN/SOPA IMAGES/SIPA USA/PA IMAGES

Protesters express anger over the role the fossil-fuel industry has played in climate change

How do we protect the interests of people who might have difficulty with that transition?
We do have to pay attention to equity and justice issues, and support the transition for workers in industries like coal mining and aviation that do need to decline to meet climate targets. But there is a smaller number of jobs affected than you might think. In the US, there are fewer people employed in the coal industry now than work at Arby's, a fast-food chain. We can ensure jobs and provide social safety nets and have a stable climate.

You co-authored a paper showing that having one less child was the greatest long-term cut to emissions an individual can make. But in your book, you write "no one is going to save the planet by not having kids". How are those statements compatible?
It's true that the number of people on the planet matters for the climate. If we have more people consuming resources the way that the top 10 per cent of high emitters do today, that has a very big long-term climate impact.

But that impact takes into account many future generations. To solve the climate crisis and stabilise the climate, we need to get emissions down to zero very quickly – at least halfway by 2030. It's us who are alive now who have to make the changes.

You have harsh words for the idea of geoengineering, for example injecting aerosol particles into the atmosphere to reflect sunlight and mitigate climate change. Why?
To me, this kind of solar geoengineering is like peak exploitation mindset. It's thinking that people can and should control nature, and that the answer to the uncontrolled experiment we're running now by adding so much fossil carbon to the atmosphere is to add more stuff to the atmosphere to try to counteract it.

That is designed for failure. It just covers up the problem and ignores, for example, that the carbon would still be there in the atmosphere, being absorbed by the oceans and acidifying them to death. It violates the principle that we need to get to the root cause of problems. We know that burning fossil fuels is the main cause of the climate crisis, so that's what we have to stop doing.

Do you worry about the politicisation of climate change, especially in the US?
There's some good news there, actually. The latest surveys show that less than 10 per cent of people in the US don't believe that humans are changing the climate. Thankfully, we don't need to engage that group to make changes happen. But we do need to activate, engage and empower the 90 per cent to demand change, and we do that through shared values.

I got a lovely email the other day from a friend of my parents who knew me when I was growing up, who I am fairly certain has voted Republican her entire life, including for Trump. She said "thank you for the work you're doing, I want my grandkids to have clean air to breathe". There are some widely shared values that we can connect with people over. Maybe it's not so much about trying to convince or convey facts if those have become politicised.

How can we marshal those shared values and beat climate apathy?
There is research showing that politicians in the UK are well aware of the problem of climate change, but don't feel pressure to act. The drumbeat from citizens needs to be much louder, not just by voting, which is super important, but by supporting and joining and contributing to climate charities and groups working towards the climate transition.

I actually have set a challenge for myself, that I've also put out in a monthly newsletter I've started called "We can fix it". And it's to contact your elected officials and talk to them about cars in your city or neighbourhood, or whatever policies are bad for the climate and bad for health and other things. That's a very effective thing to do, and it's rarely used.

Can we fix it?
At the moment, we are headed for something like 3°C of warming, which I lose sleep over. We can do it, but it will take a big effort: radical, sweeping changes through society. Fundamentally, nobody knows if we can pull this off or not. But what is humanly possible is what humans make possible. We definitely will not do it if too many people sit on the sidelines. This is an incredibly important, terrifying, nail-biting, but also very exciting time to be alive, because what we do really, really, really matters. ▮

Richard Webb is executive editor of *New Scientist*

JON SLADE

Freaky bonding

Chemists are finding new and surprising ways that atoms can stick together – some of which could generate novel materials, finds **Philip Ball**

NO SCHOOL chemistry textbook is complete without a detailed enumeration of the basic types of chemical bond: covalent, ionic and metallic. And for good reason, because bonds are the glue that binds chemistry together. "We talk about chemical bonding because we want to understand and predict materials' properties," says Matthias Wuttig, a materials physicist at RWTH Aachen University, Germany.

That makes it all the more shocking that, a century and a half after the idea of chemical bonds was first floated, we are still a long way from a complete understanding of how atoms' outermost electrons, the mediators of chemical bonds, form these links. Recent discoveries show that there are more types of bond than we thought, and that some of the familiar ones might not be quite as we had imagined. There are even bonds that, completely against chemical orthodoxy, involve no electrons at all.

We are still getting to grips with this new panoply of bonding varieties. Even so, it is

already clear that it can not only give us a better understanding of existing substances, but also unleash untapped potential in the elements, promising a whole new world of materials for applications that include solar cells, drugs, data storage and more besides.

As far back as the 1860s, scientists had begun writing out compounds in a distinctive format with sticks joining element symbols: H-H for the molecule (H_2) made up of two hydrogen atoms, for example. By 1866, English chemist Edward Frankland had coined the term "bond" to describe the links that these sticks depicted.

At this point, the whole concept of the atom was still disputed. No one envisaged the picture of the atom that we have today: a structured nucleus surrounded by electrons. The idea that bonds between two atoms could arise from them sharing electrons, known as covalent bonding, was first put forward in the early 20th century. It wasn't until the 1920s that quantum theory showed how this might actually happen: atoms seek the lowest available energy state, and electron-sharing gives the atoms a lower collective energy than they would have alone.

The terms we still use today to describe basic bonding types were laid out by Nobel-prizewinning chemist Linus Pauling in his seminal 1931 book *The Nature of the Chemical Bond*. As well as covering covalent bonds, Pauling showed that, in some unions, electrons hop from one atom onto another, producing positive and negative ions that stick together electrostatically: ionic bonds. Then there are metallic bonds, in which some electrons detach from their atoms and form a sort of electron sea that washes around and binds the positive ions they leave behind.

All of these are chemical bonds that share or poach electrons. But Pauling outlined a fourth type of bond: the hydrogen bond, which he described as an electrostatic attraction between hydrogen atoms and areas of high electron density in certain other elements, such as oxygen or nitrogen.

Even back then, it was clear that this simple classification was far from the whole story. Take the van der Waals force, another staple of school chemistry textbooks. A weak force caused by fluctuations in the clouds of electrons surrounding the atomic nucleus, it can cause atoms to stick to one another even if they won't form regular chemical bonds. It helps inert gases like helium and argon liquefy at very low temperatures. It is also strong enough, on occasion, to lock atoms into well-defined unions – when two oxygen molecules (O_2) join to form an O_4 cluster, for example, or when gold atoms stick together in so-called aurophilic bonds. So are van der Waals bonds real bonds? No one has a definitive answer because there has never been a consensus about what bonding entails.

"Talking about chemical bonding does not increase the number of my friends," says Wuttig. "It causes heated controversy because the concept of a chemical bond is not well defined." Here are five instances where the prevailing wisdom about bonds is breaking down and what this could mean for future technology. ›

1

WANNABE METALS

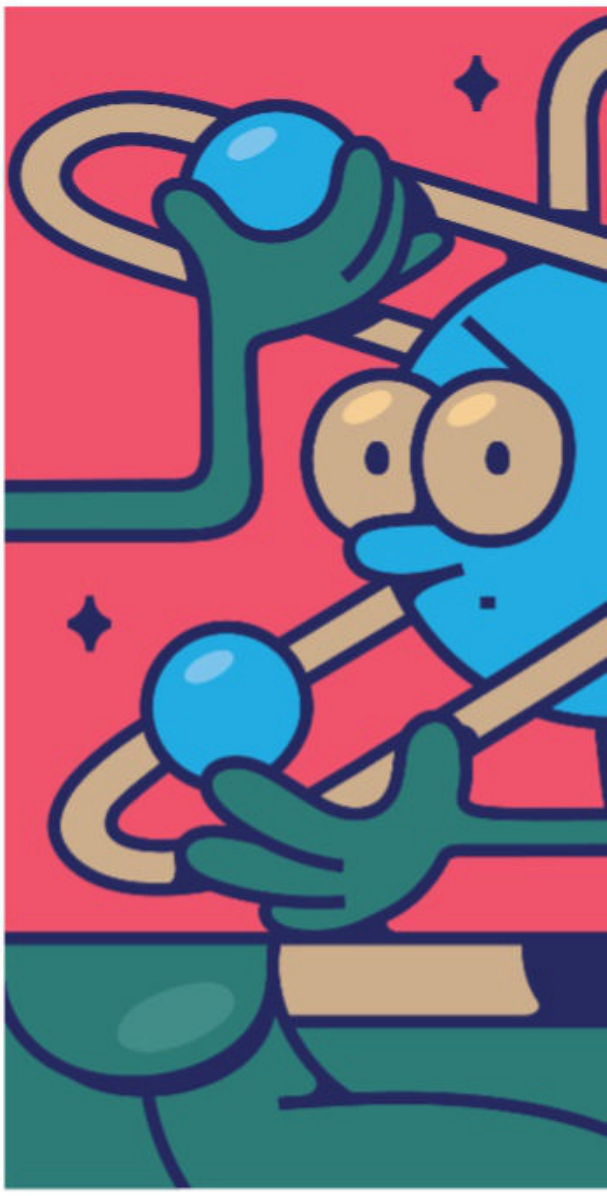
Conventionally, covalent and metallic bonding are seen as mutually exclusive. Atoms can share electrons in a localised way to bind them tightly together, as in a covalent bond, or have free electrons floating about in a soupy glue, as with metallic bonds. But they can't do both.

It might not be that simple. In 2019, Wuttig and his colleagues argued that a whole class of materials lie in a no man's land between these traditional bonding types. They typically combine elements from the borderlands of metals and non-metals – "metalloids" such as tellurium and germanium – and elements at the far right-hand edge of the metallic region of the periodic table, like lead and tin.

It is as though these elements can't decide whether their unions should be covalent or metallic – and do something different from both. One way to look at it, says Wuttig, is that each bond is formed from fewer than two electrons. Yet like metallic bonds, these "metavalent" bonds are collective affairs that exist only in extended systems – in solid materials, not lone molecules. They have unique properties distinct from covalent or metallic materials: for example, whereas covalent bonds vibrate like simple springs, metavalent bonds wobble differently.

Wuttig calls the resulting compounds incipient metals: a kind of "wannabe" metal. Their soft bonds give them low heat conductivity (in contrast to normal metals), but they are nevertheless reasonable electrical conductors. What's more, collective vibrations of the soft bonds have a strong influence on how the electrons move through the material. This means that their electrical conductivity may be particularly sensitive to influences from their surroundings, such as heat, making some incipient metals useful as thermoelectric materials that scavenge waste heat from places like car exhausts, turning it into electricity. Thermoelectrics require almost contradictory properties, combining metal-style electrical conductivity with semiconducting behaviour and low heat conductivity – a weird blend of properties that incipient metals with the right combination of elements can offer. Incipient metals might also be attractive for use in solar cells, because they absorb sunlight to mobilise electrons so that it can be harvested as electrical energy.

Incipient metals have some curious relatives called "strange metals". These are more metallic than incipient metals, while still not quite going the whole hog. They are basically metallic, but with an electrical resistance that increases in direct proportion to temperature, rather than with the square of the temperature like a conventional metal. New kinds of superconductor, which have zero electrical resistance, might appear in these border regions between covalent and metallic bonds too, along with a host of other "odd metals", such as "bad metals" and "chiral metals".



2

PHANTOM BONDS

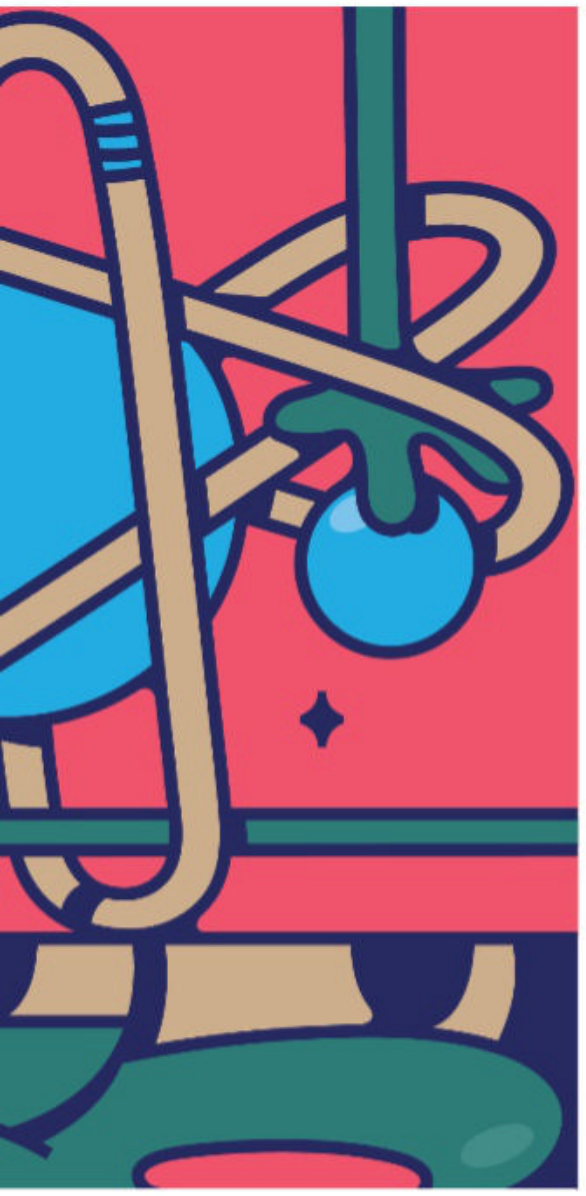
Hydrogen bonds involve hydrogen atoms already covalently bound to atoms such as oxygen, nitrogen or fluorine – elements that tend to hog electrons, leaving the hydrogen with a slight positive charge. The hydrogen is therefore attracted to negatively charged regions of other molecules, or even parts of the same molecule, where electrons congregate – specifically, to "lone pairs" of electrons that don't take part in covalent bonding.

The extra stickiness caused by hydrogen bonds explains why water (H_2O) holds together as a liquid rather than a gas under everyday conditions, and how water molecules link into a crystal lattice in ice. These bonds are also a vital part of the glue that binds the molecular chains of protein molecules into their complicated shapes, and which zips up the double helix of DNA.

Yet it is still not entirely clear what hydrogen bonds are. As a simple model of hydrogen bonding, bifluoride (HF_2^-) has been generally regarded as a covalently bonded hydrogen fluoride (HF) molecule H-bonded to a fluoride ion. But closer inspection has begun to confuse things. Andrei Tokmakoff at the University of Chicago and his colleagues have found that, as the bifluoride ion vibrates in water, the structure could vary between this picture and one in which the hydrogen atom is shared equally with both fluorines "at the tipping point where hydrogen bonding ends and chemical [covalent] bonding begins".

Bonds generally aren't rigid, but bend and stretch as well as vibrating. This suggests that

"It's as if these elements can't decide whether their unions should be covalent or metallic"



to establish the presence of a bond, we need to evaluate not just whether atoms are stuck together, but for how long. A case in point is supercritical water: water heated past its "critical point" (374°C at 218 atmospheres of pressure), where there is no longer any distinction between the liquid and gas states. Here it's long been debated whether any hydrogen bonds persist. A better understanding of what's going on would be great for the chemicals industry. Supercritical water can dissolve compounds that normal water can't, making it a useful "green" alternative to solvents based on often toxic organic compounds such as benzene or toluene.

Theoretical chemists Dominik Marx and Philipp Schienbein at Ruhr-University Bochum in Germany recently sought to settle the debate by showing in simulations that hydrogen bonds in supercritical water break so fast that they don't even have time to vibrate through a single oscillation. It is debatable whether this qualifies as a bond at all, says Marx, adding that with so many different ways to define bonds, "any bonding analysis will be subject to eternal discussion, excitement, and controversy".

3

LOOPS AND LINKS

"While there are probably many thousands of new chemical compounds made every week in chemical laboratories around the world, it is only once in a blue moon that a new bond breaks upon the scene," says Fraser Stoddart at Northwestern University in Illinois.

He should know: in the 1980s, Stoddart was one of the pioneers of molecular assemblies called rotaxanes and catenanes, mostly created in solution so far, that are permanently linked without using any electrons at all. Their "mechanical bonds" are formed by threading molecules together like links in a chain or a ring on a finger.

"Nature was using mechanical bonds long before we humans came on the scene," says Stoddart. Indeed, they are found in many living systems – for example, they can help to hold the chain in RNA molecules in a particular functional shape. "Nature executes the chemistry of the mechanical bond with an elegance, complexity and beauty that will remain a source of inspiration to synthetic chemists for centuries to come," he says.

That inspiration may pay dividends in molecular nanotechnology, where the loops and links of catenanes and other mechanically bonded molecules can be put to work as switches and rotors – the shape of rotaxanes can mimic an axle, for example. Potential applications include molecular information storage, where two switched states can encode binary data, and artificial molecular muscles, where switching causes a change in molecular length.

This field has exploded over recent years, and its achievements were recognised in the Nobel committee's decision to award the 2016 chemistry prize for such work and its role in the design of molecular machines to Stoddart, alongside chemists Jean-Pierre Sauvage and Ben Feringa. One challenge now is to fix these molecular machines to solid supports so that they work in concert rather than in the random orientations they have in solution. For instance, a molecular muscle would only really pack a punch when many such units work together.

"Nature was using mechanical bonds long before we humans came on the scene"

4

MUON GLUE

Some chemists have been exploring bonds that don't occur in nature at all. The electron may be the classic bond-forming particle, but its heavy cousin, the muon, which has an identical negative charge, but a mass 207 times greater, can also unite atoms. Muons can be made in particle accelerators and can bump electrons out of atoms, taking their place before decaying in a fraction of a second.

That might not sound much use, but because they are heavier than electrons, muons create a stronger glue, pulling atomic nuclei closer together in molecules. Researchers have been trying to exploit this effect to bring hydrogen atoms closer for a split second so that they can fuse and release nuclear energy. In an H_2 molecule bound by a muon, the two nuclei are 196 times closer.

This effect – using heavy hydrogen isotopes deuterium and tritium, which fuse more readily – is the basis of muon-catalysed ›

fusion, first demonstrated in 1957. However, the conventional approach requires cold, dense forms of hydrogen, which won't survive to sustain the reaction once fusion ignites. As a result, scientists have explored the possibility of fusion in gaseous fuel since the 1990s, but their ideas haven't yet advanced beyond the stage of theoretical proposals.

5

BOUND BY DISORDER

Ultimately, chemical bonding is about atoms and electrons arranging themselves into lower energy states. The structure and order that can result is, however, potentially undermined by the influence of entropy, a thermodynamic quantity that is generally seen as promoting disorder and, according to the second law of thermodynamics, is always on the increase.

"Normally, people assume that energy and entropy are competing all the time," says chemical engineer Sharon Glotzer at the University of Michigan. "We think energy wants to order things, and entropy wants to disorder things." However, entropy alone can lead to a kind of order, and Glotzer has shown that this acts as a form of "entropic bonding".

Chemists can carefully tune the properties of a suspension of microscopic plastic spheres in a solvent so that the particles feel no significant interaction forces at all. It has been known for decades that, above a threshold density of particles in such a suspension, an orderly "colloidal crystal" will form. With no interaction energy until the particles actually touch and push back against each other, the only driving force for the ordering is entropy.

It isn't just a question of increased density forcing the particles to pack like oranges at a greengrocer's stall. Entropic crystals form well before that point. The ordering happens when, bizarrely, the crystal state has a higher entropy than the liquid one.

For instance, Glotzer has engineered an entropic crystal of particles that assemble into an orderly cage-like framework that encapsulates other particles in the holes – an analogue of the chemically bonded materials known as clathrates. Here, all the disorder is focused on the captured "guest" particles, which "move like crazy, rotating around", she says, elevating the entropy so that the host framework is free to form an ordered structure. "If you stop the guests from spinning, the whole thing falls apart," says Glotzer. In fact, she says that she and her colleagues have yet to find a crystal structure formed by atoms or molecules bonding by covalent, ionic or metallic bonds that can't also be formed from entropic bonds of non-interacting particles.

But are these really "bonds"? Entropy, says Glotzer, is a global state – it doesn't have any meaning for just two atoms, say. But she and her team have shown that it is possible to describe how their various entropically bonded arrangements come together in terms of a hypothetical force between pairs of particles that would bring them together in isolation in the same way as they come together under the entropic influence of their many neighbours in her colloidal system.

"I would like to make colloidal robots," Glotzer says, using the entropy to locally order and disorder the components. The relative weakness of the entropic bonds here is an advantage for making structures readily reconfigurable to suit different circumstances or functions. She also imagines a "periodic table of shapes" showing which particle shapes you need for a given material or structure to assemble entropically. Glotzer is convinced that future textbooks need to include something about entropic bonds. It certainly seems Pauling's original taxonomy is overdue an upgrade. ▮

"Surprisingly, entropy alone can lead to a kind of order"

Philip Ball is a science writer. His latest book is *The Beauty of Chemistry* (MIT Press, 2021)

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*Source: A New Textiles Economy: Redesigning fashion's future (Ellen MacArthur Foundation, 2017).

The back pages

Citizen science

Listen to the animals

From recording the dawn chorus to identifying whales from their sounds, you can help track biodiversity, says **Layal Liverpool**

Layal Liverpool is a digital journalist at *New Scientist*. She believes everyone can be a scientist, including you. @layallivs

What you need

A smartphone with the Dawn Chorus app
You can also try visiting cetalingua.com and zooniverse.org

THIS month I'm taking advantage of a wonderful live performance that happens outside my window every day. I'm rising early to listen to the dawn chorus – the collective chirping, tweeting and singing of wild birds. It's all in the name of science: I'm recording the sounds on my smartphone as part of the Dawn Chorus project, to help research on biodiversity.

You can participate during May by downloading the Dawn Chorus app on your smartphone and recording morning bird sounds wherever you live. You will need to wake up early though: the Dawn Chorus team recommends starting half an hour before sunrise.

Many birds are at their most vocal around dawn, hidden from predators by the low light levels, which also leave them unable to search for their food. Low levels of background noise and the stillness of the air means sound carries around 20 times further.

Each species starts singing at a specific time relative to sunrise, so the sound of the bird choir changes as different species join in. The sound also varies between regions of the world, depending on the species present and the season. Other factors, such as weather and background noise, may also influence the chorus.

Your early morning recordings will help researchers track bird species in different parts of the world and correlate this with habitat changes in specific areas, such as deforestation or noise pollution.

DIKKYOESINI/GETTY IMAGES

"Bioacoustic monitoring is becoming an important conservation tool," says Lisa Gill at the Biotopia Natural History Museum Bayern in Germany, part of the team running the Dawn Chorus project. "Birds are also important bioindicators of habitat change," she says.

But don't worry if you aren't an early bird. Other projects need volunteers to listen to prerecorded animal sounds. Whale Chat has recruited thousands of people to listen online to underwater recordings and help identify humpback whale vocalisations. Other projects give you the chance to do the same for dolphin and manatee sounds. Researchers will use the data to investigate how marine mammals communicate. Visit cetalingua.com to join in.

If you prefer frogs, FrogSong is looking for volunteers to label frog calls in recordings. You can take part via the Zooniverse online platform for citizen science, and help researchers monitor frog populations in Australia.

Growing evidence suggests access to nature boosts our mental health. Just listening to the sounds of birds, whales and frogs made me happier and more relaxed.

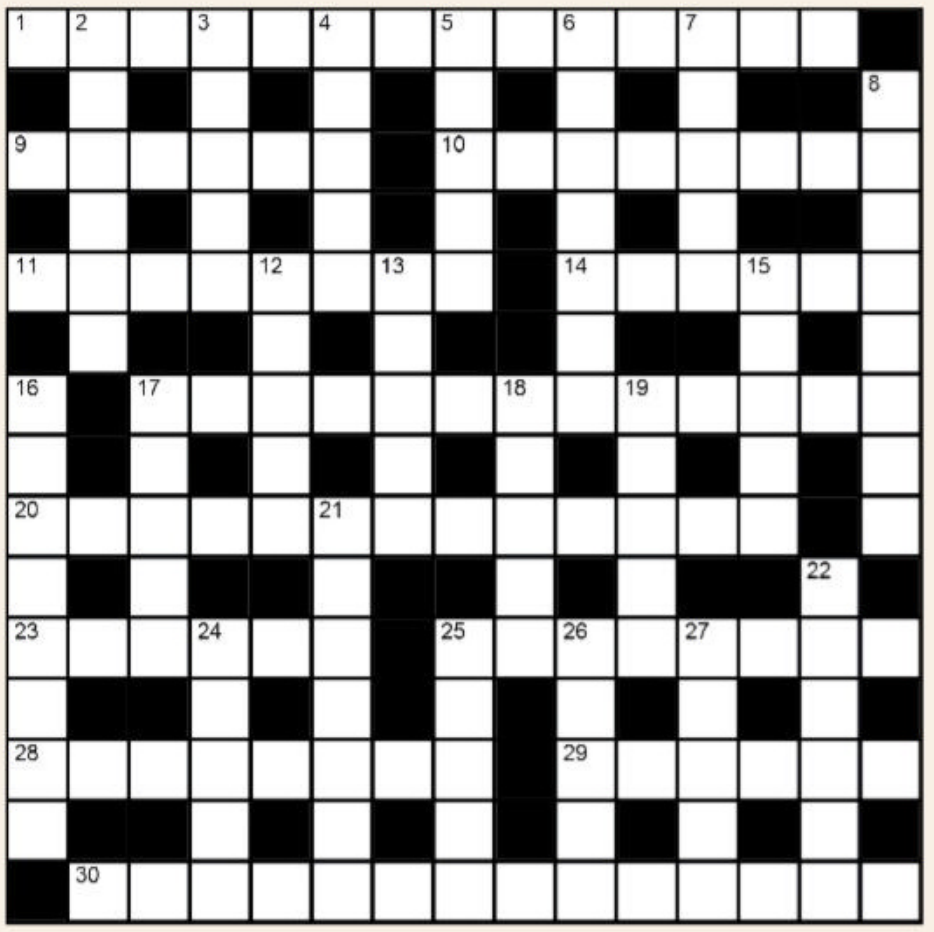
"The main goal is to get humans to stop and listen," says Gill. By appealing to the sense of hearing, she says, the Dawn Chorus project aims to create a deep connection to nature and a strong awareness of how human activities interfere with nature. ▮

Citizen science appears every four weeks

Next week
Science of cooking

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

Quick crossword #83 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 UK learning institute founded in 1969 (4,10)
9 Souped-up classic car (3-3)
10 Volcanic glass (8)
11 Variola minor (8)
14 Fractions equivalent to 0.166666667 (6)
17 Heart attack (7,6)
20 Shaped like half a globe (13)
23 Drainage channel (6)
25 Daimler micro-automobile (5,3)
28 Online avatar created by Jon Jacobs (8)
29 Quadrilaterals (6)
30 Process of removing harmful substances (14)

DOWN

2 *Homo sapiens* (6)
3 Nostrils (5)
4 Lowest point (5)
5 Noise of an engine (5)
6 Antarctic bay (4,3)
7 Pointer; alphabetical list of contents (5)
8 Carbocyclic sugar found in mammal tissues (8)
12 Rubber outer parts of wheels (5)
13 ___ elk, extinct deer (5)
15 Kind of lymphocyte (1-4)
16 Tropical hardwood tree (8)
17 Kohoutek or Hale-Bopp, perhaps (5)
18 Optical compact disc (2-3)
19 Happen again (5)
21 Apparent logical impossibility (7)
22 Igneous rock (6)
24 Social media message (5)
25 Raised edge of a continent or ice sheet (5)
26 Of gold (or Goldfinger) (5)
27 Freshwater fish (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #102

1 What is the only species of bird known to hibernate for extended periods?

2 In what year did Amelia Earhart become the first woman to make a solo, non-stop transatlantic flight?

3 What kind of dwarf star is TRAPPIST-1?

4 How many valence electrons do the halogen elements have?

5 The breakdown of proteins into polypeptides or amino acids is known as what?

Answers on page 55

Puzzle
set by Andrew Jeffrey
#114 Lara's birthday

"It's amazing," said Lara. "Today is the 29th of the month and I am 29. Tomorrow is the 30th and it is my 30th birthday. Imagine someone's age matching the date two days running!"

"Not that amazing, is it?" asked Thomas, doubtfully. "Surely that will happen to everyone at least once in their lifetime?"

"It hasn't happened to me," said Francesca, "and it never will."

"Nor me," said Martha, "and my birthday is just after Francesca's."

When are Francesca and Martha's birthdays?

Answer next week

Drawing dilemma

Why is it easier to copy a picture of an apple than to draw the apple itself? Wouldn't the image on my retina be the same whichever one I looked at?

Nina Dougall
Malmsbury, Victoria, Australia
As an artist and art teacher, I am always dumbfounded by the differences in how individuals perceive something. Within a class of 20 students, there will be 20 interpretations of how to portray an object.

What you portray is determined by your observational powers, degree of perfectionism, natural ability, training, culture, age and personality.

Then there is the factor of the artist's mood. There is always something of the personality of the artist in the moment that they are capturing in their art. This is what makes the difference between a mere reproduction and a "work of art" a topic of endless discussion in the art world.

"When you look at an apple, what you see isn't the image on your retina. The brain does a lot of processing first"

The reason it may be easier to copy a picture than to draw an original is that several major decisions, such as size, style and medium, have already been made in the picture you are copying.

Hilary Johnson
Malvern, Worcestershire, UK
When you look at an apple, what you see isn't the image that reaches your retina. The brain does a lot of processing first. It combines the images from each eye to give depth and adds in information from previous scans to fill in the detail and colour missing from peripheral vision. It also "corrects" shapes, sizes and colours to minimise the effect of different positions and lighting.

When drawing a scene, an artist has to flatten the image, undo some – but not all – of this processing and select colours that suggest the effects of light and shade. The copier finds this work already done.

Tom Hunter
Oxford, UK
Converting a three-dimensional object into a flat, 2D image requires judgements of scale and perspective. This is made more difficult by the way we continuously adjust focus between the object and its surroundings. This issue is removed when copying from a picture, allowing us to just consider layout.

The reason we often feel more when viewing a drawing or painting made from life is the direct human-to-human translation, with the artist choosing what to emphasise, together with all the imperfections that brings.

Peter Slessenger
Reading, Berkshire, UK
There is evidence that artists have projected images onto a flat surface to trace outlines to enable accurate depiction of scenes since the 1430s. Jan Vermeer may have used this technique for some paintings, which show uncannily perfect perspective of intricate details.

Ron Dippold
San Diego, California, US
Your brain doesn't see reality like a camera. It builds a three-dimensional scene from streams of incomplete data from the optic nerve. So you have a 3D scene rendered in your brain. If you only use one eye, it uses micromovements to create 3D. Reducing that to flat 2D is a real skill that takes hard work to accomplish.

David Muir
Edinburgh, UK
It is difficult to artistically portray the perspective of depth. This is why ancient, pictorial art is two-dimensional, seeming naive. In the 13th and 14th centuries, Italian masters such as Giotto started to explore basic perspective, giving a third dimension to their work. By the 15th century, Renaissance painters such as Leonardo da Vinci had command of perspective, giving their art depth and volume.

DIMITRI OTIS/GETTY IMAGES

Why do we offer cups of tea when people are upset?

This week's new questions

Dental dilemma **Is toothpaste essential? Aside from fluoride, is there any evidence of its value?** ***Rupert Fawdry****, Leighton Buzzard, Bedfordshire, UK*

Soothing brew **Why is a cup of tea so satisfying, and often the first thing offered when a person is upset?** ***Debbie Cowley****, Perth, Western Australia*

Popular support

What is the minimum population needed to sustain me in a comfortable life in the US, in terms of the people who create and maintain infrastructure, goods and services? The combinatorial explosion of dependencies boggles my mind: for instance, I enjoy *New Scientist*, so its journalists and all their dependencies would have to be added in too. And so on...

John Davnall
Radcliffe, Greater Manchester, UK
In a 2008 *New Scientist* interview, environmental activist David Suzuki discussed how the maximum population our planet could sustain with "Western" lifestyles could be as low as 200 million. Could this number provide the goods and services necessary?

The "combinatorial explosion of dependencies" makes answering this question difficult. Do we assume that "comfortable" includes feelings of security given by access to good medical care, the

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Tom Gauld
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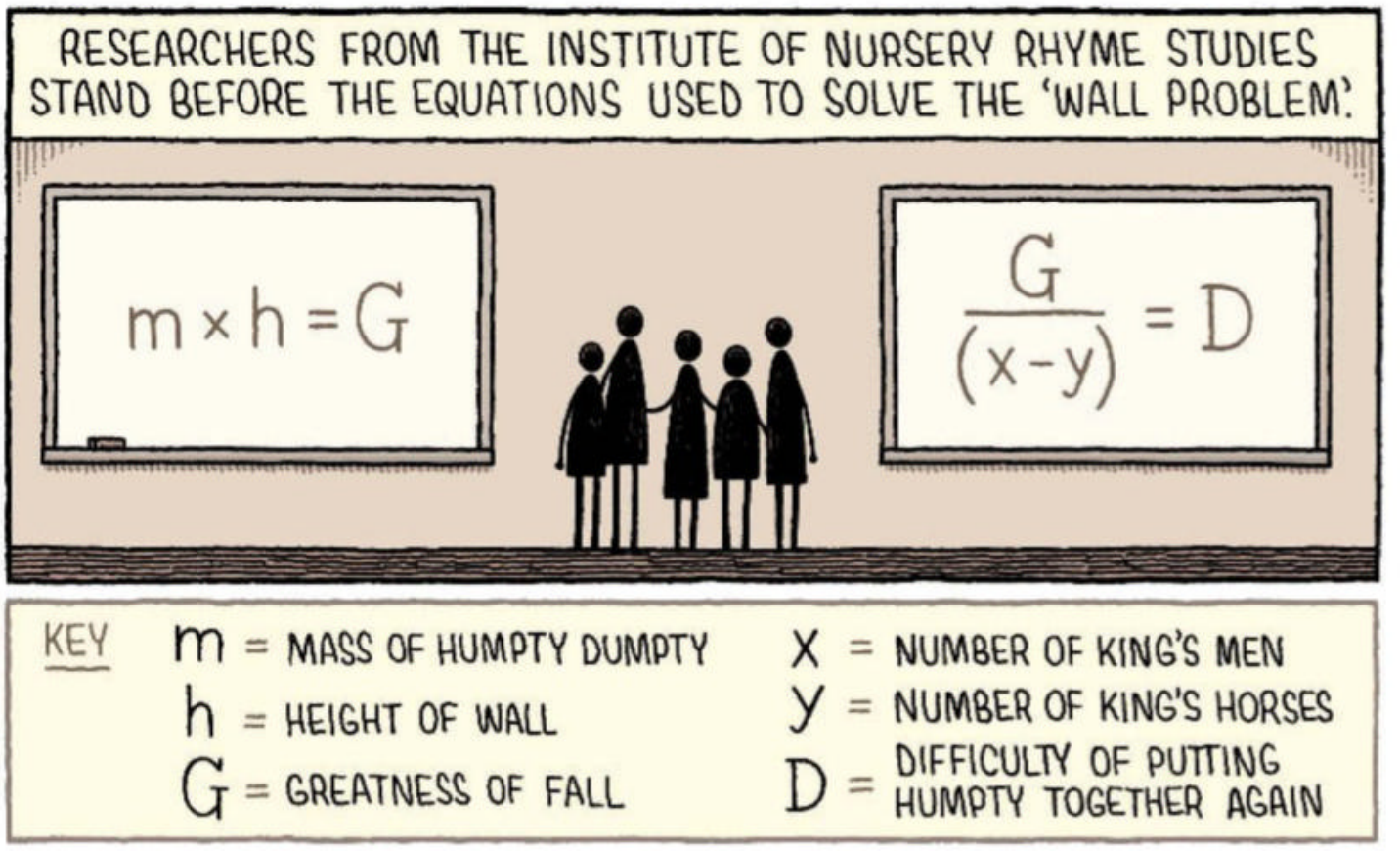

protection by emergency services and armed forces, education and pension funds with their income drawn from the profits of the labours of multitudes?

Then there is the consumption of goods and services; how much is accessibility to choice part of the feeling of comfort? I like wine and live music, but I wouldn't like either as much if I had no choice but to drink the same wine and hear the same orchestra all the time. There is also a moral point: should all those supplying one person's comforts be able to feel the same level of comfort?

Recently, I saw a revision from three to 11 of the number of Earths that the present world population is depleting unsustainably. If the current human population of more than 7 billion were reduced by a factor of 11 and then reduced again to bring everybody up to a Western standard of living, then 200 million people looks a reasonable stab at an upper bound to the question of how many people are needed to sustain a comfortable life in the US... unless the letter writer feels comfortable with a more modest lifestyle than stereotypical US standards.

"I like wine and music, but wouldn't like either as much if I had no choice but to drink the same wine or hear the same orchestra"

Hillary Shaw
Newport, Shropshire, UK
In the event of major population reduction and fragmentation, maybe by nuclear war, a much reduced population could maintain a wide range of internally traded production, expertise and services so long as they had electricity and were efficiently organised.

What is the minimum town size likely to have the range of retail goods and services, plus advanced medical facilities, that you may desire or need? In the UK, this is maybe in towns with a population of around 300,000, the size of Nottingham.

Offspring insight

How do animals recognise their progeny? Are they conscious that they reproduce? (continued)

Roger Leitch
Bath, UK
Some years ago my dog, Lola, had a litter of puppies, and my son has one of them, Ivy. When we are out with both dogs, if we tell Ivy off, Lola will "tell her off" too, trying to grab her by the scruff of the neck and shake her – a common way dogs discipline pups. This isn't easy because the dogs are about the same size.

Bryn Glover
Ripon, North Yorkshire, UK
It is true that some animals eat their offspring or mate with them, as discussed previously. But how does this lead to the conclusion that they haven't recognised them as their own? The inference may be true in human morality terms, but why should we assume that such behaviour is universal in animal life? ▮

Answers

Quick quiz #102
Answers

1 The common poorwill (*Phalaenoptilus nuttallii*)

2 1932

3 A red dwarf, or M dwarf

4 Seven

5 Proteolysis

Cryptic crossword #57 *Answers*

ACROSS 1 Beaked, **4** Emesis, **9** Lumbago, **10** Limbo, **11** Ultra, **12** Bristle, **13** Splenectomy, **18** Cluster, **20** Slump, **22** Evade, **23** Spicily, **24** Eleven, **25** Agreed

DOWN 1 Bulbul, **2** Admit, **3** Edamame, **5/15** Multitasking, **6** Symptom, **7** Stoned, **8** Double cross, **14** Plumage, **16** Scheme, **17** Spayed, **19** Theme, **21** Urine

#113 The two-ewes day paradox
Solution

Yes, Farmer Giles is right to be optimistic, although perhaps not for the reason he thinks. The chance that one of the lambs will be female is actually ⅔. We are told the test detects fragments of the Y chromosome whenever there is a male. Mixed sets of twins are twice as common in sheep as same sex twins. Why?

Call the twins A and B. There are three equally likely sex combinations for A and B when at least one is male: M-M, M-F and F-M. In two of these, one of the lambs is female, hence the probability is ⅔. This is a variant of the famous (and always hotly debated) boy-girl "paradox".

Computer confusion

Feedback is forever grateful for the alertness and exactitude of our readers, which keeps us on our toes. And not just us, but our robotic associates too.

Peter Knight writes in to say that if you ask Amazon's electronic assistant, Alexa: "What is the mass of the neutrino?", it answers, with confidence: "The mass of the neutrino is 95 kilograms." "Seems a bit heavy," says Peter.

He enquires whether *New Scientist* readers have detected any similar electronic eccentricities. To which we can only say: over to you.

Return of the mask

The covid-19 pandemic has been a source of much controversy over the past year. Many people who think coronavirus is just a big hoax have heaped scorn on those who wear face masks, despite it being in accordance with medical advice, not to mention, in many places, the law. The poor masks are pejoratively referred to as "muzzles" or "face nappies", and so on.

But that may be about to change, according to *Vice*. While some may scoff at there being any risk from the coronavirus itself, the idea of vaccine "shedding" is now causing concern in certain circles. Some people falsely believe that those who have had a covid-19 vaccine can breathe out small particles of it.

While shedding is a risk for some vaccines – such as a polio vaccine made from a live but weakened version of the poliovirus – none of the available covid-19 vaccines contain live virus, a prerequisite for any pathogen to replicate within the body. The vaccines currently used in the UK and US, for instance, work by causing the person's arm muscle to manufacture the virus spike protein.

Yet, it seems that not everyone is accepting this fact. Some of those worried about vaccine shedding are taking refuge in a defence from airborne dangers that the rest of the world has become all too familiar with: the dreaded face nappies.

It is an unusual case of two wrongs – the belief that covid-19 vaccines are harmful and that they can spread to others through the medium of breath – making a right: these coronavirus sceptics are finally wearing masks.

Twisteddoodles *for New Scientist*

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

School's out

Not all coronavirus sceptics follow this logic, sadly. The owner of Sun City Silver and Gold Exchange, in Kelowna, Canada, has banned people from entering the store if they have been vaccinated – or are wearing face coverings. You just can't win with some people.

Similarly, at a Miami school, the headteacher has forbidden teaching staff from contact with pupils if they have had a covid-19 jab.

To their credit, politicians in the Florida Senate debated a legislative amendment that would ban any such vaccine bans. Republican Jeff Brandes of St Petersburg spoke in favour, pleading with his colleagues: "Let's show that the Senate is not insane."

And the result was? The amendment failed. Readers can draw their own conclusions.

Meaningless measures

Many of you have been busy sending in obscure units of measurement you have seen elsewhere. Reader Brian Horton was left scratching his head after some sad news about the pace of glacier melting on *The Independent* website. The global volume of ice and snow lost each year would be enough to put Switzerland under 7.2 metres of water, said the article.

What has the author of the piece got against Switzerland, he wonders. The country is in one of the world's higher regions so is unlikely to be affected by sea level rise any time soon. It is also famously mountainous – or "lumpy", as Brian puts it – so the water would flow down into the valleys. "Surely it won't stay evenly spread out," says Brian. "Water doesn't work like that."

Meanwhile, another reader, who wishes to remain nameless, is confused by various websites claiming that blue whale farts are big enough to contain a horse – or, according to alternative sources, a Volkswagen car. But an in-depth investigation by fact-checking website Snopes says this may be fanciful because the size of whale farts has never been accurately measured.

It is even in doubt whether whales have the ability to fart, says the site, because rather than storing it up, cetaceans generally release their faeces and gas continuously, "akin to a slow and steady leak of air from a tire".

A few observers have claimed to witness a whale fart, but the fact that the creatures' burps from their blowholes smell like farts only serves to, er… muddy the waters.

Bristol fashion

Speaking of faecal matters, a correction is needed. In a previous column, Feedback drew attention to the existence of the Bristol Stool Chart (6 March), which classifies our bowel movements from type 1 (severe constipation) to type 7 (severe diarrhoea). We speculated that residents of the UK city may be unenthusiastic about their association with different textures of faeces, but Bristol citizen Emily Cox has put us right.

Cox says that, in her circle at least, it is de rigeur to have a poster of the eponymous faeces classification system in the smallest room in the house. As to how her community feels about its name? "Proud, very proud," she says. Feedback regrets the error.