

New Scientist

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HOPE V HYPE**

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How to spot it
and what you can do about it



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The universe began with an epic bang almost 14 billion years ago and has been expanding ever since. In this talk, astrophysicist Jo Dunkley will explain how we know this. She will also explore how our measurements disagree regarding just how fast that expansion is happening. Join us from 6pm BST on 6 May or watch on-demand later. Tickets available now.

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Star power Aliens could create vast arrays of solar panels in space

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Back to school? The decision involves balancing many different risks

Video

The queen's dialect

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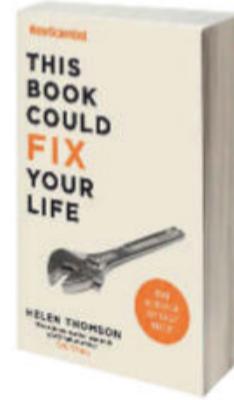
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The world, better understood

Feeling the burn

A year into the pandemic, people are exhausted – and calmer times still seem far off

ARE you suffering from burnout? Almost a year since the coronavirus pandemic was officially declared, the answer to that question for many will be an exhausted, “Well, duh!” Yet as we report in our cover story on page 34, while we may intuitively think we know what burnout feels like, it is actually a slippery concept.

Originally used to describe people overwhelmed by work pressures, it is now understood to be something that can happen to anyone under pressure, even if it has nothing to do with work. And although burnout isn’t a clearly defined medical condition, we still need to take it seriously.

Burnout is intricately connected to other mental health problems, and, critically, its effects, which include feelings of detachment, cynicism and unshakeable

exhaustion, make it very hard for an individual to take action. Hopefully our report will help, because for many of us, there is still a way to go in this pandemic before we can come up for air.

Of course, one of the key problems we face, even as more vaccines appear, is that the coronavirus is evolving.

“For many of us, there is still a way to go in this pandemic before we can come up for air”

Since we last covered this story in depth just two weeks ago, the situation has changed. We now have strong evidence that certain coronavirus variants seem to partially evade some of our most promising vaccines (see page 8).

Vaccine companies are already

developing solutions to this problem, but even if it is arguably simple to tweak a vaccine, it is yet another time-consuming hurdle for a vaccine roll-out programme that has yet to reach many (see page 12).

There is a glimmer of good news in all this. It seems that many of the vaccines we have at our disposal do go some way towards blocking people from catching and spreading the coronavirus (see page 11). Even a partial blocking of transmission will help prevent the virus from mutating further once many people have been vaccinated. It should also help protect those, such as pregnant women (see page 13), who may not be vaccinated.

In addition, it makes herd immunity more likely, and with that a path out of the current situation – and all the burnout that comes with it. ■

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Mutations

UK variant gets nastier

The race is on to eliminate variants of the coronavirus that are more transmissible and evade immune protection, says **Michael Le Page**

SOME coronavirus variants are becoming increasingly concerning as they mutate. Samples of the more transmissible B.1.1.7 coronavirus variant, which was first detected in the UK, show that it has acquired a mutation that will help it evade immune protection. It is the same mutation found in the B.1.351 variant first identified in South Africa, which is now spreading globally.

Local transmission of the B.1.351 variant has been confirmed in the US, in several European countries including the UK, and in Israel and much of sub-Saharan Africa. It isn't yet clear if it is more transmissible, but it is certain that it can partly evade the immunity we develop from natural infection by older coronavirus variants and from vaccines. The big worry is that it could evolve further and

completely evade immunity, undermining vaccination efforts.

Lab studies have shown that a mutation called E484K helps B.1.351 to evade antibodies. This same mutation has now been found in 11 B.1.1.7 viruses, according to a UK government document. It doesn't say when or where these viruses were found.

Ravindra Gupta at the University of Cambridge and his colleagues have already confirmed that with the E484K mutation, B.1.1.7 is better at evading immune protection. In other words, it is faster-spreading and also better at evading immunity. If it isn't stopped, it could outcompete the older B.1.1.7 variant, which

has already spread to many countries worldwide.

B.1.351 is also going global despite efforts to halt its spread. On 1 February, the UK announced that it had found 11 cases that couldn't be linked to travel, meaning it is spreading within the local community. The UK government is testing people in eight areas of England, regardless of symptoms, in an effort to find and eliminate the variant.

The UK has identified 105 cases of B.1.351 in total, but the rest were linked to travel. Unfortunately, the 11 cases are probably just the tip of the iceberg. The only way to detect this variant is to sequence viral samples, and only about 1 in 20

People queuing outside a covid-19 testing centre in Southport, UK

samples from people who test positive are sequenced. What's more, many infected people never get tested.

People entering England are meant to self-isolate for 10 days, but it is clear from the spread of other variants during the European summer that this isn't effective. Travel to the UK from parts of Africa, South America

"The big worry is that it could evolve further and evade immunity, undermining vaccinations"

and Portugal has now been banned, and enforced isolation in hotels will be introduced soon.

On 28 January, officials in South Carolina reported B.1.351 infections in two people with no link to each other or South Africa. The US sequences a smaller proportion of viral samples than the UK, so even more cases could be going undetected there.

Local transmission has also been reported in Belgium, Austria and Israel, and in several countries in Africa including Zambia, Mozambique, Botswana and Tanzania. Additionally, countries including Australia, New Zealand, China and Japan have detected cases linked to travel, but haven't reported local spread.

With many countries doing little or no sequencing, it is likely that the B.1.351 variant is more widespread than this. According to Björn Meyer at the Pasteur Institute in France, when the city of Cologne in Germany increased sequencing, it found that 5 per cent of coronavirus infections were due to the B.1.351 variant, revealing that the virus was already well established.

There is also concern about the P.1 variant found in Brazil, which has some of the same mutations as the B.1.351 variant, including E484K. So far, though, no local transmission of P.1. has been reported outside South America. ■

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

New variants

How to tweak the vaccines

It is now clear that the virus is evolving to evade the protection from vaccines and natural immunity. Here's what needs to be done, says **Michael Le Page**

IT IS looking likely that covid-19 vaccines will have to be updated in the coming months to remain effective against new variants of the coronavirus. Several vaccine manufacturers have confirmed that they are already working on new versions of their vaccines to make sure they remain effective. But what does updating the vaccines involve and how long will it take?

At least two vaccines are less effective against the B.1.351 variant of coronavirus that was first identified in South Africa.

Interim results from UK trials of a vaccine developed by the US firm Novavax show that it was almost

"It's almost sure going forward that we will need additional boosters with different strains"

90 per effective at preventing symptomatic infections in people in the UK (see "Next-generation vaccines that are nearing approval", page 10), but just 60 per cent effective in South Africa.

"That will largely be a reflection of the South African variant," says Paul Heath at St George's, University of London, a lead researcher on the Novavax trial. But 60 per cent is still really good, he says. "This is still an effective vaccine with the South African variant."

Results from trials of the one-dose vaccine from Johnson & Johnson show a smaller difference. This was 72 per cent effective at preventing moderate or severe covid-19 in the US, 66 per cent effective in Latin America and 57 per cent in South Africa. However, it was still 100 per cent effective at preventing hospitalisations and deaths, starting 28 days after vaccination, in all these areas.

As the P.1 variant first seen in Brazil has similar mutations,

the vaccines are likely to be less effective against this version too.

The Novavax results do show slightly less efficacy against the variant first identified in the UK, called B.1.1.7, with just 85 per cent efficacy compared with 95 per cent efficacy against older variants. However, Heath doesn't think this is significant. "The vaccine efficacy is pretty much the same," he says. "This is also really good news."

The bad news is that it is clear that the South African and Brazilian variants are evolving to evade the immune response sparked by older variants. It is likely that all the vaccines based on spike proteins, the part of the virus that gains entry into cells, will be less effective against these two variants. This would include the vaccines developed by Pfizer and BioNTech, the University of Oxford and AstraZeneca, and Moderna, plus many of the newer vaccines in development.

The real worry is that variants that are even better at evading the immune response will evolve, meaning that the vaccines will have to be updated. "It's almost sure going forward that we will need additional boosters with different strains," says Paul Stoffels of Johnson & Johnson.

Not everyone agrees. "I think for the vast majority of the population, the vaccines around now are going to do just fine," says Jeremy Kamil at Louisiana State University. But Kamil still thinks we should be preparing just in case.

Either way, here is what needs to be done.

Slow the evolution of potentially dangerous variants

It is possible to reduce the opportunity for the coronavirus to evolve to be better at evading



JAMES MACDONALD/BLOOMBERG VIA GETTY IMAGES

vaccines by reducing the number of people getting infected.

"Every time someone is infected with the coronavirus, it's like buying the virus a lottery ticket," says Kamil. It is extremely unlikely for the virus to mutate in a way that helps it, but if hundreds of millions of people around the world are being infected, it will happen eventually.

"Because the pandemic has gone on so hugely unchecked by governments all over the world, with the exception of places like New Zealand, we've bought [the virus] a lot of lottery tickets," says Kamil. And as more people are vaccinated or gain some natural immunity to the virus, any mutations

that help evade this immunity provide a strong advantage for the virus.

Fortunately, we now have vaccines to help get case numbers down. "The best way to decrease the risk of more new variants is to as quickly as possible immunise the majority of the population in the world," says Moncef Slaoui, former chief scientific advisor to the US vaccine effort, Operation Warp Speed.

This is another reason why it is so important that high-income countries help poorer ones vaccinate their populations rather than hogging supplies (see page 12) and leaving large pockets of the world unvaccinated (see page 21).



Health Check newsletter

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A researcher in the lab that developed part of the Pfizer/BioNTech vaccine

100%

Efficacy of Johnson & Johnson vaccine at preventing deaths in Latin America, South Africa and the US

85%

Efficacy of Novavax vaccine against the UK variant of the virus

Increase surveillance so we can spot dangerous new variants as soon as possible

"It's really important that we get the surveillance system globally up to speed," says Saul Faust at the University of Southampton, UK, who co-led the UK Novavax trial. The sooner we spot potentially dangerous new variants, the more time we have to prepare and the more that can be done to stop them spreading around the world.

This means doing much more sequencing of viral samples, as this is the only reliable way to identify variants. "We only know what we sequence," says Sharon Peacock, who leads the UK sequencing consortium, COG-UK. The UK has been sequencing

nearly one in 20 viral samples, a higher proportion than other countries. Some do little if any sequencing. "Many countries would not know if they had particular variants," says Peacock.

Even some high-income countries, such as the US, have been doing less sequencing, relatively, than others. "The US has really done an embarrassing job. We are behind countries like Gambia and Bangladesh," says Kamil.

Even with better surveillance it will still be hard to detect whether new variants are dangerous. In the UK, it only became clear that B.1.1.7 is more transmissible several months after it was first detected, by which time it had already

spread to many other countries. The problem is that new variants are emerging all the time and some spread faster than others by chance.

The UK has now set up an initiative called G2P-UK to coordinate efforts to study new variants, but detecting dangerous ones remains a major challenge. Despite all the focus on the UK variant, for instance, it still isn't clear why it is more transmissible and probably deadlier.

Work out what part of the vaccine to tweak

We know a mutation called E484K plays a big part in helping the South African and Brazilian variants evade antibodies to older forms of the spike protein, so this will certainly be included in any update. But there are many other mutations that could potentially be included.

"The important question is going to be selecting which variant will provide enough spectrum of protection against the new variants yet to come," says Slaoui.

The ideal strategy would be to anticipate what mutations might come next, and block these from gaining a foothold. In other words, to vaccinate people against dangerous variants that don't yet exist in the wild. One way to do this is to let the virus evolve in

"The important question is which variant will provide enough protection against new variants yet to come"

the lab in the presence of antibodies from people who have been vaccinated.

An updated vaccine could be given in the form of a second booster shot – a third dose – containing a single different

variant to existing vaccines. Alternatively, two or more variants could be combined in a single shot. It is already routine for flu shots to protect against three or four different flu viruses.

Explore broader vaccines that may make it harder for resistance to evolve

In Western countries, all the main vaccines that have been approved or are likely to be approved soon are based on the outer spike protein of the coronavirus. From the start, some immunologists pointed out that the spike protein was likely to mutate in ways that will reduce vaccine efficacy. They suggested that vaccines should be based on, or include, other coronavirus proteins that are less able to change.

Heath thinks that trial results justify the spike-protein approach. "They work," he says. "The focus on the spike was the right thing to do."

Others, including Matti Sällberg at the Karolinska Institute in Sweden, are exploring the possibility of creating boosters that contain other proteins. "We hope for a phase I trial in the spring," says Sällberg.

Some countries, including China and India, have developed vaccines based on the entire virus – so-called inactivated or live attenuated vaccines. These include more viral proteins and it is possible they will provide better protection against new variants, says Heath. However, some live vaccines aren't always suitable for all individuals, such as those who are pregnant (see page 13).

It is also possible that mixing existing spike-protein vaccines will provide broader protection, says Heath. Animal studies suggest that giving two doses of different vaccines will be more ➤

effective than two doses of the same one. A trial will shortly get under way in the UK in which participants will receive a shot of each of the Pfizer/BioNTech and Oxford/AstraZeneca vaccines, instead of two doses of the same vaccine. This approach could be extended to other vaccines as well.

Manufacture updated vaccines

It is likely that all vaccine makers are preparing in case they need to update their vaccines, though not all have confirmed this publicly. Johnson & Johnson, for instance, is working on an updated vaccine,

"Getting approval for updated vaccines could potentially be a major delay"

says Stoffels, even before its first vaccine is approved. "We don't know if it will be needed," he says.

The mRNA vaccines made by Pfizer/BioNTech and Moderna can

be updated the quickest. Once it has been decided which version of the spike protein to use, it is likely to take over a month before the first vials are ready, says Zoltán Kis at Imperial College London.

It only takes a couple of hours to manufacture each batch of mRNA, as unlike other vaccines no living cells are involved in the process. However, the mRNA is made from DNA templates that can take up to two weeks to create.

Once you have mRNA, it has to be purified, slowly mixed with lipids to encase them in fatty bubbles and finally put in vials.

Purification and mixing each take around a day, and filling the vials can be a bit longer depending on the size of a batch. These steps are sometimes done at different facilities as well, adding transport delays.

But it is the safety checks done along the way that take the most time, says Kis, adding up to as much as three weeks. "The overall time really depends on quality control," he says.



People may need a combination of vaccines for maximum protection

For other vaccine types, updates would take longer. The Oxford/AstraZeneca vaccine, for instance, consists of non-replicating adenoviruses grown in modified human embryonic kidney cells. It takes two months to grow each batch of cells. Purifying the vaccine, filling vials and quality control takes another month or so.

For an updated vaccine, a new

seed virus would have to be produced, which could take weeks. However, once the seed virus is ready, it can be added to existing batches of cells.

Work out how to rapidly approve updated vaccines

Getting approval for updated vaccines could potentially be a big delay. None of the major regulatory agencies has yet decided what the process will be.

However, both the European Medicines Agency (EMA) and the US Food and Drug Administration told *New Scientist* that seasonal flu vaccines could provide a precedent.

"Discussion is already ongoing with respect to what could be the regulatory requirements to support a change in the composition of the vaccine if needed," says a spokesperson for the EMA. "The seasonal flu would be a precedent to look at, but there will be a need to determine if any additional clinical data would be needed as well."

Once a particular type of flu vaccine has been shown to be safe and effective in human trials, that vaccine can be updated yearly with little or no additional human testing. "For seasonal flu you don't need to conduct a clinical trial because we know the types of immune responses that are likely to be effective," says Angela Rasmussen at Georgetown University in Washington DC.

Unfortunately, it still isn't clear which aspects of the immune response – called the correlates of protection – guarantee protection against the coronavirus, which could complicate approval of updated vaccines.

"The lack of really well-defined correlates of protection are throwing a wrench into the works," says Rasmussen. ■

Next-generation vaccines that are nearing approval

JOHNSON & JOHNSON

This vaccine is unique in that it has been trialled as a single shot. It can also be stored in a normal fridge.

It works by using a common cold virus to transport the genetic code for the covid-19 spike protein – which the virus uses to enter cells – into cells that then produce the spike protein themselves, triggering an immune response.

Interim results show it is 66 per cent effective overall in preventing moderate to severe covid-19.

The vaccine offered complete

protection against covid-19-related hospitalisation and death, starting 28 days after vaccination.

Its efficacy rate in a trial in the US, at 72 per cent, is lower than the 95 per cent efficacy boasted by the Pfizer/BioNTech and Moderna vaccines already approved for use in the country.

It is likely to be the next vaccine assessed by UK regulators.

NOVAVAX

Developed in the US, interim results show this vaccine was 90 per cent effective at preventing symptomatic

infections in a trial involving people in the UK.

It consists of spike proteins from the coronavirus, along with an adjuvant to boost the immune response. The spike proteins cannot replicate or cause covid-19, but they enable the body's immune system to recognise the virus.

The vaccine is given as two doses and is stable for up to three months in a normal fridge.

The UK has secured 60 million doses of the vaccine, which should be available in the second half of this year if it is approved by regulators.

How well do vaccines stop people catching and spreading coronavirus?

Graham Lawton

PEOPLE who have been vaccinated against covid-19 can still catch and transmit the virus, but are less likely to do so than unvaccinated people, the latest results suggest.

The question of whether vaccines halt transmission is one of the biggest and most important unknowns of the pandemic. If they do, vaccine-induced herd immunity may be possible. If they don't, the virus will still be able to circulate even in a fully vaccinated population and will continue to pose a deadly threat to people who haven't been vaccinated (see page 13) or who don't mount an immune response after receiving a vaccine. Circulating virus could also mutate and escape our defences, reigniting the pandemic.

The latest news is mixed. "There have been several bits of data just in the last couple of weeks that suggest that vaccines do not block transmission but are very likely to significantly reduce transmission," immunologist Eleanor Riley at the University of Edinburgh, UK, said on a Royal Society of Medicine webinar last week.

One bit of data is from a phase III clinical trial by vaccine manufacturer Moderna. It found that people given the vaccine were a third as likely to test positive for the virus when they returned for their second jab as people who got a placebo. In other words, the first dose cuts infection rates and hence transmission by about 66 per cent. The second shot was given 28 days after the first and its effect on transmission is still unknown, because the trial generally monitored people after their second shot only if they felt ill, not if they were asymptotically infected.

AstraZeneca and the University of Oxford have reported some similar figures from one of their clinical trials. Volunteers who

OLI SCARFF/GETTY IMAGES



Social distancing will continue to be important

66%
Decrease in transmission rates after a dose of Moderna's vaccine

1/3
Reduction in asymptomatic infections in people over 60, two weeks after a Pfizer/BioNTech vaccine dose

4%
Reduction in asymptomatic infections after two full doses of the Oxford/AstraZeneca vaccine

received the half dose/full dose regime – which was discovered by accident – were 60 per cent less likely to have an asymptomatic infection than people who got a placebo. However, people given the full doses were just 4 per cent less likely to get such infection than people who received a placebo.

A study in China found that infected people without symptoms are much less likely than those with symptoms to transmit the virus to others in their household, which suggests that even if vaccines don't prevent asymptomatic infections, they can still cut the transmission rate considerably.

Finally, a study by the Clalit Research Institute in Israel found that the vaccine developed by Pfizer and BioNTech reduced asymptomatic infections in people over 60 by about a third. The effect didn't kick in until 14 days after the first dose.

Taken together, these results strongly suggest that vaccines can

significantly, but not entirely, halt the spread of the virus, says Riley.

"There are no data per se on infectiousness of vaccine recipients – the link is indirect," she says. "Both symptomatic and asymptomatic infection

"Even those who have been vaccinated must wear masks in public and observe social distancing"

are less likely after vaccination and asymptomatic people less likely to transmit."

This means that we will have to continue measures such as social distancing to slow transmission until everybody has been fully vaccinated. The Clalit Research Institute warned that its results "clearly indicate that there is no complete protection against corona infection... Therefore, even those who have been vaccinated must wear masks in public space and observe the rules of social distance." ■

Vaccines

Global vaccine inequality

Mass immunisation may not happen until 2024, if at all, in places

Adam Vaughan

TO UNDERSTAND how unequally covid-19 vaccines are being rolled out around the world, look to Guinea. The World Health Organization says the West African state had administered just 25 doses as of 18 January. By comparison, 4.72 million had been given in the UK alone.

The reality is that while the EU negotiates vaccine deliveries with AstraZeneca and the US government weighs up how many millions of people should be vaccinated daily, many middle-income countries have only just begun roll-outs. Most low-income ones will take months to get started.

For Kate Elder at the non-profit organisation Médecins Sans Frontières, the day UK resident Margaret Keenan became the first person in the world to be vaccinated, in December, was the day countries failed to deliver on earlier promises of vaccine equity.

“Delivering equity means vaccines are available in low-income countries at the same time as high-income countries,” she says.

India, Mexico, Indonesia, Argentina and other lower-middle and upper-middle-income countries have begun immunisation programmes by buying a supply of vaccines. Some middle-income countries have “been supported with the Chinese or Russian vaccines”, says Elizabeth Mason at the UN-appointed Independent Accountability Panel.

However, most low-income countries cannot afford to buy vaccines. “The state of play is devastating because there is no state of play,” says Elder. Those countries are waiting on COVAX, a scheme backed by the World Health Organization (WHO) that aims to vaccinate 20 per



CELLOU BINANI/AFP VIA GETTY IMAGES

People disinfecting streets and shops in Guinea

delays to COVAX. We think the commitments will be very difficult to meet,” says Agathe Demarais at the Economist Intelligence Unit, a UK-based research group. Of the 2 billion doses Pfizer said it would make for the world this year, only 40 million have been agreed for COVAX. Despite raising more than \$2 billion, COVAX is “obviously not very attractive to pharmaceutical corporations”, says Elder. Mason is more optimistic, and says COVAX is “moving at a good speed”.

It isn’t the only effort. An African Union-led initiative recently secured agreements for 270 million vaccine doses from a variety of manufacturers. However, Richard Mihigo at the WHO told a press conference on 28 January: “We knew very well some of these doses may not

become available soon.”

Mihigo said many African countries will need different types of vaccines to successfully vaccinate beyond capital cities. Capitals will have storage that can keep Pfizer/BioNTech’s vaccine at -70°C, for example, while more remote areas may need vaccines that don’t need to be stored at such temperatures, such as

25

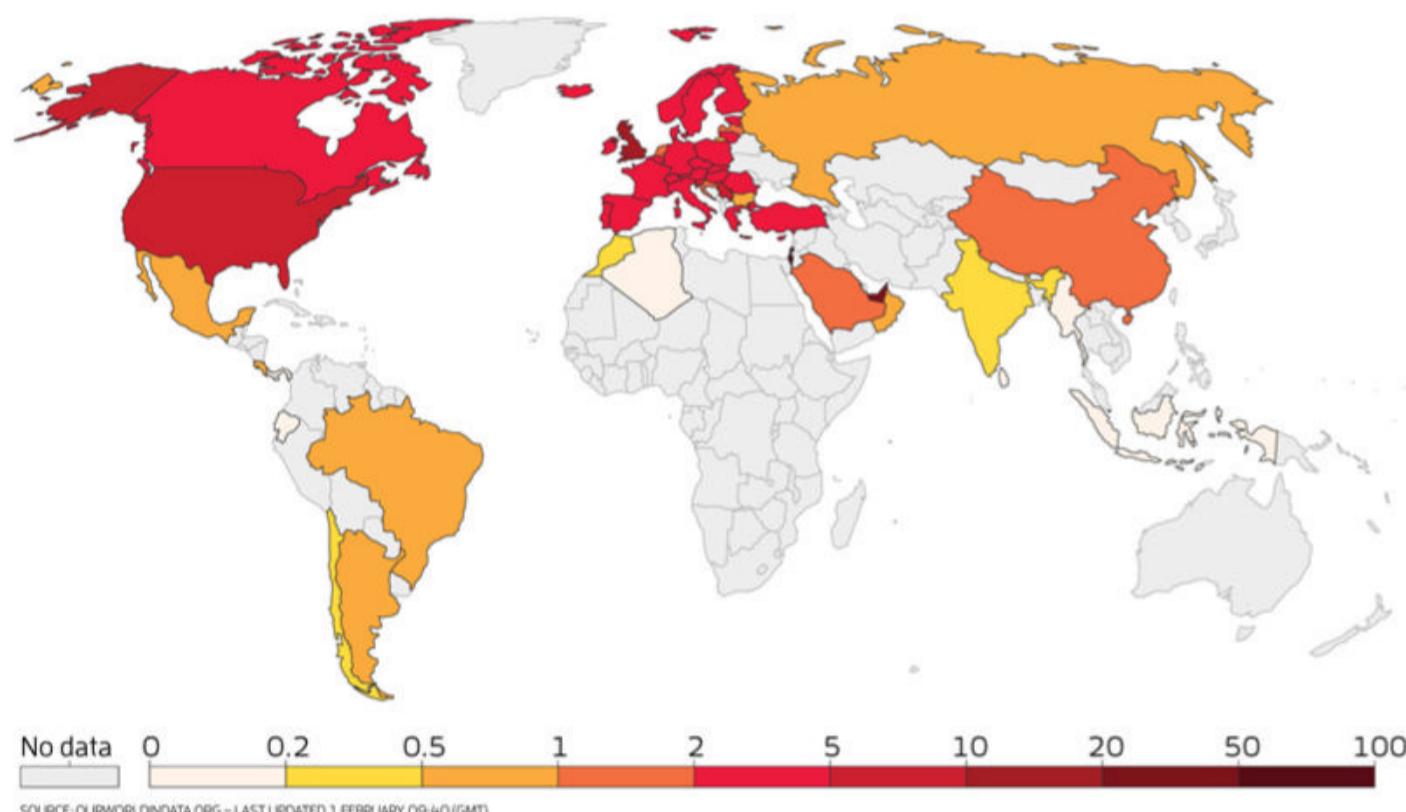
Doses of coronavirus vaccine given in Guinea as of 18 January

Oxford/AstraZeneca’s, although that still requires two doses. The single-dose vaccine from US firm Johnson & Johnson will be “very interesting” for logistical reasons in Africa, Mihigo said. On 29 January, the firm announced that its vaccine was 66 per cent effective in clinical trials.

Overall, due to difficulties with

How many covid-19 vaccines have been given out?

This map shows the number of individual vaccine doses administered per 100 people in a country’s total population. This may not equal the total number of people vaccinated as some vaccines require multiple doses



Analysis Safety guidance

Should you get a covid-19 vaccine if you are pregnant or breastfeeding? With little data available, women will have to weigh up the risks and benefits themselves, says Clare Wilson

vaccine supply, challenges in some countries around transporting and storing vaccines, and a lack of healthcare workers, mass immunisation of populations in some low-income countries may not happen until 2024, “if at all”, according to a report by Demarais on 27 January. The same milestone is expected in mid-2022 for high-income countries.

The first and most obvious consequence of slow and patchy immunisation in low-income countries is more cases and deaths that could be avoided, says Mason.

The second is the economic ramifications. “It will delay the global economic recovery. We’ll have a situation where richer countries are vaccinated, but the poorer are not, so they will have to resort to local lockdowns,” says Demarais. The International Chamber of Commerce estimates such a failure would cost the global economy \$9.2 trillion.

The third problem is that “no one is safe until everyone is safe”, a point made by WHO director general Tedros Adhanom Ghebreyesus and some world leaders. Having the virus circulating in populations for longer increases the risk of mutations leading to variants that are more transmissible, such as the so-called Brazil, South Africa and UK variants. That may render vaccines less effective in future, which would be an issue for vaccinated populations in affluent countries as well as poorer ones.

“It’s the nature of viruses to mutate. We hope vaccines keep ahead of the mutations – and that means making sure the lower and middle-income countries are vaccinated as well,” says Mason. As she points out, even with many flights grounded, there is still “a huge movement of people across the globe”. ■



JACK GUEZ/AFP VIA GETTY IMAGES

AS GLOBAL vaccination against covid-19 ramps up, women who are pregnant, breastfeeding or trying to conceive have been left uncertain as to whether they should join in.

Advice has been slow to develop, and is often contradictory. Initially, the UK’s Joint Committee on Vaccination and Immunisation said people shouldn’t get a coronavirus vaccination if they were pregnant or planning to conceive in the next three months. But the committee now says pregnant women who are likely to be exposed to the coronavirus because they work in healthcare, for instance, may wish to consider getting vaccinated after discussing it with a healthcare professional. It also says there is no need to delay conception or avoid breastfeeding.

The World Health Organization and the US Centers for Disease Control and Prevention have similar advice. Israel, in contrast, has placed pregnant women on its priority list for vaccination, after several pregnant women were hospitalised with covid-19.

Israel’s health ministry advises those who are pregnant to wait

until their second trimester to get a vaccine unless they have other risk factors. “This would seem a reasonable approach if vaccination during pregnancy is indicated,” says Adam Balen at Leeds Fertility in the UK. “The very early developing embryo is undergoing dramatic changes even before a pregnancy test is positive.”

It isn’t clear how pregnancy affects covid-19 risk. There is no evidence that pregnant women are more likely to get severely ill, but they are classed as being

“From basic principles, there is no reason to think the vaccine would be unsafe in pregnancy”

at moderate risk because they can get more sick from viruses like flu, according to National Health Service advice in England.

It may be possible for pregnant women to pass the coronavirus to a baby before it is born, but when this has happened, the baby has recovered. There is no evidence that the coronavirus causes miscarriage or affects a fetus’s development.

A pregnant woman receives a covid-19 shot in Tel Aviv, Israel

When it comes to weighing up vaccination options, those who are pregnant have little safety data to go on. All the trials completed so far aimed to exclude pregnant women, as is standard in medical research. However, in the trial of the vaccine created by Pfizer and its partner BioNTech, 23 women discovered they were pregnant after getting the vaccine and no problems have been reported.

Trials in pregnant women are usually carried out after a few years of data have accrued from women who take a new medicine without realising they are pregnant. But in the case of covid-19, “we don’t want to wait because it can be such a serious illness”, says Pat O’Brien, vice-president at the UK’s Royal College of Obstetricians and Gynaecologists.

From basic principles, there is no reason to think a covid-19 vaccine would be unsafe for pregnant women, says O’Brien. While vaccines based on live viruses are avoided in case they infect the fetus and cause harm, none of the available covid-19 vaccines are based on live virus that can reproduce. Pregnant women are offered other non-live vaccines, such as those against flu.

More information will emerge this year. Pfizer is starting a vaccine trial in pregnant women, and there are plans to create registries of people who receive the covid-19 vaccine while pregnant.

In the meantime, healthcare providers need to help people weigh up the risks and benefits, says O’Brien. “It’s an individual’s decision, with support from a professional. It might sound like a cop-out, but that happens all the time in maternity care.” ■

Africa leads HIV prevention effort

Half the people taking PrEP to reduce risk of HIV infection are in African nations

Paul Adepoju

NEARLY 1 million people are now taking pre-exposure prophylaxis (PrEP), drugs that can slash the risk of HIV infection. While early use was mostly limited to Western nations, the number of users in sub-Saharan Africa (SSA) has greatly risen, now accounting for more than half of global users.

Kate Segal at AVAC, a New York-based non-profit organisation focused on global HIV prevention, presented the latest data on PrEP use at the virtual HIV Research for Prevention Conference on 26 January. She said there had been a major expansion of PrEP users in 2020, with a rise of more than 300,000 from the previous year. In SSA, expanded access saw new users jump from 4154 in 2016 to more than 517,000 in 2020, or 56 per cent of the global total.

Out of the 10 countries with the highest number of PrEP users, seven are in SSA. South Africa surpassed 100,000 users as of December 2020, while Kenya has about 83,000, followed closely by Zambia and Uganda.

Segal attributed the trend to investments from the US

President's Emergency Plan For AIDS Relief, a major funder of HIV programmes across SSA, along with commitments by many governments in the region to offer wide access to PrEP.

"In South Africa and Kenya, credit policies [to fund access], and guidelines were adopted, ambitious targets were set and sufficient resources were allocated by national governments to meet

Pre-exposure prophylaxis can drastically cut the risk of HIV infections

them," Segal told *New Scientist*.

She says that SSA countries have ensured the drugs are available to the general population, as well as groups at greater risk of infection, such as men who have sex with men and sex workers. This contrasts with the approach in countries such as the UK, which has long resisted providing general access to PrEP.

Segal says access can be further expanded in SSA, such as by making PrEP available at local pharmacies and informing the public about the drug. "Many of

the general population still don't know that PrEP exists or what it is or how to access it. So we really need to normalise it and increase demand," she says.

John Nkengasong at the Africa Centres for Disease Control and Prevention says the coronavirus pandemic may hamper these efforts. "Covid-19 has impacted all our health programmes, not just HIV," he says.

But in Nigeria, where PrEP users grew from 76 in 2016 to nearly 32,000 in 2020, there is optimism that the decision to centrally coordinate HIV programmes will further expand access to PrEP.

Ifeanyi Nsofor, CEO of Nigerian public health consultancy EpiAfric, says that with HIV prevalence significantly falling in Africa, efforts are now turning to prevention measures such as PrEP, especially among young people.

"Focus should be on prevention and scaling up youth-friendly health facilities and deploying technology to provide information on PrEP and other issues to adolescents via mobile phones and social media," he says. ■



DANIEL BORN/THE TIMES/GALLO IMAGES/GETTY IMAGES

Technology

AI can predict the emotions a painting will evoke in us

MONET'S paintings of gardens can make a viewer feel content, while Dalí's surreal melting clocks elicit fear or confusion. Now, an AI art critic can predict the emotions that famous paintings will evoke and can sometimes explain them as convincingly as a human.

AI image analysis often focuses on describing what is going on in pictures, but the subjective feelings that works of art arouse have just as

big an effect on human behaviour, says Panos Achlioptas at Stanford University in California.

Being able to predict and emulate these responses could help machines interact with us more seamlessly, says Achlioptas, so his team built a large data set of human reactions to art using online surveys.

They asked more than 6000 participants to choose the dominant emotion elicited by 81,000 paintings in the ArtEmis data set and write a caption describing what it was about the artwork that guided their decision. Each painting

was analysed by at least five people. The images, emotion labels and captions were used to train an AI, which was then challenged to predict what emotion paintings it hadn't seen before would evoke and provide short explanations.

Judging its output is inherently difficult, says Achlioptas, because there is no right answer. A majority of annotators agreed on the dominant emotion in just 45 per

"Judging the AI's output is inherently difficult because there is no right emotional response to an artwork"

cent of the ArtEmis paintings.

So the researchers carried out a form of Turing Test by showing people a painting alongside a caption from the AI and one from an annotator, and asking them to guess which was written by a person. The AI's captions passed as human 50 per cent of the time (arxiv.org/abs/2101.07396).

Achlioptas admits that the AI's captions aren't as diverse or creative as human ones, but says the early results are promising and the data has been made open source so others can improve on the models. ■

Edd Gent

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Pregnancy

Placenta is full of mutated cells dumped by embryo

Claire Ainsworth

THE human placenta is riddled with cancer-like patterns of mutations. But the discovery is better news than it might appear: it is helping scientists open a new window on the mysterious world of early human development.

In some ways, the placenta is a forgotten organ. It begins to form shortly after fertilisation from the embryo's cells and then helps to support the future fetus as it develops before being discarded at birth.

But it is difficult to study how embryos "decide" which cells are destined for the placenta and which for the fetus.

"So far, we've been blind to the first split," says Tim Coorens at the Wellcome Sanger Institute near Cambridge, UK.

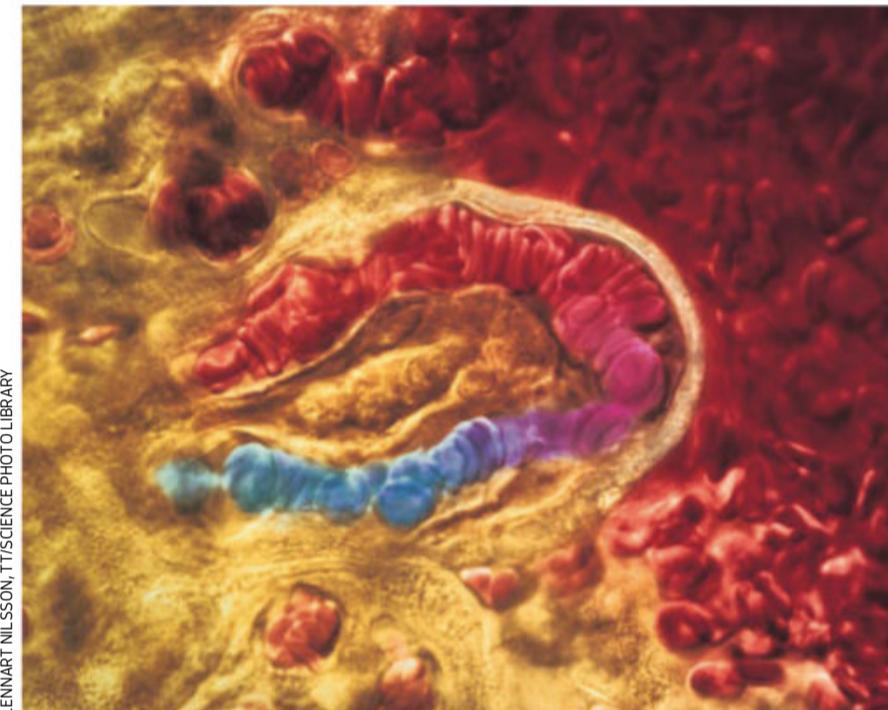
Coorens and his colleagues, including his PhD supervisor Sam Behjati, decided to retrace the lineages of cells in full-term placentas to see where they came from.

Their approach relies on the fact that cells naturally accumulate mutations in their DNA and then pass these on when they divide. By comparing patterns of mutations between samples, it is possible to trace cells' family trees back in time.

The team studied 42 human placentas, taking several small biopsies from each and sequencing the whole genomes of the cells within them.

A key discovery was just how mutated placental tissue can be. Some body cells, such as certain cells lining the colon, are known to have a naturally high rate of mutation, but the placental cells had about five times as many mutations to a single DNA "letter" as even these cells.

The placental tissue also had large numbers of changes



LENNART NILSSON/T/SCIENCE PHOTO LIBRARY

involving the addition or loss of chunks of DNA – a form of mutation that is vanishingly rare in most human tissues, but common in certain childhood cancers.

Why such a vital organ should be so cavalier about its genome remains unclear. Its disposability might provide a clue: as it only "lives" for nine months, it doesn't need to

"The human placenta had five times as many mutations to single DNA 'letters' as other tissues"

invest precious resources into repairing itself, says Coorens.

The placenta may even benefit the embryo by acting as a sort of dumping ground for potentially problematic cells.

By comparing placental samples with samples of umbilical cord, which grows from future fetal cells, Coorens and his colleagues found that a cell's "decision" to join the placental or fetal lineages happens at the earliest stages of development, even as soon

A magnified image showing blood flow in a human placenta

as the first division that turns a fertilised egg into two cells.

The team found evidence in favour of this idea in one of the placentas. It contained cells with three copies of chromosome 10, but the associated umbilical cord had the usual two.

Cell family tree tracing showed that the cells with three copies of the chromosome were directed towards the placenta during some of the first cell divisions following fertilisation (bioRxiv, doi.org/ghv9sk).

The work adds to evidence that mammalian embryos push their cells towards particular destinies at a much earlier stage of development than previously thought, says Magdalena Zernicka-Goetz at the California Institute of Technology, whose research in mice first suggested this idea.

"It is incredible for me to see that the same now is found to be the case in the human embryo," she says. ■

Robotics

Soft-skin robot can tell a hug from a poke or punch

Matthew Sparkes

SOFT robots with translucent "skin" can detect human touch and differentiate a prod, a stroke or a hug. The technology could lead to better non-verbal communication between people and robots.

Guy Hoffman and his team at Cornell University in Ithaca, New York, made a prototype robot with a nylon skin stretched over a 1.2-metre tall cylindrical scaffold atop a platform on wheels. Inside sits a commercial USB camera, which can interpret different types of touch on the nylon.

The team built a database from camera images of people making one of six interactions with the skin of the robot, such as a point, a punch or a palm touch. These were used to train a neural network, a type of AI, that let the robot detect and identify interactions with an accuracy of up to 92 per cent (*Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, doi.org/fsf9).

The researchers assigned simple commands to various touches. They could poke it to make it turn around, pat it on the back to order it from the room or even stroke it forwards or backwards to make it roll in that direction. The hug wasn't assigned a command, but shows the robot can identify touch all over its skin.

The system uses the shadow that is made on the skin to work out what type of touch a person is making, so it had a hard time identifying a hug at night. It also confused a punch with a poke during daylight.

The team used a projector to display a touchscreen interface on the robot's skin. Incorporating touch sensitivity in robots currently requires heavy and expensive sensors and electronics. The new approach is low-tech and low-cost. It means soft robots, which offer safety benefits and can fit into tight spaces, can detect touch without rigid electronics on their surfaces. ■

Brain simulation on the cheap

Video game graphics cards could be used for low-cost digital models of brains

Matthew Sparkes

A SIMULATION that runs faster on a commercial graphics card than on some supercomputers could drastically cut the cost of studying how our brains work.

Researchers have long used digital models to better understand our brains in the hope of developing cures for diseases such as Alzheimer's or Parkinson's, but simulating the number of neurons and synapses in even the simplest creature can be a struggle for supercomputers.

Before running a simulation of the brain's neurons and vast number of synaptic connections, the model must be transferred into the computer's working memory, complete with the starting state of every synapse. As the simulation progresses, the computer must keep referring to this set of data to retrieve or update the state of each synaptic connection, which acts as a

bottleneck on calculations.

Commercial graphics cards, known as GPUs, are designed to render 3D scenes by rapidly carrying out many arithmetic calculations in parallel, an ability that also makes them particularly speedy at other tasks, including simulating synaptic connections.

James Knight at the University of Sussex, UK, and his colleagues created a simulation that uses a random number generator as part of the process of creating a synaptic state. Although this random element means the simulation can't refer to the exact starting state of the model each time it needs to create a new connection, the team found it produced results comparable to conventional simulations. It also makes things faster, as the computer only needs to handle data about the synapses that it is currently modelling.

The team used an existing model of a macaque monkey's visual cortex, consisting of more than 4 million neurons, as a benchmark. In 2018, 1 second of brain activity inside the model was simulated on an IBM Blue Gene/Q supercomputer in 12 minutes. Using a commercially available graphics card, Knight's

8

Minutes to simulate 1 second of a monkey's visual cortex

team was able to carry out the task in just under 8 minutes (*Nature Computational Science*, DOI: 10.1038/s43588-020-00022-7).

A newer JURECA supercomputer has been able to run the same simulation in just 31 seconds, but these can cost tens of millions of pounds and require a team of staff to maintain. By contrast,

Knight says the Nvidia Titan RTX hardware used in his tests costs just a few thousand pounds.

"This potentially means that researchers whose primary focus isn't dealing with supercomputers could explore things with this model," he says.

But there is a flaw. When we learn, our brains are constantly weakening or strengthening the connections between synapses, an ability known as synaptic plasticity. The GPU simulation can't do this, because it always has to recalculate the connections from scratch, reverting back to the model's original state.

Knight believes a hybrid approach using his new technique and a traditional model where the state of synapses is stored in memory and can be updated would allow plasticity where needed and high speed where it isn't, but the team has yet to try this. ■

Marine life

New whale species found hiding in plain sight

A SMALL group of whales living in the Gulf of Mexico belong to a new species that went unacknowledged until now. As there are fewer than 100 of them, they are immediately an endangered species. The new species is a type of baleen whale, which filter food out of the water.

Scientists already recognised a species called Bryde's whale (*Balaenoptera edeni*), which lives in and around the tropics. It isn't clear if they are actually all one species, or several, so they are often called Bryde's-like whales.

There are still thought to be two subspecies, says Patricia Rosel at the National Oceanic



and Atmospheric Administration's Southeast Fisheries Science Center in Louisiana. Since 2003, some other Bryde's-like whales from the Indian Ocean have been recognised as a species called Omura's whale.

Rosel and her colleagues study Bryde's-like whales in the Gulf of

Mexico. "We kind of knew, starting in the 1990s, that there was this resident small population," she says.

In 2014, the researchers published an analysis of tissue samples, which showed that the whales were genetically distinct from other Bryde's-like whales.

The new species of whale has been named *Balaenoptera ricei*.

"But we didn't have a skull", which is crucial for identifying a new whale species, she says.

In January 2019, the researchers obtained a skull following a whale stranding in Florida. It was distinct from those of other Bryde's-like whales. Along with further genetic evidence, they say this is enough to establish the Gulf of Mexico whales as a new species (*Marine Mammal Science*, doi.org/fsf6).

They have named the species *Balaenoptera ricei*. Little is known about its behaviour, says Rosel, although there are hints that it dives deep to feed, unlike other Bryde's-like whales. ■

Michael Marshall

Environment

Russian mystery solved by unusual avalanche

Krista Charles

IN 1959, nine Russians died on a skiing expedition in the Ural mountains, in what is now called the Dyatlov Pass incident. No one is quite sure what happened. A criminal investigation at the time concluded that the party died following an unidentified “compelling natural force”.

Numerous theories have been put forward, but none have been convincing. Now, Johan Gaume at the WSL Institute for Snow and Avalanche Research in Davos and Alexander Puzrin at the Institute for Geotechnical Engineering in Zurich, both in Switzerland, have found a way to restore a previously rejected theory that an avalanche was to blame (*Communications Earth & Environment*, doi.org/fsh5).

“This is a very nice example of how one can apply science to solve some problems that can be shrouded in mystery and where lots of [conspiracy] theories can arise,” says Dieter Issler at the Norwegian Geotechnical Institute in Oslo.

The facts established by the

The expedition was photographed with another group of hikers before the incident

initial investigation, from journals and other items, are as follows. On 1 February 1959, the skiers set up camp on the slope of the mountain Kholat Syakhl. After midnight, they cut their way out of their tent and moved towards the forest more than a kilometre downslope.

That night the temperature was below -25°C, yet some of the party were found almost naked and barefoot. The main cause of death was hypothermia, but four hikers had severe thorax

“This is a nice example of how one can apply science to solve problems shrouded in mystery”

or skull injuries and two were found with missing eyes and one missing a tongue.

An investigation was reopened in 2015 and in 2019 the Investigative Committee of the Russian Federation concluded that a snow avalanche was to blame. This hypothesis wasn’t new, but had been previously questioned by the public and rejected by relatives. There were four counterarguments against it.

The first two points were that

the slope’s angle wasn’t enough for an avalanche and there were no traces of one afterwards. The unique local topography can explain this, says Puzrin. While the snow appeared to be at an angle of 23 degrees, the ground underneath had several step-like curves that made the average angle closer to 28 degrees – enough to cause an avalanche, but one that wouldn’t leave typical traces.

The third argument was related to the possible trigger. “They cut the slope in order to put the tent, this we see on their last photograph,” says Purzin. This created an unstable snow slab upslope that would normally collapse straight away. Instead, it failed nine to 13 hours later, he says. This collapse requires an additional load of snow, but there was no snowfall that night. “Instead of the snow, we have a very strong wind,” says Puzrin, which would have pushed snow onto the slope.

The fourth counterargument was that the injuries sustained were more severe than those typical of avalanches. Gaume created a simulation and found that the force of the falling slab could have led to those injuries. “This was actually the same program used by Disney to simulate snow in the animation film *Frozen*,” says Puzrin.

Not everyone is convinced. “It doesn’t explain why these people, after being hit by an avalanche, ran off without their clothes on into the snow. If you’re in that type of harsh environment it’s suicide to leave shelter without your clothes on,” says Jim McElwaine at Durham University in the UK. “For people to do that they must have been terrified by something.” ■



Animals

Sharks’ scales may boost acceleration towards prey

Christa Lesté-Lasserre

TOOTH-like scales on the skin of sharks reduce drag as they manoeuvre through the ocean and are at their most effective when the predators accelerate.

Josephine Galipon at Keio University in Japan and her colleagues created synthetic sharkskin from 3D-printed moulds based on scanning electron microscope images of skin samples from Pacific spiny dogfish (*Squalus suckleyi*), a type of shark.

They then covered an aeroplane wing-shaped model with the skin and studied the fluid dynamics – specifically, the vortices, or water swirls, left in the model’s wake – as they moved it through water.

In some experiments, the researchers moved the model at a constant “cruising” speed, while in others they accelerated it at a rate within the shark’s natural range.

They found that the wake was thinnest, meaning that drag was reduced the most, when the object was accelerating.

The findings suggest that the skin helps improve a shark’s speed and manoeuvrability, important when chasing down prey or evading larger predators (*Bioinspiration & Biomimetics*, doi.org/fsc4).

The study might lay to rest a decades-old debate about how exactly the scales, known as denticles, reduce drag.

“Many researchers have tried to resolve this mystery, but they may not have considered that a shark is always oscillating and turning through acceleration,” says Galipon.

The study could also change how people manufacture and use synthetic sharkskin in aquatic sports equipment, especially in terms of better understanding its benefits.

“It’s possible that, for the moment, they are not used with the right purpose in mind,” says Galipon. “The benefit may be minimal at constant speeds.” ■



JACK DYKINGA/NATUREPL

Body language

Speaker's hands influence listeners

MAKING simple up and down hand movements while speaking may affect the way people hear what you are saying.

We often use meaningless movements, such as flicking or waving our hands, known as beat gestures when speaking face to face. These typically align with prominent words in speech.

“Politicians use these gestures all the time to get their message across,” says Hans Rutger Bosker at the Max Planck Institute for Psycholinguistics in Nijmegen in the Netherlands.

Bosker and his team tested how important these movements are in influencing sound recognition. They presented Dutch participants with video of Bosker saying Dutch words that have two meanings depending on which syllables are stressed. Bosker paired each word with a beat gesture either on the

first syllable or the second syllable.

The team found that participants were on average 20 per cent more likely to hear stress on a syllable if there was a beat gesture on it. Mismatched beat gestures also biased what they heard, with 40 per cent of participants hearing the wrong sound (*Proceedings of the Royal Society B*, doi.org/fsjx).

This could be a learned association, but there could be an evolutionary reason behind it, says Wim Pouw at Radboud University in Nijmegen, who wasn’t involved in the research.

Although only tested in Dutch, Bosker says similar effects may be seen in other similar languages such as English, and may even be present in all languages. “This effect could be generalised to much more than just Dutch, but this is highly speculative,” he says.

Bosker says that his research is even more important during the current coronavirus pandemic because of mask wearing. IS

Evolution

First flowers may have been early bloomers

FLOWERING plants may have evolved 250 million years ago, more than 100 million years earlier than the oldest known fossil flowers.

Today, flowering plants – or angiosperms – are the most diverse group of land plants. The oldest angiosperm fossils so far found date to 135 million years ago in the early Cretaceous. Many researchers think this is when the group arose. The fossil record suggests the group was diverse by 130 million years ago.

But how they became so diverse so fast has perplexed scientists. The fossil record and genetics offer conflicting evidence, with the latter pointing to a much older origin.

To create a more accurate timeline, Daniele Silvestro at the University of Fribourg, Switzerland, and his team analysed more than 15,000 fossils from around 200

different angiosperm families.

The result was strong evidence angiosperms may have arisen up to 250 million years ago, long before the Cretaceous. This is because if a number of related fossils all appear between 135 and 130 million years ago, they must have evolved from a much earlier common ancestor not in the fossil record (*Nature Ecology & Evolution*, doi.org/fsjk).

If the team’s estimate is right, angiosperms spent their first 100 million years on Earth as rare components of ecosystems that were unlikely to fossilise.

While Patrick Herendeen at the Chicago Botanic Gardens is sceptical of the findings, he says he wouldn’t be surprised if angiosperm fossils from before the Cretaceous are discovered in the future.

Ibrahim Sawal

Animal behaviour

Mole rat groups chirp in their own accent

COLONIES of naked mole rats develop dialects that may help them tell friends from foes.

These rodents (*Heterocephalus glaber*) are extremely vocal. To see whether their vocalisations help maintain their social structure, Alison Barker at the Max Delbrück Center for Molecular Medicine in Germany and her team recorded more than 36,000 greeting calls from 166 naked mole rats in

seven colonies raised in labs.

After identifying the acoustic features of these soft chirps, such as pitch, peak frequency and duration, the researchers used the calls to train a machine-learning algorithm.

Not only could the algorithm reliably recognise individuals within a colony, but the chirps’ features were also highly predictive of which colony an animal belonged to, akin to human accents or dialects. This suggests that individuals from each colony have unique voices while all sharing the same dialect.

In another test, naked mole rats responded far more frequently to recordings of their own dialect than to other dialects, suggesting they use call and response when identifying colony members.

Barker and her team also found that three abandoned pups placed with new colonies developed the dialect of their adoptive homes (*Science*, doi.org/fsjh). **Bethan Ackerley**



FELIX PETERMANN



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Really brief



DAVID FORSTER/ALAMY

Personality mix is best for bird health

Wild house sparrows have distinct "personalities". When housed in a cage, some might sit quietly while others try to escape. Researchers housed birds in small groups and found they were healthier when their personalities differed from those of cagemates (*Proceedings of the Royal Society*, doi.org/fscq).

Some shark species see massive decline

Most of the 31 open water "oceanic" species of sharks and rays are at risk of extinction following a drop in their numbers of at least 71 per cent over the past 50 years. There are many more "coastal" species in shallow waters, and earlier studies suggest they are declining too (*Nature*, doi.org/fscc).

Poll: climate change a global emergency

The biggest ever poll of climate change views has found that 64 per cent of people think the issue is a "global emergency". The Peoples' Climate Vote, commissioned by the UN Development Programme, had 1.4 million responses in 50 countries. Belief we face an emergency was highest in the UK and Italy.

Materials

See-through wood: knotty issue solved

TRANSPARENT wood just got even better, moving us a step closer to windows that are far better insulators than traditional glass.

The standard process for making wood see-through involves soaking it in a vat of sodium chlorite – a chemical compound used in some bleaches – to remove a structural component of the wood called lignin. However, this takes a lot of chemicals, produces liquid waste that is tough to recycle

and can weaken the wood.

Liangbing Hu at the University of Maryland and his team came up with a method that modifies the lignin instead of removing it completely. It is quicker, uses fewer materials than the usual method and leaves the wood stronger.

The researchers' method stems from the recent discovery that lignin can be made transparent by removing only the parts of its molecules that give them their colour. They brushed hydrogen peroxide, which is often used as a disinfectant, over the surface of the wood and then left it under a

UV lamp designed to simulate natural sunlight. After soaking the wood in ethanol to remove any remaining gunk, they filled any pores with clear epoxy, a step that is also part of making lignin-free transparent wood.

The end product allows more than 90 per cent of light to pass through it and is more than 50 times stronger than if all lignin is gone (*Science Advances*, doi.org/fsj4). The material is lighter and stronger than glass and could be used for load-bearing windows and roofs, says Hu, possibly even a see-through house. Leah Crane

Environment



Plastic in soil has impacts that are akin to those of drought

MICROPLASTIC may be as damaging to soil ecosystems as drought.

Yudi Lozano at the Free University of Berlin and her team suspected that microplastic fibres may affect soil-water interactions, so they examined the impact of this pollution on grassland soils.

The researchers collected dry loam soil and mixed in polyester microfibres. They planted seven grassland plant species in the soil, keeping some well-watered and others in drought-like conditions.

To simulate a moderately high level of microplastic pollution, the fibres were at a concentration of 0.4 grams for 100 grams of dry

soil, less than the 7g per 100g possible in heavily polluted areas.

The team focused mostly on the effects on the soil ecosystem, not plant growth, looking at respiration in the soil, pH, retention and cycling of nutrients, soil clumping and overall soil ecosystem health, or multifunctionality. Under well-watered conditions, the presence of fibres meant multifunctionality was up to 34 per cent lower (*Journal of Applied Ecology*, doi.org/fsjq).

This impact of microfibres in well-watered soils is of a magnitude comparable to that caused by drought in non-polluted soils, the team says. Donna Lu

Palaeontology

Evolution of thumb shaped human story

OUR thumbs allow us to use a variety of tools, from hammers to smartphones, and a new analysis suggests they have a long history. Now, researchers have found that some hominins were developing more dexterous thumbs about 2 million years ago, possibly allowing them to exploit more resources, eventually leading to the emergence of human culture.

Katerina Harvati at the University of Tübingen, Germany, and her team looked at thumb efficiency across various human species. They looked at the shape of thumb bones and soft tissue and used 3D models of thumb samples to work out their torque.

"Levels of dexterity very similar to what we see in modern humans were already present 2 million years ago," says Harvati.

Previous research suggests that *Australopithecus*, an earlier genus of hominin, may have been the earliest tool-makers, but the team found they lacked the dexterity of Neanderthals and *Homo naledi* (*Current Biology*, doi.org/fsj6).

The researchers suggest that *Australopithecus* may have been a tool user, but the *Homo* genus gained dexterous thumbs and became adapted for more efficient tool-making. Krista Charles

The columnist

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Letters

We must rethink the delay in second shot for health staff **p24**

Aperture

A stunning depiction of a tree drawn by nature in a lake **p28**

Culture

Reimagining the dig that found an Anglo-Saxon burial ship **p30**

Culture columnist

The Mandalorian is to be savoured, says Bethan Ackerley **p32**

Comment

Vaccines for all

The fastest way to end the covid-19 crisis is for countries to put the interests of the world ahead of their own, says **Seth Berkley**

IMAGINE if, when a pandemic swept across the globe, scientists responded quickly to develop effective vaccines only for a small number of wealthy countries to buy up almost the entire global supply, leaving virtually none for the rest of the world. That is precisely what happened in 2009 with the H1N1 flu pandemic. We must not allow it to happen again with covid-19.

In some ways we got lucky with H1N1: the virus became less virulent over time and vaccine supplies eventually increased enough to be included in the seasonal flu shot, enabling more people to get access. The jury is still out on whether something similar will happen with the coronavirus, but, either way, a return to normality will continue to elude us until people in all countries are protected.

Thankfully, we now have several vaccines, so to end this crisis there must be rapid, fair and equitable access to them, particularly for those people living in the world's poorest countries, which are most in danger of missing out.

This is the goal of the global vaccine coalition COVAX. Along with my colleagues at Gavi, the Coalition for Epidemic Preparedness Innovations and the World Health Organization, we are working hard to make sure that covid-19 vaccines don't just end up going to the highest bidder. With 190 governments and economies involved,



representing 90 per cent of the global population, we are now on the cusp of beginning vaccination.

This month, the first of more than 2 billion doses will start to be rolled out to high-risk individuals in 92 lower-income countries. For people in these countries to get new vaccines within a matter of weeks of those in the wealthiest nations is simply unprecedented. However, challenges still remain.

Despite working together with COVAX, governments

covid-19 vaccines to the highest bidders, just like in 2009, this will only prolong the crisis. Even if doses are promised to every country further down the line, delaying the availability of doses around the world will allow the coronavirus to continue to circulate, mutate and potentially adapt better to the human host. That works against everyone's best interests.

While COVAX was created with the world's poorest people in mind, it works to everyone's benefit. For the lowest-income nations, which would otherwise be unable to afford these vaccines, COVAX is quite literally a lifeline and the only viable way in which their citizens will get access to covid-19 vaccines.

However, there are also many upper-middle-income nations that can afford to pay for their vaccines yet lack the resources to secure doses for their citizens through bilateral deals with manufacturers. And for those 35 or so governments that are wealthy enough to secure bilateral deals, it acts like an insurance policy, guaranteeing them doses if those deals should fail, but also protecting their citizens through vaccinating others. In a global pandemic, you are only safe if everyone is safe. ■



Seth Berkley is CEO of Gavi, the Vaccine Alliance

Field notes from space-time

Cosmological calculations Studying the universe and the flow of fluids may seem worlds apart, but they involve some of the same equations, writes **Chanda Prescod-Weinstein**



Chanda Prescod-Weinstein is an assistant professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her research in theoretical physics focuses on cosmology, neutron stars and particles beyond the standard model

Chanda's week

What I'm reading

British physicist Julian Barbour's The Janus Point: A new theory of time is quickly becoming one of my favourite reads in popular science.

What I'm watching

I almost shouldn't admit in public that, over the break, I watched every episode of MTV's Are You the One?

What I'm working on

Some new students just joined my research group, so I am getting them up to speed!

This column appears monthly. Up next week: Graham Lawton

ONE of the best parts of sharing my scientific interests with the public is how engaged people are with the ideas. In my time writing for *New Scientist*, I have received lots of lovely and thoughtful notes from diligent readers. Occasionally, there is a question that I quietly respond to in a future column. Since I only write once a month, I can't address all of the questions, but I was particularly pleased last month to get an email asking me in what ways calculations in cosmology are similar to calculations involving fluids. The person who sent the question is a plumber, and I was gratified that they saw the clear connection between their trade and mine because the answer is yes, they are quite similar.

To explain, it is helpful to say that, of course, one of the wonderful things about physics is that it is consistent. General relativity is as true here on Earth as it is in distant regions of space where dark matter so heavily distorts space-time that it acts like a funhouse mirror, creating gravitational lenses.

My former colleagues at the Massachusetts Institute of Technology, David Kaiser, Alan Guth and the late Andrew Friedman, have helped conduct experiments which show that quantum mechanics can be tested using supernovae – exploding stars at the end of their lives. In other words, all of our experimental data indicates that the laws of physics we learn here on Earth seem to apply everywhere.

Obviously this is good news. If we thought the rules changed in different places, we wouldn't know how to interpret the cosmos, since there are so many phenomena that we can't get close to or reproduce in the lab,

like supernovae and the neutron stars they sometimes leave behind. Importantly, these phenomena are really complex, so even when using the laws of physics that we know, we look for simplifications.

It turns out that in astrophysics, fluids are actually one of the most important tools that allow us to gain insight into systems without having to reinvent the wheel every single time.

You might object to this because your gut intuition is that outer space is nothing like water coming out of a tap. But there are some similarities. Like water, matter in

"All of our data indicates that the laws of physics we learn here on Earth seem to apply everywhere"

the cosmos is a substance that deforms under the application of an external force, for example, gravity. This is essentially the formal definition of a fluid.

There is another way to make the case for why matter in the cosmos can be treated like a fluid: the first law of thermodynamics.

The idea behind this law is that in isolated thermodynamic systems – ones where heat and temperature are of particular importance – energy is conserved.

The first law of thermodynamics tells us that the total change in energy of a system is equal to the difference between the energy that is given to the system in the form of heat and the amount of energy that the system releases in the form of exerting force on its surrounding environment.

We will have to fudge a little on what exactly energy is because even to a professional physicist

it is a bit of a tautological idea, but you can think of an object's energy as its ability to exert force or produce heat.

And you may have heard before that one of Albert Einstein's great contributions with special relativity was articulating that there is actually a clear way of converting mass to energy and vice versa, through his famous equation, $E = mc^2$.

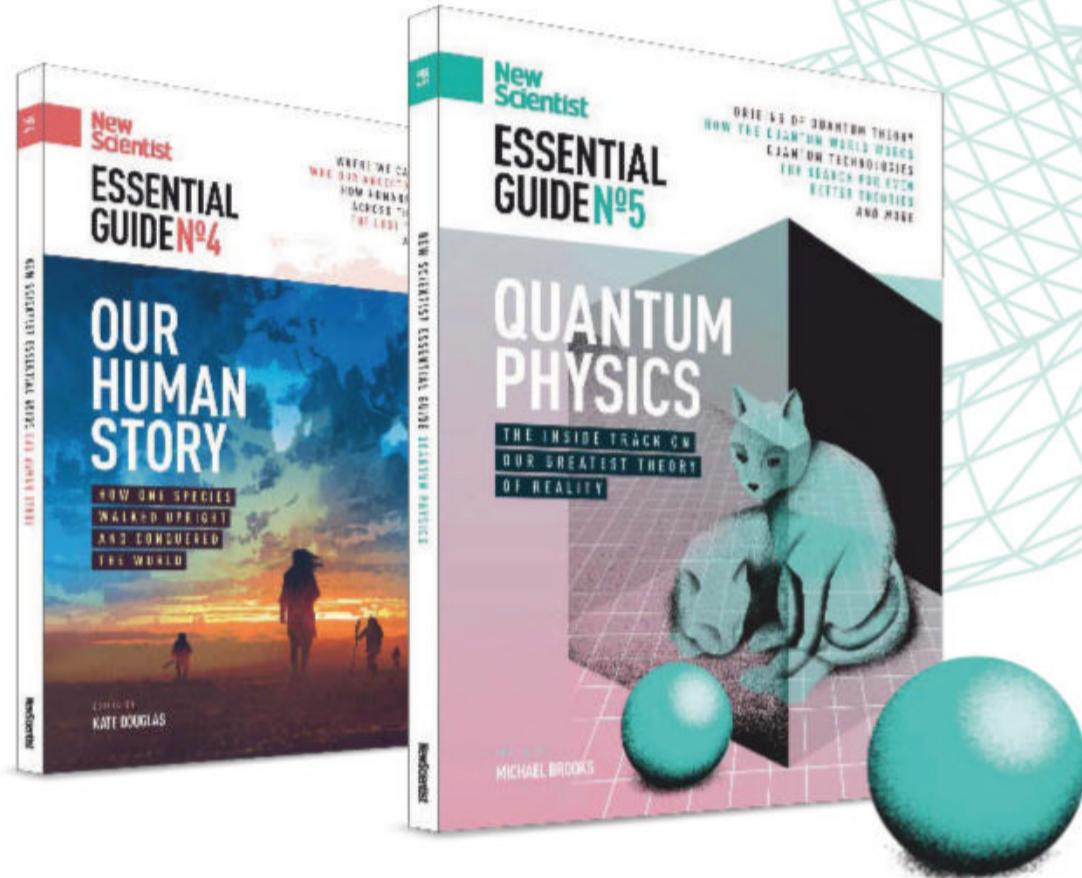
So, if we accept that energy and matter are functionally equivalent, we find ourselves in a situation where it seems clear that we can apply the first law of thermodynamics to the cosmos.

Thus, like water, matter in the universe is conserved – for the most part at least, aside from some quantum flickers here and there – being neither created nor destroyed.

It is actually the case that using the mathematical form of the first law of thermodynamics and taking the expansion of space-time into account, we can derive what is often called "the fluid equation". This explains how the density of the universe changes as it expands and is identical to what I might use to describe fluid flow here on Earth.

This might seem strange, but I find it reassuring. So many things about the world are uncertain, yet knowing just a few rules and some mathematics opens up the ability to describe vast swathes of the universe.

Today, so much of research in cosmology, for example studying the evolution of galaxies that I described in my last column (9 January, p 20), relies on using computers to solve complicated versions of the fluid equation. These computer codes follow the flow of particles as they create the beautiful structures we call galaxies. ■



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Editor's pick

We must rethink delay in second shot for health staff

16 January, p 8

From Andrea Needham,
Hastings, West Sussex, UK

You report on the decision of the UK government to delay second doses of covid-19 vaccines for 12 weeks in order to get a first dose to more people. The British Medical Association has come out against this plan, saying that the strategy to delay second doses of the Pfizer/BioNTech vaccine is "evermore difficult to justify".

I have elderly friends who are glad to be vaccinated, but will not change their behaviour in any way afterwards: they will still stay at home, have groceries delivered and have minimal, or no, contact with anyone outside their household. They are happy to have their second dose delayed, in order to vaccinate more people, as they recognise that their risk of catching covid-19 is low.

However, I am a nurse working directly with people with covid-19. I feel that the government is forcing me – and hundreds of thousands of other front-line health workers – into a giant experiment to see how effective the vaccine is if not given according to schedule.

If we get sick, that has a direct impact on others with covid-19; we are already seeing huge staff shortages in acute covid-19 units. We need to be given the best protection available – we need our second shots on time.

UK virus variant may not need to spread to go global

23 January, p 11

From Jeff Blyth,
Brighton, East Sussex, UK

Your report says that the "more infectious coronavirus variant from the UK has gone global". This implies that it has spread from a person in the UK, thought to be living in the Kent area.

However, since its greater infectiousness may only involve one key mutation, it surely would

have been fairer to point out that this variant could be arising spontaneously in other people in other countries and doesn't necessarily stem from the UK, even if it was first identified there.

It is worth recalling that the "Spanish flu" of the early 20th century didn't originate in Spain, but the Spanish made an early job of reporting it.

The Venetians gave us quarantine

9 January, p 38

From Michael Peel, London, UK
While the English village of Eyam is famous for its quarantine in response to plague in 1665, the word itself comes from 14th-century Venice, when the crews of ships were isolated for 40 days after arrival to minimise the risk of transmitting bubonic plague.

The drive to have green cars needs another step

16 January, p 23

From Nick Baker,
Rowhedge, Essex, UK

Your generally upbeat comment on the progress of electric vehicles, and their contribution to local and global health, doesn't mention that half of the electricity for charging currently comes from fossil fuels.

Looking to 2030, and the ban on the sale of new fossil fuel-powered vehicles in the UK, there will be an increased and sizeable demand for electricity from the transport sector. But we will only be able to claim this is carbon-free if we have already met the electricity demand for all other uses from non-fossil fuel sources. Otherwise we are simply robbing Peter to pay Paul.

Perhaps a technology should only be considered zero-carbon when new infrastructure for the

generation of clean electricity it requires is also provided.

Collective intelligence will be the key

16 January, p 36

R. Wade Schuette,
Columbia, Missouri, US

Robert J. Sternberg proposes ways for rethinking intelligence, but mixes individual intelligence with collective social intelligence. This matters because it is surely collective social intelligence that will be needed to address problems such as climate change.

There is an unstated assumption that by maximising individual intelligence we will maximise collective intelligence. However, as any sports coach will tell you, a team of stars doesn't generate a star team. We condition people to focus on individual skills, then act surprised when teams of them act like committees and fail us.

From Peter Haigh,
Bellevue Heights, South Australia

The discussion of the narrow understanding of what constitutes intelligence might benefit from study of Indigenous cultures.

Indigenous Australians have the world's longest continuous culture and they have a radically different understanding of cosmology, land management, fish and animal husbandry and many other areas to that of Western cultures. To have lived sustainably and apparently peacefully for many millennia in their changing and frequently harsh environment implies a more appropriate intelligence than the Western one that has wrought so much damage in a couple of hundred years. Perhaps it is just the adaptive one that Sternberg seeks.

Don't forget this use of low-carb diets too

9 January, p 32

From Annemarie La Pensée,
Liverpool, UK

The article "Breaking with bread" discussed medical applications of low-carb diets. It covered type 2 diabetes extensively, but not type 1 diabetes. However, whether to use a lower-carb or extremely low-carb diet in management of type 1 is currently a very hot topic.

There is some evidence that a very low-carb diet results in better outcomes in terms of managing the condition and, adherents would say, makes it much easier to live with day to day. However, this use of a low-carb diet is seen as controversial by some, particularly in childhood. Rich material that I for one would have been keen to see discussed in what is otherwise a fascinating and timely article.

Plants have long been the friends of metal hunters

9 January, p 42

From Derek Morris,
Harpenden, Hertfordshire, UK

In discussing the metal content of certain plants as a means to "farm" mineral resources you say that "for decades, these plants were regarded as mere curiosities". However, the related science of geobotany goes back a fair way.

The Romans were aware that some plants reflected the underlying geology and 17th-century Scandinavian miners used indicator plants like *Lychis alpina* (pyrite plant) to locate ores.

Since the launch of the Landsat Multispectral Scanner in the 1960s, research has been done to identify from space plants or plant communities that reflect underlying mineralisation. ■

For the record

■ Conservationists will implant fertilised eggs of northern white rhinos into surrogates from the southern white rhino population (23 January, p 16).



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Signal Boost

Welcome to our Signal Boost project – a page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from **The Word Forest Organisation**



Equatorial nations are experiencing the worst effects of climate change. In Kenya, droughts, floods and other extreme weather events are increasing, with devastating consequences for agriculture and food security, plus causing widespread human and animal displacement.

That's why The Word Forest Organisation, a UK-based charity working to plant trees, empower disadvantaged communities and facilitate education in Kenya, is focused on bringing permaculture food forests to local communities.

TACKLING CLIMATE CHANGE

So far, we've helped plant more than 147,000 trees in Boré, Kenya. Fast-growing trees in the tropics grow up to 10 times faster than anywhere else on the planet; they're actively cleaning the air we breathe and just one tree can absorb up to a quarter of a tonne of CO₂ and other pollutants in a small handful of years.

We place huge importance on supporting the communities that work to nurture the

trees, many of which provide vital fruits, nuts and medicines. Most tree planting and care is done via the women's empowerment group we founded, the Mothers of the Forest, which has over 40 members. The Mothers have planted thousands of crop-bearing trees, boosted local food and water security and gained an income through selling the crops. In 2019, we facilitated literacy and numeracy lessons for the Mothers, many of whom had never been to school, which was crucial to helping them find financial security.

OUR PERMACULTURE PROJECT

To boost sustainability and crop diversity without harming the environment, we have equipped the Mothers of the Forest with the knowledge and tools they need to use permaculture and regenerative agriculture

techniques. These include encouraging biodiversity, using natural pest control methods and limiting water usage. Education and training provided by local tutors and facilitated by us has resulted in the creation of a one acre "food forest", which will increase food and water security in the area.

We now plan to replicate the project at primary schools where we've built classrooms. Once the children and teachers learn the principles of permaculture, they'll be able to grow food in a sustainable way, providing a much-needed boost to their school meals, which can be irregular and lack variety.

From February we are thrilled to welcome meteorologist Clare Nasir as our Patron and Bill McGuire, Emeritus Professor of Geophysical & Climate Hazards at University College London as our Special Scientific Advisor.

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Nature's tree art



Photographer **Derry Moroney**

THIS stunning image of a tree-like pattern in the water is a testament to the beauty of nature's own art – and to the power of technology.

Using a drone, the arboreal pattern was captured in Lake Cakora in Yuraygir National Park on the north coast of New South Wales, Australia.

Derry Moroney, an amateur photographer, discovered the pattern in the lake while exploring his local area of Brooms Head and took this photo.

The lake is surrounded by lush foliage, including tea trees, and is situated inland from Brooms Head. It connects to the open ocean via the area's main beach. There are smaller rivers flowing into it.

The image bears an uncanny resemblance to a branching tree, rather like a “tree of life”, because of the lake's drainage channels. As water floods into these channels after big storms, tea tree oil from the local trees seeps into the crevices and colours the water.

Post-storm is the best time to visit, says Moroney. “There's always so much excitement wondering what I might get to see,” he says. “Even without the storms, I am so intrigued, that I find myself down at the lake almost every two weeks seeing how much it has changed.” □

Gege Li

Deep in the earth

Beneath the frills of Netflix's *The Dig* lies real treasure in the reimagined version of how the UK's Sutton Hoo site was excavated, says **Francesca Steele**



Film

The Dig

Simon Stone

Available on Netflix

BASIL BROWN, played in *The Dig* by Ralph Fiennes, was the principal archaeologist behind the 1939 excavation of Sutton Hoo in Suffolk, England. It is now considered one of the most important finds in Britain, the majesty of its 27-metre burial ship and 7th-century Anglo-Saxon treasures reframing historians' view of the so-called Dark Ages.

However, it was very nearly missed – and Brown wasn't always acknowledged for his efforts. He was a self-educated archaeologist and astronomer, who spent much of his income as a tenant farmer and insurance agent on that education. Being an independent scholar without an academic post was an irregularity that led to the omission of his name at the British Museum's display of the Sutton Hoo treasures for decades.

The Dig, based on the novel of the same name by John Preston, rights that wrong. It is directed by Simon Stone with a distinctly British tone of restraint worthy of film producer Ismail Merchant and director James Ivory, who made the 1990s hits *Howards End* and *The Remains of the Day*.

The film approaches English passions cautiously, shining a light on Brown's incredible contribution, as well as that of Edith Pretty (Carey Mulligan), the landowner who hired Brown to dig under the mounds on her estate because she had a "feeling" they would find something of note.

Fiennes and Mulligan are flawless as the excavators that the professionals underestimate, imbuing their characters with an



LARRY HORRICKS/NETFLIX

intelligent zeal for the field that isn't dampened by their places in society: he's a lowly contractor for the Ipswich Museum, she's a wealthy widowed landowner who went to finishing school. They share a quiet determination and mutual respect, initially arguing over which of the 18 mounds to tackle first, but finding common

"The Dig is obsessed with class boundaries. It fizzes with curbed passions amid honey-coloured fields"

ground in the soil and its secrets. "That's life what's revealed," Brown says in a thick Suffolk accent. "And that's why we dig."

Brown forms a friendship with Pretty's young son Robert, a keen amateur archaeologist. It is all the more affecting as we learn that Pretty is dying so Robert will soon be an orphan (Pretty died in 1942).

This is a film of two halves, the first about archaeology, the second concerned with

the personal lives of the people behind the dig. The first half is more successful, illustrating the patience necessary for excavation, especially in England where it is always raining, exposing fragile finds to the elements. It also reveals the dangers. In one of their earliest conversations, Pretty rescues Brown when the earth falls in on him and he claws desperately at the dirt. It is a good illustration of the risks an ordinary man took to exhume historical artefacts, only to be cast aside later.

Like *Howards End* and *The Remains of the Day*, *The Dig* is obsessed with class boundaries. It fizzes with curbed passions amid the honey-coloured English fields, the indomitable march of time making each ordinary moment both horribly transient, as the second world war calls up young men to die in the background, and simultaneously everlasting.

History is made of such things, and forgotten items – like Anglo-Saxon gold and Brown himself – can be retrieved.

In the second half, we learn

Flawless: Carey Mulligan as Edith Pretty and Ralph Fiennes as Basil Brown

more about other characters on the dig, including supercilious chauvinist Charles Phillips (Ken Stott) who arrives from the British Museum to oversee things. Then there are archaeologists Stuart Piggott (Ben Chaplin) and his wife Peggy Piggott (Lily James), whose strained marriage disintegrates before our eyes as Peggy forms an attachment with good-looking photographer Rory (Johnny Flynn).

The acting is impeccable, particularly from James, but the romance and domestic crises feel a little heavy-handed in a film that is otherwise so self-possessed. *The Dig* doesn't need such frills. Like Sutton Hoo, the treasures aren't showily arranged but lie quietly, in the silences between people, and in simple shared hopes that stretch across generations. ■

Francesca Steele is a film critic and writer working in London

Don't miss



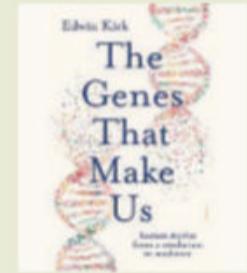
Watch

Earth, But Not As We Know It is a free online event by London's Science Museum on 13 February, bringing James Lovelock and his peers into a conversation about his controversial idea that Earth acts like a living organism.



Explore

Manchester Science Festival returns from 12 February with an online programme on our changing climate and ideas for a better future. There are photography exhibitions and talks on everything from improving air quality to eco-anxiety.



Read

The Genes That Make Us by Edwin Kirk combines his experiences from lab work and clinical practice to present stories from a revolution in medicine – one that may ultimately change what it means to be human.

New ways to love art

Museums and galleries are finding more personal ways to wow audiences during the pandemic, writes **Simon Ings**



Exhibitions

IN NOVEMBER, the International Council of Museums estimated that 6.1 per cent of museums globally were resigned to permanent closure due to the pandemic. The figure was welcomed with enthusiasm: in May, it had reported nearly 13 per cent faced demise.

Something is changing for the better. This isn't a story about how galleries and museums have used technology to save themselves during lockdowns (many didn't try; many couldn't afford to try; many tried and failed). But it is a story of how they weathered lockdowns and ongoing restrictions by using tech to future-proof themselves.

One key tool turned out to be virtual tours. Before 2020, they were under-resourced novelties; quickly, they became one of the few ways for galleries and museums to engage with the public. The best is arguably one through the Tomb of Pharaoh Ramses VI, by the Egyptian Tourism Authority and Cairo-based studio VRTEEK.

And while interfaces remain clunky, they improved throughout the year, as exhibition-goers can see in the 360-degree virtual tour created by the Museum of Fine Arts Ghent in Belgium to draw people through its otherwise-mothballed Van Eyck exhibition.

The past year has also forced the hands of curators, pushing them into uncharted territory where the distinctions between the real and the virtual become progressively more ambiguous.

With uncanny timing, the V&A in London had chosen Lewis Carroll's *Alice* books for its 2020 summer

Curious Alice is a VR experience created by the V&A and HTC Vive Arts

show. Forced into the virtual realm by covid-19 restrictions, the V&A, working with HTC Vive Arts, created a VR game based in Wonderland, where people can follow their own White Rabbit, solve the caterpillar's mind-bending riddles, visit the Queen of Hearts' croquet garden and more. *Curious Alice* is available through Viveport; the real-world show is slated to open on 27 March.

Will museums grow their online experiences into commercial offerings? Almost all such tours are free at the moment, or are used to build community. If this format is really going to make an impact, it will probably have to develop a consolidated subscription service – a sort of arts Netflix or Spotify.

What the price point should be is anyone's guess. It doesn't help for institutions to muddy the waters by calling their video tours virtual tours.

But the advantages are obvious. The crowded conditions in galleries and museums have been miserable for years – witness the *Mona Lisa*, imprisoned behind bulletproof glass under low-level diffuse lighting and

protected by barricades. Art isn't "available" in any real sense when you can only spend 10 seconds with a piece. I can't be alone in having staggered out of some exhibitions with no clear idea of what I had seen or why. Imagine if that was your first experience of fine art.

Why do we go to museums and galleries expecting to see originals? The Victorians didn't. They knew the value of copies and reproductions. In the US in particular, museums lacked "real" antiquities, and plaster casts were highly valued. The casts aren't indistinguishable from the original, but what if we produced copies that were exact in information as well as appearance? As British art critic Jonathan Jones says: "This is not a new age of fakery. It's a new era of knowledge."

With lidar, photogrammetry and new printing techniques, great statues, frescoes and chapels can be recreated anywhere. This promises to spread the crowds and give local museums and galleries a new lease of life. At last, they can become places where we think about art – not merely gawp at it. ■



VICTORIA AND ALBERT MUSEUM, LONDON/HTC VIVE ARTS

The TV column

The Star Wars empire strikes back State-of-the-art special effects combined with a compelling story make *The Mandalorian* very much to be savoured, says **Bethan Ackerley**



Bethan Ackerley is a subeditor at New Scientist. Follow her on Twitter @inkerley



WHEN George Lucas set out to create *Star Wars*, he wanted to use special effects that had never been seen before. Over the course of the franchise's history, that dream has been pursued relentlessly with mixed results.

The original *Star Wars* trilogy was brought to life by Lucas's visual effects company Industrial Light & Magic (ILM) through a groundbreaking combination of blue screens, miniatures, puppets and camera trickery. The prequel films (released between 1999 and 2005) were ambitious too, pioneering the use of digital film and fully computer-generated characters, but relied heavily on digital effects that didn't always stand up to scrutiny. Since 2015, the latest *Star Wars* films have showcased some stunning effects, but it is now in TV show *The Mandalorian* that the series' most exciting technological developments are taking place.

Set five years after *Return of the Jedi*, *The Mandalorian* follows a bounty hunter tasked with finding The Child (a pointy-eared alien better known to fans as Baby

Yoda). Unable to surrender the infant to his nefarious client, the Mandalorian is forced to traverse the galaxy to protect his charge from remnants of the Empire.

So far, so *Star Wars*. Yet what makes *The Mandalorian* so special is how it builds on the successes and failures of every story in the franchise, especially when it

"The many alien worlds of *The Mandalorian* are realised on a single stage in Los Angeles called 'the Volume'"

comes to technology. Though you wouldn't know it, the many alien worlds it features aren't filmed in deserts and tundras around the world, but are instead realised by ILM on just one stage in Los Angeles, nicknamed "the Volume".

This cavernous set is encircled by LED panels on its 6-metre walls and ceiling. Instead of shooting actors against green screens and adding a virtual background later, environments – Tatooine's desert plains, say – are projected onto the

An armoured bounty hunter protects Baby Yoda in *The Mandalorian*

walls during filming, blending seamlessly with practical props.

The advantages of this approach are manifold. While shooting with green screens means lighting and reflections have to be tweaked in post-production – a difficult task and part of why the prequel trilogy was so maligned – the Volume accurately lights a scene while it is being filmed, so every world our hero steps onto (in his gleaming beskar armour, no less) feels like a real location.

Those alien planets can be edited on set, so the crew can quite literally move mountains. ILM also uses Unreal Engine from Epic Games, the firm behind *Fortnite*, to create 3D environments in real time in the Volume. The screens respond to positional data from a camera, so as it moves, the setting shifts to provide realistic changes in perspective.

Beyond the Volume, the show builds on the techniques of its predecessors, using puppetry and animatronics alongside actors to create believable aliens. You only have to look at fans' reactions to The Child and to "Frog Lady", season two's amphibious breakout star, to see how successfully they have been realised. Even old-school miniatures are used.

The Mandalorian represents the next generation of technology in *Star Wars*, which is fitting for a brand so obsessed with lineage. That doesn't mean it should be judged on this alone. It is also a compelling story about fatherhood and duty, albeit one with meandering side quests that sometimes divide viewers. Yet with a universe this beautifully realised, who wouldn't stop to take in the view from time to time? ■



TV

The Mandalorian
Created by Jon Favreau
Disney+

Bethan also recommends...

TV

Disney Gallery: The Mandalorian

Disney+

This fascinating series explores key elements of The Mandalorian. A highlight is the episode looking into how composer Ludwig Göransson built the cool soundtrack around giant recorders.

Film

Empire of Dreams: The story of the Star Wars trilogy (2004)

Ken Burns

The original Star Wars films were taken from the brink of disaster and made into a global phenomenon. This documentary tells the tale.

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Heading for burnout?

As the pandemic wears on, many of us are feeling burned out – but there are things we can do to protect ourselves.

Caroline Williams reports

IAM not just busy, I am being overwhelmed by an onslaught of requests like yours..."

There is a certain irony to the email I have just received: the pioneer of burnout research is feeling utterly swamped by work. Christina Maslach, a psychologist at the University of California, Berkeley, spearheaded the study of burnout back in the 1970s and has been working on ways to tackle the problem ever since. Her expertise was already highly sought after even before the coronavirus pandemic. Now she can barely move under the weight of her inbox.

It is hardly surprising. In the year since the word lockdown became ubiquitous, it seems as if almost everyone has hit the wall at least once. But amid the emotional roller coaster of work stress, homeschooling, social isolation and the not inconsiderable fact that there is still a pandemic raging outside, how can you tell when you have reached the end of your tether? When does feeling understandably stressed in difficult times turn into an irretrievable case of burnout? And what can you do to protect yourself?

Thankfully, five decades of research means we have a fairly good idea of what burnout is and what causes it. According to Maslach's Burnout Inventory, an assessment tool she co-developed, burnout arises when three factors coincide: an overwhelming feeling of emotional exhaustion, feelings of cynicism and detachment and a feeling of lack of accomplishment. For those experiencing burnout, these criteria might manifest in feelings like being exhausted even after plenty of sleep, being emotionally distant from loved

ones or no longer caring about jobs that need doing.

This definition, like most of the research that has been done on the subject, focuses on burnout in the workplace. In 2019, the World Health Organization chimed in, classifying it as "an occupational phenomenon" that results from "chronic workplace stress that has not been successfully managed".

Yet, while the situation we find ourselves in now is about much more than work stress, Maslach says that the experience of burnout is the same. "What's different is that it's happening more," she says, and in response to new types of stress.

Hidden picture

Exactly how much more is hard to ascertain in terms of hard data, not least because we are still in the eye of the storm. But some strong trends are emerging from studies that have been investigating people's emotional state before and during the pandemic. For instance, one survey of more than 17,000 adults in the UK in April 2020, a month into the country's first lockdown, found that mental health had already deteriorated considerably compared with before the arrival of covid-19.

However, according to Carmine Pariante, a psychiatrist at King's College London, the UK population as a whole has been remarkably resilient to the changes it has faced. But when you drill down into the detail, there are two very different pictures hidden among the averages. "For some populations, like young people, women with small children and people with pre-existing mental health problems, the



NATHALIE LEES



deterioration was quite noticeable," he says.

Studies in the US have uncovered similar findings. One recent survey of burnout among doctors there, for example, found that women were affected more than men, probably because women are also absorbing more of the increased workload at home.

Clearly, most of us aren't dealing with the life-or-death situations faced by many medical workers, and which may be fuelling problems (see "Front-line burnout", p36). But with renewed lockdowns and travel restrictions in many countries, the fear is that more vulnerable groups will be pushed further towards burnout and could be joined by people who coped alright first time round.

Burnout isn't, Maslach is keen to point out, a mental disorder, although it can certainly stem from and lead to mental illness. Instead, it is a natural reaction to a situation that has become intolerable to the person experiencing it.

Still, the more insidious kind of burnout from the pressures we all face during the pandemic isn't to be sniffed at. Last month, Mark Ormrod, a former Royal Marine who lost both legs and an arm in an explosion while serving in Afghanistan, told the BBC that homeschooling his two children while also trying to keep up with his day job ranked among his "most traumatic memories".

A random poll of workers in the US found that almost 60 per cent were feeling the effects of burnout in August 2020, up from 45 per cent in the early days of the pandemic, with 39 per cent of those affected blaming their burnout symptoms on the struggle to balance work and home life.

And research by psychologist Moïra ➤

Front-line burnout

Burnout in the medical profession was a concern long before covid-19 threw it into the spotlight. Now there are fears that, for many, the pandemic could be the last straw.

There is some evidence that, when in the thick of a crisis, focusing on the task rather than emotions can help to protect the mental health of medical practitioners. A study of Italian doctors during the first wave of the epidemic there found that those who used practical strategies to get through their workload were at lower risk of burnout than those who attempted to manage their emotions as they went. The researchers concluded that this was because, in the early days, “emotions related to the pandemic [were] too intense to be regulated and used productively”.

The worry is that once the immediate threat passes, this tendency to push emotions aside will backfire. “My fear is that once we come out the other side and have a chance to realise what we’ve survived, the impact will be monumental,” says National Health Service anaesthetist in England and mental health advocate Christina Hoskins.

In a recent article in the NEJM, Jo Shapiro at Harvard Medical School, who studies clinician burnout, and Timothy McDonald, a Chicago-based medic and lawyer, made the case for a large-scale effort to safeguard the mental health of clinicians from the pandemic’s impact. They suggest peer support and a system of monitoring and interventions to assist front-line staff as they come to terms with the past year. Actions aimed at encouraging people to help themselves, they note, have been shown not to work.

Mikolajczak at the Catholic University of Louvain (UCL) in Belgium has found that people experiencing parental burnout can have higher stress levels than those experiencing chronic pain.

What is more, while burnout isn’t a mental illness, it can leave people vulnerable to more serious mental health problems. “We know that burnout, even within the classical work-related literature, is a major risk factor for depression and anxiety,” says Pariante. There are a number of factors that we know put us at risk of both burnout and mental illness.

Out of control

The first is control, or more importantly, a lack of it. In the pandemic, front-line workers in the medical profession are likely to be feeling this the most keenly. Dealing with infected people every day isn’t only exhausting, it also takes away much of the control over their personal chances of catching the virus and of protecting their loved ones from exposure.

For people who have the relative luxury of

being able to avoid the virus by working at home, feelings of lack of control can come from elsewhere. The fact that lockdowns are imposed rather than voluntary seems to be an important factor. A recent review in *The Lancet* looked at the effects of enforced quarantine or social isolation during outbreaks of SARS and Ebola. It found that voluntary quarantine is less likely to cause emotional stress and long-term mental health problems than restrictions that are mandated by law.

This is probably down to the psychological impact of having freedom of choice taken away, says Lynden Miles, a social psychologist at the University of Western Australia in Perth. Because we are no longer able to choose how often we go out and who to meet, lockdowns may lead to the psychological phenomenon of “learned helplessness”, he says, where a person “gives up once they realise their efforts to improve the situation are futile”. Learned helplessness is associated with depression and post-traumatic stress. And in terms of Maslach’s definition of burnout,



Still feeling tired after a good night's sleep is a classic sign of burnout

it very much comes under the banner of “cynicism and detachment”.

The *Lancet* review also concluded that enforced quarantine is less stressful when people feel that they are sacrificing their freedom for the greater good. In the UK, comparisons have been made with the so-called Blitz spirit, especially during initial lockdown. This is the sense that personal suffering is worth it for the common cause – and is said to have sustained morale during the bombing of the UK in the second world war.

According to an August 2020 study comparing the pandemic and the Blitz, there are many similarities, including the fact that a community wide stiff upper lip is more myth than reality. As with the pandemic, the bombing had peaks. During a later wave of attacks, when air raids were faster, quieter and more deadly, government surveys recorded that Londoners’ spirits dropped to an all-time low.

Given the resurgence of the coronavirus at the end of 2020 in much of the world, along with the emergence of significantly more transmissible variants, this comparison holds up. And there is already some evidence that second and third lockdowns are denting morale.

Sara Simblett, a clinical psychologist at King’s College London, is part of a team that has been tracking stress-related coping strategies before and throughout the pandemic. While data sets from the current UK lockdown have yet to be fully analysed, there are early indications that resilience is waning, with people feeling much less confident about being able to cope in the long term compared with the short term, she says. It remains to be seen whether this prediction is borne out by the team’s follow-up data, due to be published soon.

A lot will depend on how people feel about the high-level decisions being made about our freedoms. In the workplace, poor or unfair decisions mandated from above, or unequal enforcement of those decisions, is a key risk factor for burnout. Similarly, a sense of unfairness in government-mandated

Becoming overwhelmed by boredom can also take a toll



STEVE HICKEY/ALAMY

“Burnout is a major risk factor for depression and anxiety”

restrictions and their enforcement could well be fuelling a sense of burnout in people asked to obey them.

In short, if you are forced to surrender your freedom and make sacrifices for the greater good, then the people restricting your freedom had better be doing the same.

According to research published in August 2020, this pact between citizens and the UK government was severely dented when Dominic Cummings, a key adviser to the prime minister, was accused of breaking lockdown rules by driving his wife 420 kilometres from their home, even though he suspected she had covid-19. The episode was directly linked to a significant drop in confidence in the UK government’s handling of the crisis and to the chances of people following the rules. There are signs that confidence in the UK government has fallen further with successive lockdowns.

A similar trend has been seen in the US, ➤

Canada and in some European countries, where indecision and changes to rules have been linked to public anger and decreasing confidence in authorities' handling of the pandemic, all of which is likely to increase feelings of burnout.

Adding to these factors, we know that burnout can be fuelled by feelings of being unable to escape from home. Research on parental burnout, for instance, has found that going to work has protective effects as it offers a breathing space from the pressures of home. Even a commute can give us a chance to clear our heads. All of these escape mechanisms are now, of course, much harder to come by.

The more we understand about the causes of burnout, the more we can do to try to protect ourselves. On a personal level, the biggest challenge may be to take back as much control as possible over the day-to-day. That may not be easy when the usual options that help us battle through tough periods – going on holiday, meeting friends or enjoying certain hobbies – are off the table.

Meaningful connections

Even so, one thing we do know is that any kind of stress, whether from work, home or the fear of a deadly virus, can be reduced by meaningful social interaction. Even in the absence of actual physical contact, there are plenty of ways to keep in touch emotionally and how you do it doesn't matter, says Pariante – it could be via a text, the phone, a socially distanced walk or a video call. Doing this takes effort, which is particularly difficult if you are reaching the exhausted or cynical stages of burnout, but we are a social species. "It's easy to be lazy, but in the end, you will pay for it if you're not committing to some level of social connection," says Pariante.

We can also borrow from the many well-researched tips for safeguarding our mental health, including getting as much fresh air, exercise and time in green spaces as possible, regardless of the weather.

Simblett's research has found that, during the first UK lockdown, going for daily walks or

DEEPOP BY PLAINPICTURE/INTI ST CLAIR



Exercising can help to protect your mental health

Forget burnout, I'm bored-out

With so much emphasis on burnout caused by being overwhelmed, it is easy to overlook the other side of lockdown and social isolation: many people are unable to work, isolated and as tied to home as everyone else.

The term boreout was coined in 2007 by two Swiss business consultants and has begun to creep into the world of employment psychology. It is defined as the emotional toll of not having enough to do or not finding meaning in your everyday work, or the stress that comes from having plenty to do, but all of it being utterly boring.

As with burnout, the problem often boils down to a lack of control. This means that the best way to avoid the anxiety and exhaustion that accompany boreout is to try to spend time doing things that mean something to you, whether that is learning to cook, volunteering in a food bank or reading something stimulating instead of mindlessly scrolling on social media. What matters is that it takes you out of the here and now and stretches into the future, when this will, eventually, end.

other forms of exercise proved to be an important coping strategy for many. For those who are isolating or shielding and therefore not allowed out of the house, exercise is perhaps even more important. If online exercise classes aren't your thing, turn up the music and dance: studies have found that it lifts mood at least as effectively as other forms of exercise and, when done with another person, encourages emotional bonding, hitting two anti-burnout strategies at once.

Other than that, it is a case of building in as much separation between your work life and home life as possible, and making a commitment to do things that make you feel good. Finally, when things get too much, it pays to know when to stop.

Maslach, the doyenne of burnout research, provides a masterclass in how to do this. Faced with yet another request from a journalist asking about burnout, she answered two out of five questions, sent some links to further resources and wished me good luck. If we are going to come out of this in one piece, we will need to manage expectations: do what you can and know when to say no. ■

Need a listening ear? UK Samaritans: 116123 (samaritans.org). Visit bit.ly/SuicideHelplines for hotlines and websites for other countries



Caroline Williams is a consultant for New Scientist. Her next book is *Move: The science of body over mind*

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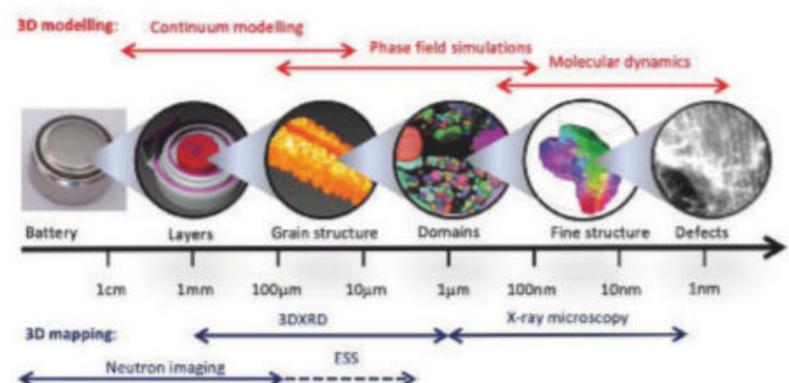
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PhD: Study plastic deformation in metals using Dark Field X-ray Microscopy (Deadline 8 February 2021)

PhD: Neutron studies of nanofluid characterization (Deadline 5 April 2021)

Enough of experts?

We're reliant on specialist knowledge to guide us through the coronavirus pandemic – so it is more important than ever to understand what expertise is and where it comes from,

Roger Kneebone tells

Richard Webb



IF ROGER KNEEBONE is an expert, he has spread his expertise widely. Trained as a medical doctor, he spent many years working as a trauma surgeon in the township of Soweto in Johannesburg, South Africa, at the height of apartheid, before returning to the UK to become a general practitioner in rural Wiltshire.

Now in his third career as a professor of surgical education at Imperial College London, he has been at the forefront of many innovations aimed at widening the scope of influences that students are exposed to. These include setting up a Centre for Performance Science with the neighbouring Royal College of Music and helping to devise the Chemical Kitchen project, which exposes chemistry undergraduates to lab skills through the “non-threatening” parallel of cooking.

Kneebone has also tried his hand at many extracurricular activities, from flying light aeroplanes and learning to juggle to building harpsichords – with varying degrees of success, he freely admits. He recently wrote a book,

Expert: Understanding the path to mastery. Drawing on the experiences of people from musicians to magicians and tailors to taxidermists – and some scientific and medical experts for good measure – it examines the ubiquitous, but understudied, process of becoming an expert.

Richard Webb: Experts are very much in the public eye at the moment.

Roger Kneebone: I finished writing the book just before the UK's March covid-19 lockdown began. But now more than ever we need to think about how we make use of the most valuable aspect of expertise – the wisdom based on experience that allows people to give sensible guidance about what to do and what not to do. My motivations in writing the book were to ask what does “being an expert” mean and where does that expertise come from?

So what does being an expert mean?

That's actually a surprisingly tough one to answer. Broadly, it means that you are

demonstrably extremely good at what you do, having spent a long time learning your craft; that you can pass your knowledge on to other people; and that you are recognised by other people as being extremely good at what you do.

But there are complications. For a start, people often underestimate their own level of expertise and others might recognise you as an expert in ways you don't yourself. So you, for example, have a background in physics, right? You might be regarded by some as an expert in physics, or you might be regarded by others as an expert in putting together a magazine. But there's a chance you don't entirely see it that way.

Often there's a social judgement involved, too: we think of brain surgeons or fighter pilots or concert pianists as having greater expertise than mechanics or plasterers or plumbers. We often overlook the experts all around us who don't occupy very high positions in this hierarchy or whose area of expertise isn't regarded as “important”. That's a great mistake.

In the run-up to the UK's 2016 EU referendum, government minister Michael Gove infamously said that the UK had had enough of experts.

Is expertise generally undervalued?

I think there's been a very dangerous sense growing that experts are sort of a needless luxury. They're telling us what to do, and what do they know about it?

The coronavirus pandemic has brought the value of expertise into sharp focus. In medicine, there's the mantra that a surgeon knows how to operate, a good surgeon knows when to operate and a really good surgeon knows when not to operate. The same goes for someone who comes to check your boiler, or a whole host of other things.

Expertise isn't just about knowing stuff and being able to do stuff, but about having the judgement to apply that knowledge in the right way: to improvise, to bring accumulated experience to bear on a new situation where there may be no clear answers, but we need to make decisions anyway. Governments and tabloid newspapers have an instinctive dislike of operating under conditions of uncertainty because they want simple answers to questions. If we dismiss the value of experts, just pooh-pooh them and say we don't need them, we are depriving ourselves of something crucially important.

Is part of the problem that we have developed a very "them and us" idea of expertise?

There is that very unhelpful sense that an expert is the same as an elitist. One of the things that struck me working together with and observing people in all different walks of life is how universal the process of becoming an expert is – and that, in fact, the same process applies to us all, whatever we do or are interested in. We don't necessarily always make it particularly far along the path, but we all follow it, whether we're learning a language or to play a sport or a musical instrument or whatever.

But there are also the experts we need because they can do things that we can't. It might be flying planes or doing operations, or advising us about pandemic lockdowns or having sensible things to say about education

"Expertise isn't just about knowing stuff; it's having the judgement to apply knowledge in the right way"

Expertise is built on physical experience - whether in learning to interpret graphs or play an instrument



during covid-19 – all these things are swirling around at the moment, where we see stupendous failures of judgement of various kinds, which I think are very often because of an unwillingness to accept the value of experts.

Part of it is because people haven't made this connection between other experts and what we all do. An expert epidemiologist, say, may have gone a long way along a particular path, but they're still on that same path we all are. They're not a completely different species – the process itself is a universally human one.

In your book, you talk about the three stages of becoming expert in something: apprentice, journeyman and master. What's the difference?

In the apprentice stage, generally somebody else is taking responsibility for your cock-ups, and also taking credit for your successes. You have to spend a load of time doing stuff that other people tell you, whether you like it or not, whether you think it's useful or not and whether you even understand it or not – and you usually don't. It can be boring, it can be tedious, it can be frustrating, whether you're learning to take bloods in my case when training to be a surgeon, making a stone surface flat or smooth if you're trying to be a mason, learning tricks as a magician or anything you can imagine.

But during that time, you find all sorts of other things happen that you're not aware of. You come to understand the materials you're working with and what you have to do to work with them. You understand how to occupy the space you're in, how to interact with other people, how to work in a workshop or community. And that takes a long time.

And as a journeyman and master?

As a journeyman, two very interesting things happen. You change your focus of attention from yourself and the things that you've learned – the exams you've passed, the stuff you want to show off – to whoever your work is for: an audience, patient, customer or client. Simultaneously, you're moving to becoming an independent person with your own individuality and style, what jazz musicians call "voice".



In medicine, as in many walks of life, knowing when to intervene and when not to is a critical aspect of expertise

for doing things like music or dance or drama that allow them to explore their physical space, for performing to other people and working in groups – all those things that the process of becoming expert builds on – are being stripped out of the curriculum. More and more, we're being encouraged to think that really only the sciences are worth doing, all the rest is touchy-feely stuff that doesn't matter. This absolutely couldn't be further from the truth – partly because, as humans, we need those different aspects, but partly because there is just as much craftsmanship and performance in expert laboratory science as there is anywhere else. We are impoverishing people at an early, formative stage and it's very difficult to get these things back.

As a master, you must obviously take responsibility not only for the people you're working for, but for other people who are also doing that work: apprentices, trainees, PhD students or whoever. But under the surface, you're having to develop that quality of wisdom and to shape other people's direction.

There's two crucial skills you only develop in this phase. First, how to deal with error, both in terms of recovering from an error – crucial obviously as a surgeon, but in a whole host of other areas, too – and building up your own resilience. And you learn to improvise – not in the sense of just knocking something up on the spur of the moment because you haven't thought about it in advance, but in being able to respond to the unexpected, and to bring into play all the knowledge and experience you've gained to make a sensible response to an unpredicted situation. That's the sort of wisdom in expertise we're looking for now.

And building that sort of expertise takes a lot of time and effort?

Absolutely, and there are no shortcuts. One of my colleagues at Imperial, Sara Rankin, a professor of stem cell biology, mentioned a breakthrough her research group made recently when they were looking at populations of cells under the microscope. She said, "I think

we should just have another look at those ones in the top-right-hand corner; I don't know why, I just feel we should" – and she was right.

There's something that she was only able to do because she'd spent 20 or 30 years actually doing stuff with her sleeves rolled up with cell cultures and looking at microscopes. Her expertise was a very physical thing, a sense of where to look, an awareness of the whole context of what she was doing. Experts I've talked to in all sorts of fields say again and again, it's about getting things into your hands and your fingers – even if it's just interpreting graphs or printouts as a scientist or engineer, it's a physical thing, and it takes time to become good at it.

Do we give people the necessary time and space to become an expert?

If you accept that becoming an expert in whatever requires a very long time, and it requires a nutrient environment, where you have time to do stuff, and get things wrong at the beginning and be protected, and then become independent and go through all these stages, when you look at what's happening from quite an early age, certainly in the UK, there are real problems.

All those opportunities that people used to have at school for doing stuff with their hands,

Coronavirus limits our ability to physically learn together, possibly long-term. How do we deal with that?

That's a very interesting issue. I've been talking with some colleagues – a magician, a musician, a teacher and a clinician – about how to make sense of the online world in teaching practical skills, whether it's playing a keyboard instrument, doing magic tricks or putting a central line in somebody in an intensive care unit. There are some interesting possibilities, including technologies such as haptics, but at the moment there are more questions than answers on that one.

Would you say you are now an expert on being an expert?

(Laughs) One thing that unites all the people I spoke to is that becoming an expert has a beginning, but it doesn't have an end. All of them say, "Well, I can't do it as well as it could be done". There isn't some point you get to sit down in a chair, beam benignly and say, "Now I'm an expert". It is a continuous progression, and that's what makes it so fascinating to study. ■



Richard Webb is executive editor of *New Scientist*

1 Hope or Hype?

Hydrogen has long been a candidate for a clean fuel revolution. Can it finally make the grade? **Adam Vaughan** investigates

IF HYDROGEN is the future, it has been for quite some time. In his 1875 novel *The Mysterious Island*, Jules Verne imagined the element replacing coal as a fuel, split out of water to "furnish an inexhaustible source of heat and light". Similar noises were made in the 1970s oil crisis, when hydrogen was touted as an alternative fuel for cars. And then there was US president George W. Bush in 2003, latching on to a new enthusiasm for hydrogen vehicles during the first wave of real concern about climate change. "We can make a fundamental difference for the future of our children," he said.

Now hydrogen is back – again. From the US to Australia, and the European Union to China, the past year has seen an almost daily torrent of multibillion-dollar government funding pledges, tests of new technologies from trains and planes to domestic boilers, industry statements and analyses, and championing by leaders such as UK prime minister Boris Johnson. "We're finding it hard to keep up with," says Simon Bennett at the International Energy Agency.

"The idea of a hydrogen economy is not new," says Martin Tengler at analysts Bloomberg New Energy Finance. "Now we're in another hype cycle. The question is: is it different, or not?"

Tengler is one of many who thinks it is. Meanwhile, another question hangs much heavier than hydrogen in the air: is it really a clean, green fuel to help combat climate change? Or does the significant lobbying of fossil-fuel interests for a hydrogen economy indicate other priorities? ➤

SIX USES FOR HYDROGEN

1 TRAINS, PLANES AND...

The glossiest of many new uses touted for hydrogen is in transport. Hydrogen cars have faltered before, as oil prices yo-yoed and battery powered electric cars emerged as a viable technology. But for larger vehicles, the batteries required are big and heavy, possibly creating an opening for hydrogen.

Two hydrogen fuel-cell trains built by the firm Alstom were put into commercial service in Germany in 2018, and one in Austria in 2020. The UK has also been trialling this approach on its rail network.

Hydrogen's high energy content in relation to its weight has also caught the eye of plane-makers. In the UK, 2020 saw the flight of a six-seater hydrogen passenger plane, while European aerospace firm Airbus unveiled three concept hydrogen planes.

"When we go to larger commercial aircraft-type applications, we see the need for hydrogen, because in very simple terms it has thousands of times more energy per kilogram than even the best batteries today," says Glenn Llewellyn at Airbus. Julian Renz at green aviation company ZeroAvia, which undertook the six-seater test flight, says he thinks hydrogen-powered planes will be cheaper to maintain than battery ones, because of the limited life cycle of batteries.



GEOFFROY DECRECY

"Is hydrogen a clean, green fuel - or does fossil-fuel lobbying suggest a different story?"

Hydrogen is the lightest element in the universe and the most abundant. On paper, it has a lot going for it as a fuel. Although it rarely exists on its own on Earth, it can be produced using clean electricity to split essentially inexhaustible water, producing only oxygen as a by-product.

Once made, hydrogen acts as a chemical energy carrier, rather like oil or gas, that can be piped or transported to where it is needed. It stores three times as much energy per unit of mass as conventional petrol, and when it "burns" in air – releasing that stored energy – it simply combines with oxygen to produce water again. In that sense, it is the ultimate green fuel.

Perhaps the most notorious attempt to use hydrogen to change the world ended with the fiery demise of the German airship Hindenburg in New Jersey in 1937, when the hydrogen gas used to give it buoyancy caught fire. Technology for the safe storage of hydrogen has since come on in leaps and bounds. In recent decades, the idea of creating a "hydrogen economy" has focused on developing liquid hydrogen as an alternative green fuel, mainly for cars.

2 ... AUTOMOBILES

While most analysts think battery electric vehicles are the future for passenger cars, some car-makers believe that the faster refuelling of hydrogen vehicles will win the day in some places. "I definitely see a market for hydrogen passenger cars," says Mark Freymüller at Hyundai. Under a European scheme, in which Hyundai is offering cars on a pay-per-use model, the vehicles are fuelled solely with green hydrogen. "It is important to be emission-free," he says. Hydrogen trucks may also prove more viable than battery electric lorries, because of the size and weight of battery needed to power a lorry.

One thing that is different now is how hydrogen is being touted as a way to decarbonise "hard-to-abate" sectors that are difficult to power directly with clean electricity. These range from long-distance road haulage, aviation and shipping to naturally carbon-intensive industrial processes such as steel and petrochemical production (see "Six uses for hydrogen", starting page 44).

Green, grey or blue?

The past two years of climate pledges by businesses and governments, from the UK to China, has made clear that even these industries will have to transform if we are to meet the overarching goal of net-zero carbon emissions by mid-century. And hydrogen figures big in that goal: the European Commission's Joint Research Centre says that between 10 and 23 per cent of the EU's final energy consumption could be covered by hydrogen in 2050; the energy company Shell puts the figure at 10 per cent globally by 2100.

Meanwhile, the rapidly falling costs of power from wind and solar farms has made the large-scale, clean production of hydrogen using clean electricity plausible. The problem is that the vast bulk of hydrogen isn't currently made that way.

Humanity already produces around 70 million tonnes of hydrogen each year, mainly for use in making ammonia fertiliser and chemicals such as methanol, and to remove impurities during oil refining. Some 96 per cent of this hydrogen is itself made directly from fossil fuels – mostly natural gas, followed by coal and then oil. This overwhelmingly uses a process known as steam reformation that releases carbon dioxide.

Only 4 per cent of hydrogen is made in the way Jules Verne envisaged, using electrolysis to split it out of water. Much of the electricity to supply even that measly share of the hydrogen market comes not from green sources, but from fossil fuel power plants. Far from being green, the

3 HOME HEATING

Many uses for hydrogen are mooted, but some are far from guaranteed to materialise. One is decarbonising home heating, with proponents arguing that countries, including the UK, could repurpose existing gas pipe networks to carry hydrogen and swap natural gas boilers for ones capable of burning hydrogen.

Leeds in the UK has been mooted as an early candidate for switching entirely to hydrogen instead of natural gas for heating and cooking, with a 2016 report by the local energy network finding the idea "technically possible and economically viable". In November, the UK government said it would support a village-scale hydrogen heating trial by 2025.

Sceptics say it would be more efficient to use renewable electricity directly with heat pumps to warm homes, rather than losing energy by converting it to hydrogen first. A recent report by Jan Rosenow and a team at the UK Energy Research Centre concluded that there is so much uncertainty about hydrogen's role in decarbonising heat that other options should be the UK's priority in the next decade. These include networks that pipe heat to many homes from a large, central source such as an industrial plant, energy efficiency improvements and heat pumps.

hydrogen produced globally today has a carbon footprint on a par with the UK and Indonesia combined, says Tengler – about 830 million tonnes of CO₂ annually.

That brings us to the strange point where transparent hydrogen gets colourful, at least linguistically. "Grey" hydrogen is so-called because it is made from fossil fuels using steam reformation. It costs about \$1 a kilogram. "Blue" hydrogen typically "buries" the emissions associated with producing it using carbon capture and storage (CCS) technology – an approach which exists, albeit only on a pilot scale so far – for about \$2 per kilogram at the cheapest. Finally, there is "green" hydrogen, produced by electrolyzers running off renewable electricity. For the most part, this costs upwards of \$4 a kilogram.

When it comes to decarbonisation, "there's no point in grey hydrogen", says Rob Gibson at



In 2019, a project heated homes in the Netherlands with 100 per cent hydrogen for the first time



A hydrogen car refuels at a filling station in Germany

4 SUPPORTING THE GRID
Firms running electricity grids like hydrogen. The National Grid ESO in the UK says it must be deployed if we are to achieve net-zero emissions, and sees hydrogen supplying the flexibility that natural gas does today, by providing electricity when wind and solar output is low, or heating during cold snaps. "It has the potential to provide a lot of flexibility," says Rob Gibson at National Grid ESO.

National Grid ESO, which runs the UK's electricity transmission network. But a move towards large-scale green hydrogen production would be very costly, says Evangelos Gazis at Aurora Energy Research in Oxford, UK. This is where blue hydrogen comes in. "If we want to reach scale, probably [blue] will be inevitable," says Gazis. Others, such as Ralf Dickel at the Oxford Institute for Energy Studies, make the case that blue hydrogen is needed in the short term because using renewable electricity to displace coal and gas power plants achieves deeper CO₂ curbs than using it to make green hydrogen.

Four of the biggest existing blue hydrogen schemes are in North America, and the UK government is funding three trial projects. Some advocates argue that such schemes will be an enabler for green hydrogen, helping to build infrastructure to tackle the fiddly question of getting hydrogen to where it is needed (see "A devil of a detail", page 48). Others see blue hydrogen very differently. Because it still involves extracting gas, oil and coal, Friends of the Earth Europe has branded it "fossil hydrogen", a lifeline for struggling fossil fuel firms.

Certainly, the sponsors of a group such as the UK's All-Party Parliamentary Group on Hydrogen are a who's who of fossil-fuel interests, including Shell, petroleum refiner Equinor, gas network firm Cadent and gas boiler-maker Baxi. But Tengler doesn't buy the argument that such support is a cover for business-as-usual. "Just because they are fossil-fuel companies, we shouldn't exclude them from the future," he says.

There is, however, the undeniable problem that blue hydrogen doesn't capture all the CO₂ released while making the gas. A first CCS stage removes between around 50 and 70 per cent. Adding a second, costly step takes that to 85 to 90 per cent, with some pioneering projects aiming for more. Equinor's H2H Saltend blue hydrogen scheme near Hull, UK, should capture 95 per cent of CO₂ using an alternative to steam reformation known as autothermal reforming.

Still, for most blue hydrogen schemes, at least 10 per cent of emissions aren't captured. ➤

"Offsetting carbon emissions from hydrogen might need a forest the size of Spain"

A DEVIL OF A DETAIL

While hydrogen has many potential advantages as an energy carrier (see main story), it poses some significant problems. While containing a lot of energy per unit mass (high gravimetric energy density), hydrogen takes up a lot of space (low volumetric energy density). What's more, hydrogen molecules are so small they can leak out of a container.

Both factors make storing and moving it problematic. "Hydrogen is a devil of a thing to transport," says Thomas Baxter at the University of Aberdeen, UK. "That's why most hydrogen plants are adjacent to the use."

It means visions of countries with big renewable electricity generation resources becoming exporters of "green" hydrogen are just that for now, visions. Such ambitions are a key plank, for example, of Australia's National Hydrogen Strategy, published in November 2019, but are seen as a long way off, given the volumes required and the extra costs of liquefying hydrogen and shipping it. "For the time being, we would expect local production is where all the projects will be," says Simon Bennett at the International Energy Agency.

To fulfil hydrogen's potential, more transport capacity will be needed generally, be it by tanker truck, ships or pipes – many of which will need upgrading to carry hydrogen without leaks.

Tengler calculates that offsetting such carbon emissions with reforestation would require an area between the size of England and that of Spain, which is about four times as big. The scale of offsetting depends on what fossil fuel the hydrogen is extracted from and how much is being made by 2050.

He still thinks it is worth it, on the basis that using blue hydrogen still creates fewer emissions than burning coal, oil or gas. "There is that portion of emissions that just don't get captured. Does that mean we don't do it? I would say we still probably should. If there's the option of blue or nothing, then do blue," says Tengler.

Jan Rosenow at the Regulatory Assistance Project, a non-profit organisation that works to expedite a clean-energy transition, disagrees. He likens blue hydrogen to the coal industry's attempts 15 years ago to promote "clean coal" plants fitted with CCS. That never happened, because the rapidly falling cost of alternatives including renewables rendered it uneconomical.

If not blue hydrogen, then what are the prospects for green hydrogen? The EU, for example, has less than 1 gigawatt of electrolyser capacity now, but in July 2020 it set ambitious targets of 6 GW by 2024 and 40 GW by 2030. Germany is working with Morocco to build a project using solar power.

A dizzying cast of big companies have entered or are planning to enter the green hydrogen fray, including oil giants Repsol and Shell and the world's biggest offshore wind farm builder, Ørsted. Spanish electricity company Iberdrola is building a solar power plant to create green hydrogen in 2021, initially for conventional uses such as making fertiliser. "When we develop enough technology and scale, we can go for other sectors like the hard-to-abate, lorries, probably planes," says Samuel Perez at Iberdrola. Analyst Rystad Energy, based in Norway, counts 60 GW of green hydrogen projects planned globally – but it expects only half will appear by 2035 due to high costs.

Closing the gap between the price of green and grey hydrogen will take time. Producing one kilogram of hydrogen requires about



AIRBUS



ALSTOM/CHRISTOPH BUSSE

5 HEAVY INDUSTRY

Steel is one of the world's biggest carbon emitters, partly due to the coking coal used in the production of the metal from iron ore. In August, operations started at a steel-making plant in Sweden to use hydrogen instead of the coal, which produces water instead of carbon dioxide. The project, called HYBRIT, aims to make fossil-free steel commercially available by 2026. Any scale-up will require green or blue hydrogen (see main article) to make the switch worthwhile.

Oil refineries are one of the biggest users of hydrogen today, mainly to lower the sulphur content of diesel fuel. That is partly why projects such as Ørsted's Gigastack hydrogen production plant in the north-east of England have sited an electrolyser, powered by an offshore wind farm, next to a refinery.



Airbus aims to get zero-emission hydrogen planes flying by 2035



A train powered by a hydrogen fuel cell near Vienna, Austria, in 2020

50 to 55 kilowatt-hours of electricity (a medium-sized UK home uses about 8 kWh a day on average) and 9 to 10 litres of water. Up to 86 per cent of the costs of green hydrogen are for electricity to power the electrolyzers. But wind and solar power costs have dropped rapidly in the past decade, and are expected to fall further.

The electrolyzers themselves account for the remaining cost. They are an old technology, but one that its makers claim can be made cheaper. Graham Cooley at UK manufacturer ITM Power says a 10 megawatt electrolyser costs half as much as it did three years ago, and the price will fall further, especially because of developments in China, now a major manufacturer of these devices.

Duncan Clark at Ørsted, which is in phase two of its Gigastack project using a wind farm off the Yorkshire coast of the UK to supply green hydrogen to a nearby oil refinery, says the technology is at a "special moment", akin to where offshore wind power was a decade ago before costs dropped dramatically and

installations proliferated. "Only a few things are big and interesting enough to rival offshore wind, and green hydrogen is one of them," he says.

Even so, government interventions are likely to be needed, such as subsidies to make green hydrogen cheaper and carbon taxes to make grey hydrogen more expensive. "The market in the next 10 years is likely to be policy-driven. There will be a strong reliance on public funding for projects," says Bennett.

Carry on regardless?

Hydrogen's success may in the end be decided by society's willingness to pay for it. Green hydrogen will need billions, either through taxation or energy bills: Bloomberg New Energy Finance estimates that it will require \$150 billion over the next decade globally to bring the cost down to a competitive level. "Someone has got to pick up the bill," says Bennett.

Nonetheless, Bennett is optimistic that

6 MAKING GREEN AND BLUE

Shell is among the companies exploring whether the port of Rotterdam in the Netherlands could host the world's biggest green hydrogen scheme. Spanish oil firm Repsol is eyeing the possibility of making green hydrogen next to its refineries. Far bigger green hydrogen projects are being floated, such as Australia's vast "Asian Renewable Energy Hub" to use renewable electricity to produce hydrogen for use domestically and for export to Asia.

Blue hydrogen projects, which use natural gas to make hydrogen but capture most of the carbon dioxide that is usually released in the process, include Equinor's Saltend plant in the UK. The company hopes to make a final investment decision on this in 2023. It has applied for UK government funding. Other blue hydrogen proponents include fossil fuel companies such as Woodside, Australia's biggest oil and gas producer, and the government of Alberta in Canada, which hopes to use the approach to reduce CO₂ emissions in the state, which is better known for its highly polluting tar sands oil fields.

the current round of hype over hydrogen is different. This is partly because of the near-unanimity from different industries on its potential and partly because, for many hard-to-abate sectors, we have few alternatives on the table. "If we don't have [clean] hydrogen available by 2030 or 2040, we think we're going to be in a sticky place for some of these sectors," says Bennett.

"There are certainly risks on being overly bullish on the future hydrogen economy," he says. "But I think it's a bad time to be an out-and-out sceptic because there's clearly momentum and funding going into projects in the short term regardless." The question today no longer seems to be if hydrogen will help us fight climate change, but a matter of whether it ends up as the star turn or just a bit player. ■



Adam Vaughan is chief reporter at *New Scientist*. You can follow him @adamvaughan_uk



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Citizen science

Games for your brain

You can help advance understanding of mental health conditions by playing games on the Brain Explorer app, finds **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 or tablet
The Brain Explorer app
brainexplorer.net

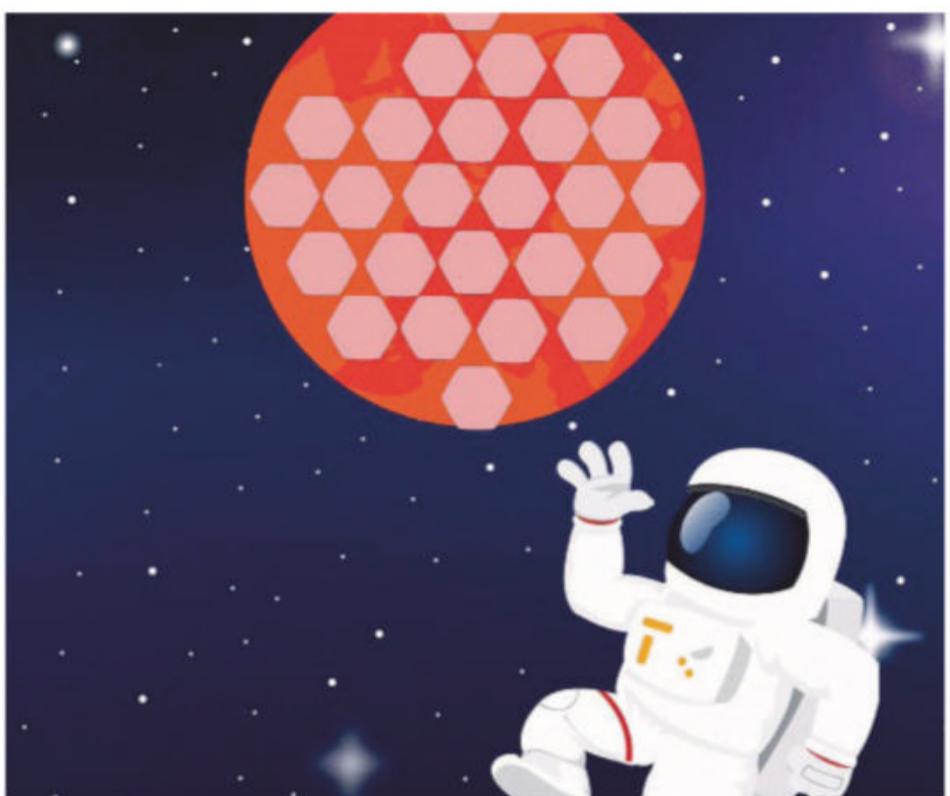
OUR brains hold the key to understanding how mental health conditions first develop. All of us possess traits related to psychiatric conditions to some extent. That's why researchers are looking to you and me – and the population at large – to help them better understand the origins of common mental health conditions, including depression, anxiety and obsessive-compulsive disorder (OCD).

Last year, the World Health Organization described mental health as one of the most neglected areas of public health, even though, globally, close to a billion people live with a mental health condition. To gather more data on how our brains work and how common mental health conditions arise, Tobias Hauser at University College London and his colleagues launched the Brain Explorer citizen science project.

All you have to do to participate is download the Brain Explorer app on your smartphone and start playing games, interspersed with brief questionnaires.

My favourite is *Treasure Hunt*, in which, as a space miner, you must search for rare, buried treasure on different planets. The game gives you a chance to investigate what type of treasure is the most abundant on each planet, and indirectly tests how decisive you are by looking at the way you gather information.

In an earlier study, Hauser and his team found that adolescents with OCD tended to gather more information on average than



BRAIN EXPLORER

those without. He hopes to study how this extends to the wider population with anonymised data from Brain Explorer.

This may be helpful for informing treatments too. "In our lab, we've used this kind of task previously in the context of drug studies," says Hauser.

He and his team found that people given a drug that blocks a brain chemical called noradrenaline became more impulsive and tended to gather less information before making decisions.

Hauser suspects the population-level data will also help us better categorise mental health conditions. "Many people that score high on anxiety also score high on depression and so on. So the boundaries between disorders

are not very clear," says Hauser. "What we call one disorder, like OCD, is probably consisting of multiple distinct neural impairments and processes."

Using data from the app, he says, it may be possible to tease apart different clusters of behaviour and psychiatric traits associated with different mental health conditions.

About 4000 people have downloaded and played on the app since it first launched in December. "This is over 100 times more than the number of participants we have in our normal lab research studies," says Hauser. ■

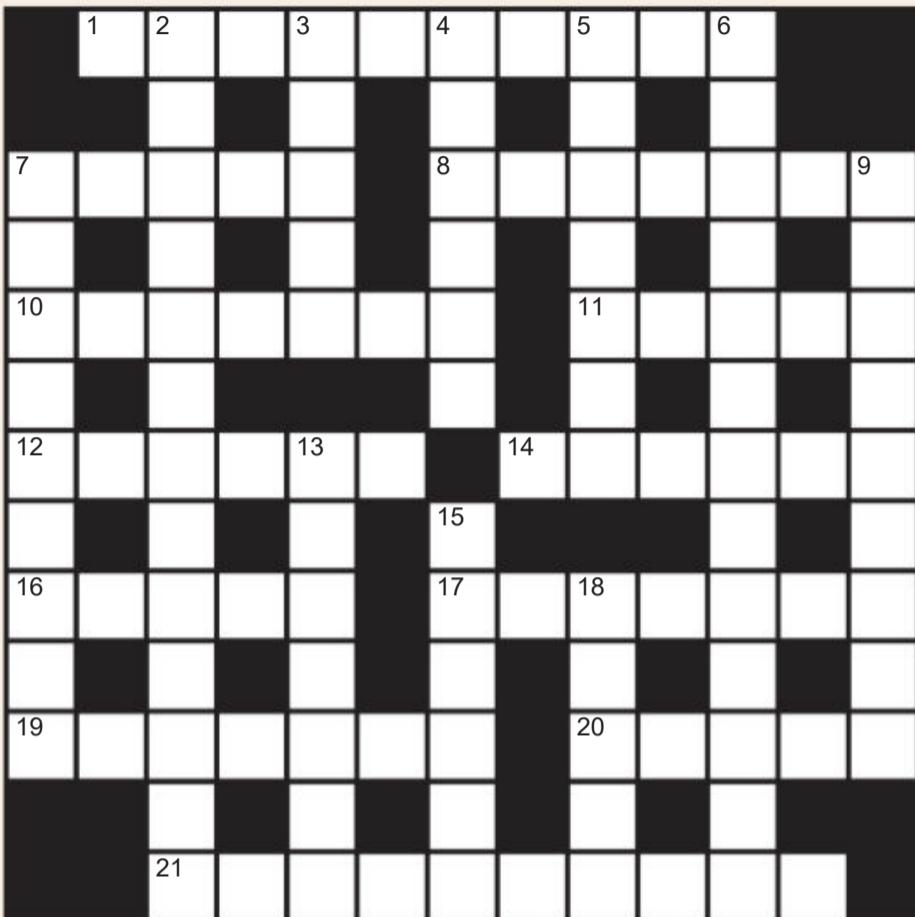
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Next week

Science of cooking

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

Cryptic crossword #50 Set by Rasa



Scribble zone

Answers and
the next quick
crossword next week

ACROSS

- 1** Waves at accommodating Conservative hill dweller for something to reduce tension? (10)
- 7** Daughter committed to reversing defeat for English house (5)
- 8** Mashed tuber added to the empty measuring vessel (7)
- 10** Virus variants initially reproduce in dirty spots (7)
- 11** Physicist Virginia takes in bad lot (5)
- 12** Musician Brian? Yuck, knock it off (6)
- 14** Draw out pests tail first with that object (6)
- 16** Avoid hail at centre of vortex (5)
- 17** Unstable element destroyed a ruin next to well (7)
- 19** Almost affix mosaic piece designed to be touched (7)
- 20** Eccentric earls' beam (5)
- 21** Northern regions feature two hairstyles with split ends (10)

DOWN

- 2** Plain-clothes officer arranged con procedure, arresting five (10,3)
- 3** Agents in pursuit of whistle-blower backing up physicist (5)
- 4** Ancient unit houses southern artist (6)
- 5** After abandoning church, chief opponent makes appearance (7)
- 6** Story excerpts probing lower ten rare events (5,8)
- 7** Hypercube experiment has raised concerns (9)
- 9** Tom involved in second-hand transaction, returning neoprene, for example (9)
- 13** Bolder jerk upset over rise in disorder (7)
- 15** Terrible reek surrounds 17A, seen with a cry of epiphany (6)
- 18** Remove head from beer-and-juice drink for Irene of Holmes lore (5)

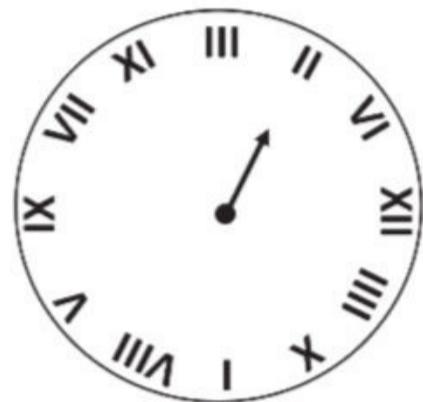
Quick quiz #87

- 1** Remains of the hominin *Homo antecessor* were first discovered in which country?
- 2** Coprophagy is the consumption of what?
- 3** In what year will Halley's comet next be visible from Earth?
- 4** A vertical or nearly vertical shaft in a glacier is known as what?
- 5** Who invented the first commercial synthesiser in 1964?

Answers on page 55

Puzzle

set by Holly Bimbing
#99 Around the clock



Pranksters have tampered with the school clock. They have removed the minute hand, repainted the numbers so that some or all of them are now in the wrong position and left the clock lying on the desk so there is no way of telling which is the right way up.

The note they left says: "We won't tell you how many numbers are in the right position because if we did, you could work out the time."

The hour hand is pointing directly at the number 2. What time is it?

Answer next week



Our crosswords are now solvable online
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"The trouble with the world
is that the stupid are cocksure
and the intelligent are full of doubt."
Bertrand Russell



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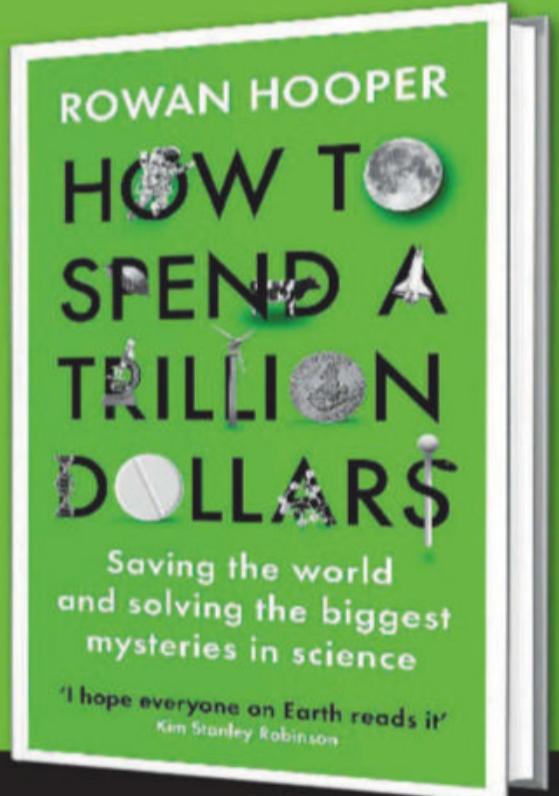
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Rowan Hooper doesn't have a trillion dollars – but if he did...

'Original and ingenious...
I hope it sells a trillion.'

PHILIP PULLMAN



P
PROFILE BOOKS

THE ULTIMATE THOUGHT EXPERIMENT – OUT NOW

Right, wrong

Why do some people struggle to tell left from right? (continued)

Bob Ladd

Edinburgh, UK

None of the previous answers to this question stepped outside a broadly European frame of reference, which takes for granted that left and right are part of the natural order of the world.

There are plenty of languages and cultures that don't use these concepts, including many that use "geocentric" rather than "egocentric" phrases to talk about spatial relations, for example, "to the east of you" rather than "to your left". As long as everyone shares the frame of reference, either system works fine.

Bob McCrossin

Cooroy, Queensland, Australia

Left/right orients the world with respect to you. The Guugu Yimithirr people of north Queensland orient to the cardinal points of the compass, for example "look out for that cassowary to the north of you".

This internal compass is imprinted from infancy and it makes it hard to get lost in the bush. Many peoples use this

"Recruits had hay attached to their left boot and straw to their right. The command to march was then 'hay-foot, straw-foot'"

system to position themselves, and it must be very satisfying to orient to the world rather than try to make the world orient to your egocentric self.

Talia Morris

Cape Tribulation, Queensland, Australia

I have some degree of left-right confusion, but it is acquired rather than innate. It developed during my school drama training. There, we were taught the terms "stage



DIANA BOGUTSKAYA/ALAMY

This week's new questions

Trouble brewing Is there any harm in drinking too much tea? I drink a lot of it and notice how much it stains mugs, so what impact does it have on my body? *Josie Cochrane, London, UK*

Meta memory When I can't remember something, but know that the memory is in my head, how do I know that I knew it? *Peter Smith, Cropston, Leicestershire, UK*

left" and "stage right", meaning right and left as seen by the audience, but the opposite as seen by the actors.

Nigel Dodd

Cheltenham, Gloucestershire, UK

It is a huge relief to find that I am not alone in having an issue with telling left from right.

Some years ago, I took up salsa dancing. Distinguishing my own left and right was hard enough, but relating those concepts to my teacher who may be facing in any direction was nearly impossible. I would lend my watch to the teacher simply to have a label attached to his left wrist.

My car has identical control stalks to the left and right of the steering column and I get them confused, which is unfortunate,

since pulling up on one of them signals right while pulling up on the other puts the car into reverse.

I could go on. However, there may be some benefits. I have no trouble driving on the "wrong" side of the road when abroad and using a car with all the controls reversed. My brain doesn't seem to care if everything is reversed.

Keith Ross

Villembits, France

In the previous answers to this question, there were plenty of comments confirming that left-right confusion is common, but none gave any explanation as to why. I have always blamed my left-right difficulty, together with my mild dyslexia, on having differently handed parents.

My mother was strongly left-

handed and my father strongly right-handed. My brother, fully left-handed, has no difficulty distinguishing left from right.

I am weakly right-handed: I dig the garden left-handed, I play table tennis with either hand, but write with my right hand, which I use preferentially in most activities. My sister, though predominantly left-handed, plays tennis and knits right-handed and also finds it hard to sort left from right.

Now retired in France, I still find it difficult to judge which side of the road to walk on in order to face oncoming traffic.

Ken Jensen

Gibsons, British Columbia, Canada

Recruits to the army that fought the British in the American Revolution were almost exclusively farmhands who had difficulty with the concept of left and right. As a result, it was difficult to teach them to march in synchrony. The army sergeants solved the problem by recognising that these men understood plenty about life on the farm.

The recruits had pieces of hay attached to their left boot and straw to their right. The command to march was then "hay-foot, straw-foot" rather than left or right. This worked a charm, apparently.

Helen Bennett

Oxford, UK

In learning to tell left from right, childhood piano lessons paid off as I could visualise myself sitting at a piano; my left hand was the one that played the low notes.

Michael Paine

Beacon Hill, New South Wales, Australia

This discussion reminds me of a devious challenge put to undergraduate engineering students: using only words, explain to an alien the difference between left and right.



Want to send us a question or answer?

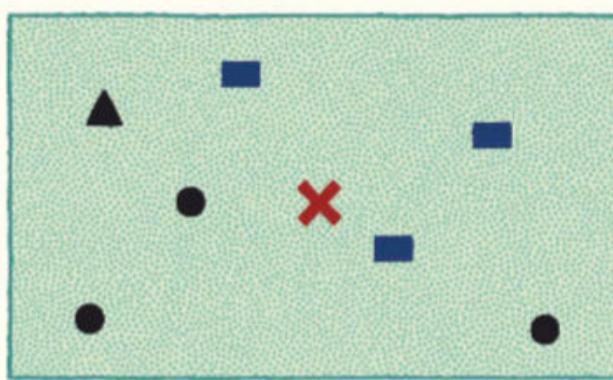
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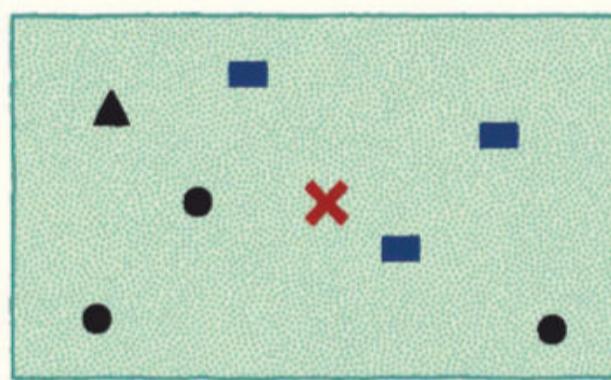
REWORKING MY PRIMATE FEEDING STUDY DUE TO COVID RESTRICTIONS

ORIGINAL VERSION



- MOTION-ACTIVATED CAMERAS
- 1000 km² OF TROPICAL FOREST
- ▲ MOUNTAIN GORILLA
- MONKEY
- ✗ FRUIT TREE

NEW VERSION



- MOTION-ACTIVATED CAMERAS
- KITCHEN
- ▲ SPOUSE
- OFFSPRING
- ✗ BISCUIT TIN

In step

When I go walking with my wife, six of her paces are equivalent to five of mine. Does this mean she gets more exercise than me?

Anthony Woodward

Portland, Oregon, US

It all depends on what you mean by exercise. Exercise requires us to do work, and this is calculated by the force that is used multiplied by distance moved. For their entire walk, the husband and wife in question cover the same distance. However, the force used may differ. Newton said force is mass multiplied by acceleration. If the wife weighs less than the husband, she will have done less work, and in that sense got less exercise, however many steps she took.

Let us consider each step. You might think that most of your energy goes into forward motion when walking. In fact, only a tenth of the force exerted by your foot on the ground contributes to this. The remainder is used to lift half your body off the ground so that the leg

"Most of the energy used when walking isn't for forward motion, but to lift one half of your body off the ground"

on that side can move forward, and this effort is probably similar for both people in question.

Another way of assessing the intensity of exercise is in terms of the energy used. The graph of energy use per kilometre versus speed is U-shaped. One study found the most energy-efficient walking speed is 5.6 kilometres per hour; going faster or slower than this requires more energy to cover the same distance. The bottom of the U-shaped curve is fairly flat, so that a walking speed 15 per cent faster or slower than that hardly increases the energy cost.

The difference in stride rates between the husband and wife outlined in the question is just 17 per cent, suggesting that their energy expenditures are very similar. Walkers tend to choose

a stride rate that requires the least energy expenditure.

Aerobic exercise has many health benefits, and these will be the same for the husband and wife on the walk, irrespective of the number of steps each takes.

Brian Horton

West Launceston,
Tasmania, Australia

When we walk, our arms and legs act like a swinging pendulum. A long pendulum has a slower natural frequency than a short pendulum. Therefore tall people will find it easier to swing their arms and legs at a slow tempo, whereas short people will swing them at a higher one.

As a result, a short person will take more steps per minute than a tall person, but they may both be able to walk comfortably at the same speed, despite a difference in steps per minute. Therefore, the energy used per minute isn't just related to steps per minute, because a shorter person can walk at a faster tempo than a tall person with the same effort. ■

Answers

Quick quiz #87

Answer

1 Spain

2 Faeces

3 2061

4 A moulin

5 Robert Moog

Quick crossword

#75 Answers

ACROSS 1 Badger, 4 Sneakers, 9 Beauty, 10 Magic eye, 12 Lutetium, 13 Grease, 15 Salt, 16 Strabismus, 19 Accelerate, 20 Acre, 23 Reject, 25 Gremlins, 27 Learning, 28 Pigeon, 29 Cascades, 30 Enzyme

DOWN 1 Bubbles, 2 Diastolic, 3 Entity, 5 Neap, 6 Acid rain, 7 Enema, 8 Siemens, 11 Vulture, 14 Battery, 17 Machinery, 18 Placenta, 19 Acrylic, 21 Essence, 22 Amnion, 24 Jeans, 26 Once

#98 Puppies galore!

Solution

Harriet has 10 puppies and Matilda has nine. A little thought should convince you that it isn't possible for Harriet to have more males AND more females than Matilda, which means she either has more males OR more females.

Since there is no bias towards males or females, both outcomes must have the same chance, so the chance that Harriet has more female puppies than Matilda is 50 per cent.

Through the motions

A strange feeling of relief and gratification floods through Feedback as, after years of straining, science finally plops out an answer as to how wombats produce cube-shaped faeces.

This question has been hanging in the air for some time, with preliminary results having emerged in 2018. But the job remained half-done until the publication by bioengineer Patricia Yang and her colleagues of the definitive paper, "Intestines of non-uniform stiffness mold the corners of wombat feces", in the journal *Soft Matter*. Yang's previous research record includes finding that all mammals weighing over 3 kilograms clear their bladders in 21 seconds (plus or minus 13 seconds), regardless of body size.

Now, co-opting the massed ranks of the Australian wombat research establishment to supply intestines for dissection and employing some hardcore fluid dynamics modelling, her team concludes that wombat number twos require peristaltic contractions of gut regions varying by a factor of two in thickness and four in stiffness to produce pellets with flat faces and sharp corners.

As ever, Feedback salutes the onward march of science. But we are left with that age-old criticism: it's very good at telling us the how, but less good at telling us the why.

Bird brain

Also asking why is Bonita Ely, who writes in from Marrickville, New South Wales, Australia, with a touching story of a loving pair of pigeons, who perch under the eaves of her neighbour's roof on an electrical junction box. "He brings her bits of grass to make a nest that immediately blow away in the wind," she writes. "She coos encouragingly, and lays eggs that fall off the box and break on another box directly below. They've been doing this for years."

Rather ruining the moment, Bonita adds that at least their genes won't be passed on. We pause, and consider this might depend on

Twisteddoodles for New Scientist



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how many years "years" is. If it extends beyond a generation, this could mean that other pigeons have taken their place and it is an instance of the inheritance of stupid behaviour, stretching once again the conceptions of evolutionary theorists.

Wrong type of software

AppleDaily in Hong Kong reports that the railway system in Dalian, China, came to a standstill for up to 20 hours on 12 January when programs using the Adobe Flash Player software stopped running. This came after, in a long-trailed move, Adobe stopped supporting the software on 31 December 2020.

Whether the railway authorities apologised for the almost two-week delayed arrival of the disruption to the service isn't stated. However, the report continues that they "fixed

the issue by installing a pirated version of Flash at 4:30 a.m. the following day".

This is, we consider, an innovative response to the problems posed to crucial computer systems worldwide by obsolete "legacy" software (7 November 2020, p 44).

Meanwhile, news from Great Britain that its railways continue to run at historically high levels of punctuality during the UK's third lockdown suggests a rather more obstinate barrier to the running of an efficient railway: people wanting to travel on it.

Dare not speak its name

Feedback's all-seeing eye spots the appearance elsewhere in this issue of Roger Kneebone, professor of surgical education at Imperial College London (page 40). We mention this so you don't have to.

Foiled

Tony Rimmer writes in to query our ongoing references to the use of tinfoil hats to shield from unwanted electromagnetic radiation, alien mind control and the like. Surely, he asks, devotees of metallic headgear would use the much more widely available aluminium foil?

We think not, Tony. A brief survey of electromagnetic attenuation lengths in various metals – we never did get out much, and lately it has been just that bit less – satisfies us that tinfoil's considerably higher atomic weight affords vastly superior protection against probing photons. The question, indeed, must be why the tin in our foil was replaced by aluminium in the first place. Wake up, sheeple!

Big. Very big.

Feedback sometimes mocks miscued attempts to express the size of things in terms of the size of other things that are presumed to be more familiar. But Raffi Katz fears our esteemed colleagues may be going a little too far in the other direction to prove a point.

"Dinosaur found in Argentina may be largest land animal", we recently titled a story (23 January, p 18). Newly emerged titanosaur fossils, we went on to say, may represent "the largest land animal that scientists have ever found" – indeed, the researchers behind the find wrote, "probably exceeding the *Patagotitan* in size". This latter dinosaur is itself "sometimes claimed to be the largest land animal to ever exist", we wrote.

Regardless of the truth of that, we were told that the new find was "undoubtedly a huge animal, among the largest ever discovered". "Whatever happened to measuring creatures against whales or double-decker buses?", Raffi wails. We are chastened and bowed, and promise betterment in future.

To get a handle on the true size of the titanosaur, we refer you to an article from 2020, "The biggest dinosaur ever may have been twice the size we thought". ■

BIG THINKER SERIES

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