

New Scientist

WEEKLY January 30 – February 5, 2021

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a first vaccine shot?*

How deadly is the UK variant?

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the Denisovans, the lost people
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Cover image: Brian Stauffer

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Weekly

More coronavirus variants; lack of diversity in genetic databases; a contender for the largest ever dinosaur; what Joe Biden's presidency means for climate change.

Escape Pod

Our fabulous new podcast provides a dose of escapism: this is a coronavirus-free zone! This week, the team look at the maths icon Paul Erdős and the incredible relationship between plants and fungi.

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Newsletter

NEW

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ANDREAS FERNBRANT

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A twist of human fate

The story of the lost Denisovans shows the path our species might have taken

THE human story only becomes more intricate and fascinating. For hundreds of thousands of years, a mysterious group known as the Denisovans lived in the east of Asia – even as our species was emerging in Africa and beginning to spread around the world. Their homeland spanned thousands of kilometres and they existed as a group longer than we have as a species. Yet they were utterly unknown until 2010, when they were identified from DNA preserved in a bone fragment.

A decade later, the Denisovans remain enigmatic. We know they were a sister group to the Neanderthals, who lived in Europe and west Asia around the same time, and that they interbred with Neanderthals and with us. But only a handful of bones have been identified and we don't have a complete skull,

so it is impossible to reliably imagine what they looked like.

If we cannot know their appearance, can we at least guess at their minds? We now have evidence that they survived in the extreme environment of the Tibetan plateau, long before modern humans attempted it. Furthermore, in recent years,

“For millennia, our species seems to have advanced in lockstep with the Denisovans”

archaeologists have found tools and other artefacts that may have been made by the Denisovans (see page 34). The provenance of the more impressive objects is hotly disputed, but it seems that many of the tools really were made by this group.

On the evidence so far, the Denisovans

may have been creating the same sort of tools that Neanderthals, and our species, made at the same time. For millennia, the three groups seem to have advanced in lockstep. Only in the past few tens of thousands of years, long after our species' origin, did our ancestors start producing complex objects and art that surpassed that of the Denisovans and Neanderthals.

It is tempting to imagine that our species evolved greater intelligence at that time. But maybe it was simply that our population swelled, so the various groups needed ways to demonstrate their identities – and harnessed latent talents to do so. In that case, perhaps a small twist of fate would have been enough to lead the Denisovans to make these cultural breakthroughs first, and it would be us, not them, almost lost in the mists of time. ■

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**New
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New Scientist Escape Pod

Hello and welcome to the Escape Pod. Your flight will last about 15 minutes and we expect no turbulence, just a smooth, pleasant ride

Yes, this is a new podcast from *New Scientist*, with hosts Rowan Hooper, Anna Demming and Timothy Revell. This podcast won't include any references to coronaviruses or other unpleasant happenings on the planet below. There are plenty of other places you can find out about those.

Instead this is about escapism. Sit back, relax and let us whisk your mind away to... pretty much anywhere or anything that will inspire and distract you.

Do join us on the Escape Pod - A lockdown podcast from *New Scientist* to take your mind away from the relentless news cycle - and to brighten up your week. Tickets are free. See you then.

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Rowan
Hooper



Anna
Demming



Timothy
Revell





THIERRY MONASSE/GETTY IMAGES

European health commissioner
Stella Kyriakides

negotiations and didn't finalise the contract until August. That left little time to sort out supply issues.

By contrast, the UK finalised its contract with AstraZeneca in May. Peston also says that all these deals were on a "best effort" basis, given the challenge of producing such huge numbers of doses in record time.

"The European Union will take any action required to protect its citizens and rights"

AstraZeneca is charging all countries the same price apart from small adjustments based on local costs. The company declined to comment on specific details, but did confirm that it is supplying the vaccine on a non-profit basis. "The vaccine will be supplied at no profit globally for the duration of the pandemic," a spokesperson for AstraZeneca told *New Scientist*.

The EU has also ordered 600 million doses of the vaccine created by Pfizer and BioNTech. It received fewer deliveries than expected in the second half of January due to Pfizer upgrading its factory in Puurs, Belgium, but normal supply was due to resume on 25 January, with increased deliveries from 15 February.

Many less wealthy countries around the world have yet to procure any vaccine. There is a global initiative called COVAX, led by the World Health Organization (WHO), which is trying to ensure that poorer countries get a supply. It has raised \$6 billion to buy and distribute vaccines.

"More than 39 million doses of vaccine have now been administered in at least 49 higher-income countries," said Tedros Adhanom Ghebreyesus, director-general of the WHO, on 18 January. "Just 25 doses have been given in one lowest-income country. Not 25 million, not 25,000, just 25." ■

Immunisation

EU squeeze on vaccines

Vaccine producers exporting to countries outside the European Union, including the UK, will face new roadblocks, says **Michael Le Page**

THE European Union has taken a first step towards clamping down on the export of coronavirus vaccines after pharmaceutical firm AstraZeneca told the bloc it would deliver far fewer doses than expected in the next months. The EU hasn't stopped manufacturers from selling to outside nations, including the UK, but has taken a step towards this by requiring vaccine manufacturers to give notice before exporting.

"In the future, all companies producing vaccines against covid-19 in the EU will have to provide early notification whenever they want to export vaccines to third countries," said Stella Kyriakides, the EU commissioner for health, on 25 January. "Humanitarian deliveries are, of course, not affected by this. The European

Union will take any action required to protect its citizens and rights."

Even before it was clear whether any vaccine would work, many countries signed deals with vaccine-makers to provide set numbers of doses by certain dates. As part of these, countries paid in advance for the preparation of manufacturing facilities.

AstraZeneca was meant to deliver 80 million doses of its vaccine to the EU by the end of March. The EU hasn't yet approved this vaccine, but is expected to do so soon.

Last week, AstraZeneca told the EU that it would only be able to deliver 31 million doses. According to Reuters, this is because the EU

doses are being made at a vaccine factory in Belgium run by a company called Novasep that has faced production problems.

"This new schedule is not acceptable," said Kyriakides. She sent AstraZeneca a letter in response, asking questions such as how many doses have been made where and to whom they have been sent. "The answers of the company have not been satisfactory so far," said Kyriakides.

According to Robert Peston, political editor for ITV News, part of the problem is that although AstraZeneca reached initial agreements with several EU countries in June, the European Commission then took over the



Daily coronavirus news round-up

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Vaccines

Can you relax after one dose?

Millions of people have now received their first shot of a vaccine against covid-19. Where does this leave them, asks **Michael Le Page**

ABOUT 70 million doses of vaccines against covid-19 have now been administered worldwide, including in excess of 20 million in the US.

In the UK, where more than 7 million people have received a first dose, most people will be required to wait for about three months before they receive the second dose.

This has left many wondering how protected they are, and what measures they still need to take for their safety and that of others. Here's what you need to know.

Am I safe once I have had one dose of a coronavirus vaccine?

The short answer is no. "Don't for a moment imagine you are safe. That would be a horrific thing to do," says Danny Altmann at Imperial College London. "You absolutely can't remotely modify your behaviour until well after your second dose."

The first thing you need to know is that it takes at least two to three weeks for any protection to kick in after the first dose, so during this time you are just as vulnerable.

The second is that it isn't clear how much protection a single dose of any vaccine provides (more on this later), because the trials weren't designed to tell us

"Don't for a moment imagine you are safe. That would be a horrific thing to do"

this. What is certain is that no vaccine provides complete protection even after two doses. With the vaccine from Pfizer and BioNTech, about 1 in 20 people may still get symptomatic infections. With the vaccine made by AstraZeneca and the University of Oxford, as many as 1 in 3 people might still be vulnerable.



JOE GIDDENS/AFP VIA GETTY IMAGES

Third, your risk of catching the virus depends on how likely you are to be exposed to it. In countries such as the UK, Ireland and the US, levels of infection are currently very high.

"Individuals, even though they have been vaccinated, will be at more of a risk now than they were in the summer," says Matt Keeling at the University of Warwick, UK.

By contrast, countries such as Australia and New Zealand aren't rushing to vaccinate people. With the virus almost entirely eliminated there, people have near zero risk of infection.

If you get covid-19 despite being vaccinated, you can still become seriously ill and die. Some 10 to 20 per cent of infected people also get long covid – lasting symptoms such as fatigue and headaches. We don't yet know if these

symptoms will last months, years or even a lifetime, says Altmann. "This is really scary stuff."

And remember, it isn't just about you.

Can I still infect other people once I have been vaccinated?

Yes, there is a high chance that you can. And infecting just one other person might start a chain of infections that leads to many deaths over the coming months and years.

The vaccines' clinical trials were designed to tell if they prevent symptomatic infections. The billion-dollar question is whether vaccinated people who are protected against becoming ill can still get asymptomatic infections and pass the virus on to others.

It could be months before studies give us a clear answer, but

A woman gets the Oxford/AstraZeneca vaccine in Mansfield, UK, on 25 January

other lines of evidence suggest that this is likely. For instance, initial results from a study of healthcare workers by Susan Hopkins at Public Health England and her colleagues found that natural infection provides about 94 per cent protection against symptomatic infections for at least five months, similar to the best vaccines.

However, natural infection only provided 75 per cent protection against asymptomatic infections. At least some reinfected people had high levels of the virus and were probably infectious.

There is also evidence that the B.1.351 and P.1 variants of the coronavirus, that first emerged in South Africa and Brazil,



respectively, can partly evade the immune response, meaning that existing vaccines might not be as effective.

The bottom line is that, even after vaccination, you could be infectious without knowing it.

"In public spaces and the workplace, you'd absolutely want to take the same precautions you've been taking until more people are vaccinated," says Angela Rasmussen at Georgetown University in Washington DC.

In countries where it is allowed, however, Rasmussen thinks small meetings with family or friends who have also been vaccinated would be OK.

"You could see parents once you've all been vaccinated, for example," she says. "But ideally, you'd still want to take some precautions in these situations."

How much protection would I have after a single dose of a vaccine?

We don't know for sure. According to the clinical trials, the Pfizer/BioNTech vaccine is 52 per cent effective after the first dose, rising to 95 per cent after the second dose. The Oxford/AstraZeneca vaccine is 65 per cent effective after one dose, rising to 70 to 90 per cent.

The one-dose numbers were calculated by counting symptomatic infections in between the first and second dose. However, it takes at least two weeks for the immune system to ramp up in response to the vaccine and for immunity to start to kick in. So the UK's Joint Committee on Vaccination and Immunisation instead calculated one-dose efficacy by only looking at what happened after the first two weeks or so, but before the second dose.

It concluded that once that initial period had been taken out of the calculation, the efficacy of the Pfizer/BioNTech vaccine

at preventing symptomatic infections is around 90 per cent, and for the Oxford/AstraZeneca one about 70 per cent. It was because of these numbers that the UK decided to delay second doses so more people can get a first dose.

While this makes sense, the calculations are based on very few cases, so have big uncertainties. We need more data to get a better idea of first-dose efficacy. Studies of this are under way.

90%

Protection from illness one Pfizer shot seems to give after two weeks

In the meantime, there have been reports of a study at the Sheba Medical Centre in Israel finding only 33 per cent efficacy of the Pfizer/BioNTech vaccine at preventing infections two weeks after one dose. Keeling says we don't know enough about the study to draw any conclusions.

However, it seems this study was based on testing regardless of symptoms and counted both asymptomatic and symptomatic infections so even if the findings are correct it doesn't necessarily mean other estimates are wrong.

Is there any way to tell if the vaccine has worked for me?

Yes. Labs can measure the blood levels of the most important type of antibodies, known as neutralising antibodies, which block infection by binding to the part of the coronavirus spike protein that helps it get into cells.

While there is still debate about which aspects of the immune response give us protection, if people have high enough levels of neutralising antibodies, they should be protected from infection, says Altmann. "I would say they would be absolutely, totally safe."

Unfortunately, such tests aren't widely available – they are very different to the cheap, rapid antibody tests used in some places. In principle, though, testing of neutralising antibody levels could be used as the basis for immunity passports.

Such tests would probably have to be repeated at least once a year, because antibody levels fall quite rapidly in the months after infection or vaccination. In most people, they are thought to eventually stabilise rather than continuing to fall.

There is once again discussion about immunity passports, says Altmann, but there are big technical, logistical and ethical issues. "It's an absolute nightmare," he says. Nevertheless, he expects them to arrive in some form.

When will vaccination campaigns allow life to return to normal?

Not any time soon and maybe not fully for years.

"Vaccination is not a magic bullet in that its effect will not be instantaneous," says Anne Cori at Imperial College London.

People queue to receive a vaccine injection in Birmingham, UK



"The impact of vaccination will only be seen once we manage to get very high coverage."

This depends on how fast we can roll out vaccines and on how many people take them, says Cori, which is why everyone should get vaccinated as soon as they can.

Israel has already given one vaccine dose to about 45 per cent of its population and at least 78 per cent of those over 60. There are hints that this might be starting to make a difference. Not only is the number of cases starting to fall, the number of people becoming critically ill is declining even faster than the number of cases.

However, modelling studies by Cori, Keeling and others point to bleak conclusions. They suggest that even by April, when up to 30 million people in the UK, almost half the population, might be vaccinated, relaxing all restrictions could lead to an even bigger wave of infections than the current one.

In the worst-case scenario, if vaccines provide little protection against asymptomatic infections, there could be up to 6000 deaths a day in such a wave, according to Keeling's results. "This is not a prediction," he stresses.

In fact, even if restrictions are maintained until December, when the vaccination roll-out is complete, there could still be a major outbreak unless vaccination is around 85 per cent effective at blocking transmission.

The reason is that vaccines don't protect everyone from covid-19 and not everyone will get vaccinated, so there will still be millions of susceptible people.

"You can never get to 100 per cent protection in a population," says Keeling. "There are still dangers unless the vaccine works incredibly well at blocking infections." ■

South America

Herd immunity no-show

Most people in Manaus, Brazil, have had covid-19, but the virus is still spreading

Luke Taylor

HOSPITALS in the Brazilian state of Amazonas are collapsing under the strain of covid-19 once again. This is despite a high rate of coronavirus cases during the first wave of the virus, and suggests that if herd immunity by infection is possible, it may be harder to achieve than previously thought.

In Manaus, the capital of Amazonas, hospital beds are unavailable. People are queuing to buy oxygen tanks from private suppliers to try to treat family or friends, as oxygen supplies in hospitals were exhausted by 15 January. Oxygen donations from nearby regions are now being rationed. The state is “in the most critical moment of the pandemic”, said the state’s governor, Wilson Lima, on 15 January.

It is the second time that Manaus has been in crisis since the pandemic began. In May 2020, the region recorded one of the worst fatality rates in Central and South America, then the centre of the pandemic.

Poverty, crowded housing and lack of widespread access to clean water have fuelled the virus’s spread. Between March and October, 76 per cent of people in Manaus had contracted covid-19, according to a recent study co-led by Lewis Buss at the University of São Paulo (*Science*, doi.org/frmr).

“[The initial surge] created a favourable climate for a false victory over the epidemic in Manaus,” says Jessem Orellana at the Oswaldo Cruz Foundation in Brazil. “We had politicians, business leaders and a large part of the local population defending that Manaus... had already reached herd immunity.”

A preliminary version of Buss’s study suggested that the virus’s spread could have slowed due to herd immunity. State authorities justified their inaction on that



REUTERS/BRUNO KELLY

belief, says Orellana, and the public practised less social distancing. The second wave of cases has disproved the idea that the region has reached herd immunity. It also raises questions as to how the coronavirus remains so virulent in a region where the majority of the population has already been infected.

76%

People in Manaus, Brazil, who have covid-19 antibodies

Buss and his colleagues ran tests on 1000 blood samples from donors with no covid-19 symptoms, finding that 53 per cent of people had antibodies present.

“This serves as a lower bound on the prevalence of infection in Manaus and would be expected to confer an important level of population immunity,” he says.

The researchers then applied a

People in Manaus queue to buy oxygen after hospitals ran out

model to account for the natural decrease in antibodies over time. In total, they estimate that more than three-quarters of people in Manaus have coronavirus antibodies.

Using blood donor samples presents room for inaccuracies, as they don’t entirely reflect the general population. The model accounting for waning antibodies is also based on estimates. “But even if they are biased, it’s very likely that a large proportion of the population has been infected,” says Deepti Gurdasani at Queen Mary University of London.

“It raises a lot of questions about being able to reach the herd immunity threshold,” she says. “But more importantly, what it brings home is that even if you could reach the herd immunity

threshold in some way, which obviously hasn’t been reached in Manaus, the cost is huge.”

Experts have opposed the idea that herd immunity to the coronavirus can be achieved by most of a population becoming infected. In a 2020 memo, 7000 scientists, healthcare workers and public health professionals from around the world said that natural herd immunity could be impossible as it is unknown how long covid-19 antibodies last after infection.

The emergence of new variants of the coronavirus, some of which appear to evade antibodies of the original variant, have increased doubts about natural herd immunity. Existing vaccines could be slightly less effective for new variants, but they should still offer protection. They could also be updated to account for mutations.

A variant called P.1 has emerged in Manaus with similar mutations to the fast-spreading variant identified in South Africa. P.1 has been seen in Japan and is likely to have spread elsewhere.

The first reinfection caused by P.1 was reported in Manaus last week. “It is plausible to suggest that P.1 has some combination of properties that are producing the situation in Manaus,” says William Hanage at Harvard University.

It’s not yet clear what role it is playing in Manaus, given the widespread presence of antibodies in the local population. A higher transmission rate of P.1 may be raising the herd immunity threshold, or antibodies could be declining more quickly than expected, leading to reinfections.

It is more likely, says Hanage, that P.1 has evolved to evade those antibodies and is reinfecting people. This idea has only been supported in small-scale studies and needs further investigation. ■

Is the new UK variant more deadly as well as spreading faster?

Evidence is mounting that the variant first detected in the UK is more lethal, but there is no need to panic, reports **Michael Le Page**

IT APPEARS that the new coronavirus variant first identified in the UK is slightly deadlier as well as more transmissible than older variants. But thanks to improved treatments, the risk that people who are infected will die could still be lower in the UK than it was during the first wave of the pandemic last March.

"The additional mortality from the new variant is concerning," says Graham Medley at the London School of Hygiene & Tropical Medicine (LSHTM). But the main reason why so many people are dying now in the UK is the number of infections, he says. "If you want to reduce the number of deaths, you have to reduce the incidence. That is the critical thing."

There is now strong evidence that the B.1.1.7 variant is around 50 per cent more transmissible than previous variants.

Determining whether any variant is deadlier than another is much harder, given that there are far fewer coronavirus-related deaths than infections. It remains unclear whether the P.1 variant in Brazil and the B.1.351 variant from South Africa are any deadlier than previous variants. South Africa has reported

40 to 80 per cent higher mortality in the hardest-hit regions compared with its first wave, but attributes this to increasing pressure on the healthcare system.

To find out if B.1.1.7 is deadlier, researchers looked at what happened to around a million people who tested positive for the coronavirus in the UK. Of these, around 100,000 were very likely to have had B.1.1.7, based on tests.

Paramedics unload equipment at the Royal London Hospital



DAVID CLIFF/NURPHOTO VIA GETTY IMAGES

The researchers compared people infected with B.1.1.7 to matched controls who had other variants. In addition to matching people's age, sex and ethnicity, the researchers also attempted to account for the fact that hospitals in some areas were busier than others and might not have been able to provide the same level of care.

Four independent teams have now analysed this data, in various ways. All concluded that people infected with B.1.1.7 have a higher risk of dying, with two teams finding a rise of about 30 per cent, one a 65 per cent rise and one a 90 per cent rise.

"Any way that you do it, you get an estimate that is very similar," says John Edmunds, also at the LSHTM. Although these estimates may not seem that similar, a coronavirus variant could theoretically be 500 or even 5000 per cent deadlier.

A more transmissible virus is worse than a deadlier virus, says Edmunds. "Unfortunately, it appears this [variant] might be both."

While this sounds alarming, the overall risk of dying if infected remains low. For instance, during the first wave, the infection fatality rate was around 1 in 100 in high-income countries. It is thought to have fallen significantly since. "Treatments have been improving," says Peter Horby at the University of Oxford, who chairs the UK's New and Emerging Respiratory Virus Threats Advisory Group. "That may well offset any differences in this new variant."

For people who have had at least one dose of a vaccine, the risk of dying will be even lower still. So these findings are no cause for panic, but they are a reminder of how important it is that we all redouble our efforts to avoid becoming infected and infecting others. ■

Variant detection

Virus variants found in sewage before tests reveal them

VARIANTS of coronavirus can be detected in wastewater long before they are spotted by tests in people.

Those infected with coronavirus shed it in their faeces. Hundreds of municipalities around the world already test wastewater for the presence of the virus as part of their surveillance operations. Now research suggests they could also check which genetic variants are circulating to flag up

potentially dangerous new versions.

Kara Nelson at the University of California, Berkeley, and her colleagues recently extracted useful sequence information from San Francisco's sewage. Another team, led by Niko Beerenwinkel at ETH Zurich, detected the genome of the B.1.1.7 coronavirus variant – first seen in the UK – in Swiss sewage sampled in mid-December, two weeks before the first confirmed case of the variant in Switzerland.

"We've demonstrated it can work and are now trying to apply it at larger scales," says Nelson. Working with the California Department of

Public Health, her team hopes to have a wastewater sequencing system running in four weeks.

The virus is diluted in wastewater but is detectable if more than 1 in 1000 people are shedding it, says Sharon Peacock at the COVID-19 Genomics UK Consortium. That is a relatively low infection rate: parts of the UK have recently seen rates of about 1 in 30. The UK does sewage surveillance for coronavirus and is

"We are optimistic that it can be a really effective way to provide surveillance for large populations"

working on adding sequencing capabilities to it, says Peacock.

Wastewater monitoring has the added advantage of sampling everyone who uses the sewage system, not just those who turn up for a test or treatment. That includes asymptomatic carriers who may be spreading new mutants.

"We are very optimistic that it can be a really efficient and effective way to provide surveillance for large populations," says Nelson. It could be very useful in low-income countries that don't have the capacity or funds for mass testing. ■
Graham Lawton

Misinformation

Making a conspiracy theorist

The way websites moderate their content affects the spread of fringe views

Matthew Sparkes

CLAMPING down on conspiracy theories may not help tackle extremist views online, instead it might cause them to proliferate.

Shruti Phadke at the University of Washington in Seattle and her colleagues analysed 6 million posts from 60,000 people on social news aggregation site Reddit, as well as their memberships of user-created communities called subreddits, in an attempt to identify the roots of online radicalisation. All the people's profiles were roughly similar, but half of them were members of at least one subreddit focused on discussing political and scientific conspiracy theories.

Phadke's team found that downvoting or banning users for voicing controversial or inaccurate views was sometimes a precursor to people joining a conspiracy group, where they then faced little pushback and were further radicalised. Almost 9000 of those who eventually joined conspiracy groups had faced some sort of moderation, such as posts being removed, but only 3000 of those who didn't join such a group had.

Having content moderated made it 6 per cent more likely that someone would join a conspiracy group. Having posts downvoted by other users made it 19 per cent more likely (*Proceedings of the ACM on Human-Computer Interaction*, doi.org/frvj).

"It's as if they're being shunned by other communities, getting ostracised, and then they go into these conspiracy communities

Conspiracy theory groups like QAnon find followers on social media sites

and find a home for their thoughts," says Phadke.

She believes that the solution is to make moderation explainable and to use "gentle nudging", such as steering anyone expressing fringe views to reputable sources.

New Scientist asked Reddit about the findings but didn't receive a comment.

The difficulties of moderating extreme or inaccurate views online have long been apparent. Conspiracy theories such as QAnon have proliferated online, and former US president

Donald Trump's tweets fell foul of Twitter's terms of service this month and he received a lifetime ban.

During the early stages of the pandemic, social media platforms such as Twitter and Instagram began adding links to authoritative sources alongside users' posts about covid-19, but amid widespread criticism for allowing misinformation to spread, they have also started banning content that they deem particularly harmful.

Jaron Lanier at Microsoft Research and author of *Ten Arguments for Deleting Your Social Media Accounts Right Now* says that banning "is the only thing that's worked at all, as uncomfortable as it is".

When Facebook banned far-right group Britain First in April 2019, for example, the group was forced to rely on smaller social media sites like Gab. On Facebook, the group had 1.8 million followers but on Gab it still has only about 12,300.

"Over time you do reduce the threat to society," says Lanier. ■



REUTERS/PATRICK FALLON

Climate change

Extreme drought set to rise steeply by 2100

THE number of people living in extreme drought could hit nearly 700 million by the end of the century, more than triple the number today. The total area of land affected could also more than double by 2100.

Yadu Pokhrel at Michigan State University and his colleagues have modelled how the amount of water stored on land will change under varying degrees of climate change.

They studied a measure known as terrestrial water storage, which represents the sum of all water available on land, including water stored in canopies, snow, rivers, lakes and groundwater. To do this, they used hydrological models to predict the movement and distribution of water. These models take into account variables including rainfall, temperature, humidity and wind speed.

Under a high-emissions scenario, in which global carbon emissions peak around 2080 and decline afterwards, 688 million people, or 8 per cent of the world's projected

future population, could be in extreme to exceptional drought by 2100, compared with 200 million, or 3 per cent, in the period between 1976 to 2005. The global land area under extreme drought would also rise to 7 per cent, up from 3 per cent (*Nature Climate Change*, doi.org/ghsxwm).

People in the southern hemisphere will probably be disproportionately affected,

"If water use and climate change continue at the same rate, the impacts are going to be really severe"

particularly those living in Australia and the Amazon basin. Under such a scenario, two-thirds of land would also experience a reduction in terrestrial water storage.

"There's a need to impose stringent climate mitigating measures, and where possible to increase water use efficiency, primarily in the agricultural sector," says Pokhrel.

"If we continue using water at the same rate as the rate that we do, and if climate change continues at the same rate, the impacts are going to be really severe," he says. ■

Donna Lu

Artificial intelligence

Machine identifies songs from people's brainwaves

Matthew Sparkes

ARTIFICIAL intelligence has learned to identify the songs someone is listening to from their brain readings.

Derek Lomas at Delft University of Technology in the Netherlands and his colleagues asked 20 people to listen to 12 songs through headphones. The volunteers did this blindfolded and in a dimly lit room to minimise the effect of their other senses on the results. Each person's brainwaves were recorded using an electroencephalography (EEG) cap that detects electrical activity.

The EEG readings from each person were cut into short segments and used along with the matching music clip to train an AI to spot patterns between the two. The AI was then tested on unseen portions of the data, identifying songs with an accuracy of 85 per cent.

But the software struggles if it is trained on EEG data from one person and then attempts to identify a song when someone else listens to it. Accuracy in such tests dropped below 10 per cent (*CODS COMAD 2021*, doi.org/frks).

The researchers believe that this is due to each person's aesthetic response to a song being unique and people tending to focus on different elements of the music during training. Ultimately, however, they aim to identify aspects of EEG responses to music that are common to all humans.

Lomas hopes that this will further our understanding of the brain, as well as boost knowledge of how and why humans consume music.

"I think it's really provocative to think about how the combination of machine learning and high-density data from EEG can be combined to bring insights into moving emotional experiences, but also to figure out what's going on inside your head," he says.

Music is ultimately "just voltage fluctuations", he says. "And it's the same with the EEG." ■

Nutrition

Climate may undermine food security efforts

Donna Lu



PRAKASH MATHEMA/AFP VIA GETTY IMAGES

WARMING temperatures and changing rainfall patterns may reduce diet diversity among children around the world – and may even undermine efforts to improve food security.

Meredith Niles at the University of Vermont and her colleagues analysed the results of health surveys from more than 107,000 children in 19 countries – in Asia; North, south-east and West Africa; and Central and South America. The surveys were conducted between 2005 and 2009.

In the surveys, the diversity of a child's diet was quantified with a score based on their intake of foods from different food groups, including cereal grains, dairy products and meat. The data included details of each child's diet the day before they were surveyed.

On average, the children – aged 5 and under – ate food from 3.2 food groups out of a possible 10. But there was variation from country to country. Children in Colombia ate from 4.8 food groups on average, while those in Lesotho ate from just 1.8.

To study whether climate affected the diversity of the children's diets, the researchers linked the results from each country to 30 years of rainfall and temperature data in the surveyed regions. They found that higher long-term

19
countries included in the study, in Asia, Africa and the Americas

temperatures were associated with lower overall diet diversity for children everywhere except Central America.

There were shorter-term trends too. In North Africa and South America, there was typically a reduction in diet diversity in countries that experienced higher-than-average temperatures in the year prior to the survey. In Central America and West Africa, diets typically became more diverse in countries that experienced above-average rainfall in the previous year.

The researchers controlled for geographic and socio-economic

A woman selecting corn at a market in Kathmandu, Nepal

factors that could affect diet diversity, such as household wealth, and population and livestock density.

In some countries, the researchers say that the negative effect of climate change on diet diversity was so great that it outweighed the beneficial impact of development efforts focused on education, improved toilet facilities and poverty reduction. These negative impacts may even undermine efforts to improve food security, the researchers suggest (*Environmental Research Letters*, doi.org/frkx).

Diet diversity is a useful metric for regions with high rates of child malnutrition, says Daniel Mason-D'Croz at the Commonwealth Scientific and Industrial Research Organisation in Australia.

"That they're getting a fruit or a vegetable or animal product in addition to the rice or the maize [staple] – that's an important thing to know," he says.

Mason-D'Croz points out that the years the health surveys were done coincided with the 2007 to 2008 world food price crisis, during which food became much more expensive. The crisis was caused by many factors and not just climate change, and may have affected diets across the world.

"There were food riots in some of the countries that were in the study," says Mason-D'Croz. A follow-up study with more recent data could confirm more authoritatively the effect of climate in reducing diet diversity, he says. ■

Palaeontology

Under the bonnet

Strange fossil is the first to show an ammonite without its shell

Colin Barras

AMMONITES are among the most common marine fossils from the age of the dinosaurs, but no one has discovered one like this before. It was found in Germany and shows one of the swimming marine molluscs without its distinctive spiral shell (pictured bottom right), offering a rare opportunity to study ammonite internal anatomy.

Christian Klug at the University of Zurich, Switzerland, recognised the shield-like structure on the left as part of a *Subplanites* ammonite jaw, but the rest was a mystery until a colleague photographed the specimen under ultraviolet light to highlight subtler features.

Through comparison with other molluscs, Klug and his colleagues could spot an eye (the small dark spot in the bottom-left) and the gut (the curved pink area on the right). All other body parts are present too, except for the arms (*Swiss Journal of Palaeontology*, doi.org/frkh). ■

MAIN: KLUGET AL (2021); RIGHT: BJORN WYLEZICH/ALAMY



Geology

Volcanic rock slide travelled 60 kilometres

AN ACTIVE volcano in Ecuador has collapsed twice in the past 250,000 years, causing vast rock slides that reached more than 60 kilometres away. It could happen again, but it isn't possible to predict when – although there is no reason to think it is imminent.

Sangay lies on the eastern edge of the Andes mountains, overlooking the western edge of the Amazon rainforest.

"It's a volcano that's in the jungle," says Viviana Valverde of the Geophysical Institute in Quito, Ecuador. As a result of its remote location, for decades it wasn't regarded as a major risk, but she says that is now changing.

Since the late 1990s, it has been

known that "the volcano has two scars", says Valverde. These suggested that the eastern mountainside had collapsed twice within the past 250,000 years.

Valverde and her colleagues investigated 541 rocky hummocks to the east of Sangay, and found that many of them contained rocks from the volcano. These were left behind by at least two rock slides, known as debris avalanches, that took place when part of the volcano collapsed.

The debris avalanches reached at least 60 kilometres from the volcano's crater – much further than such rock slides were thought to be able to travel from Sangay. Several towns lie within

the debris avalanche zone.

Most volcanoes experience occasional flank collapses, but the debris avalanches don't usually travel so far. Valverde says Sangay's height is key – it rises 4000 metres above the surrounding landscape.

The earlier debris avalanche cannot be precisely dated, but based on the ages of the volcano's rocks, the team estimates it

happened between 250,000 and 100,000 years ago. The second debris avalanche happened around 30,000 years ago, based on the carbon dating of a woody branch the researchers found buried among the rocks (*Journal of Volcanology and Geothermal Research*, doi.org/frjs).

Sangay remains highly active, so Valverde says a third collapse and debris avalanche is possible – but there is no way to say when.

It is difficult enough to predict major volcanic eruptions, but a further complication is that the debris avalanches may have been partly triggered by earthquakes, which are also hard to predict. ■

Michael Marshall



Sangay volcano rises above the jungle

ECUADOR/PLANET/GETTY IMAGES

WHAT IS AVAXHOME?

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Safer, than torrent-trackers

18 years of seamless operation and our users' satisfaction

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Technology

Being graded by an AI could improve your piano playing

Matthew Sparkes

AN ARTIFICIAL intelligence that can grade the skill of a pianist with near-human accuracy could be used in online music tutoring.

Brendan Morris at the University of Nevada, Las Vegas, and his colleagues selected almost 1000 short video clips of people playing piano from YouTube and got an expert pianist to manually grade each on a 10-point scale.

The researchers used half of these videos and their associated grades to train a neural network, a form of AI, creating a model that can assess piano playing in unseen videos. They then used the other half of the clips to test the model.

The team ran the test three times, first giving the AI access to just audio, then just video and finally to both together. The audio-only version was 65 per cent accurate when compared with the grades assigned by an expert, increasing to 74 per cent for video-only and 75 per cent for the combined version (arxiv.org/abs/2101.04884).

Morris says that although the software works well, it is unclear how the AI chooses its grades. This lack of transparency is a common problem with neural networks.

"We don't know specifically what it's doing. As with a lot of AI, we can't say exactly what's happening," says Morris.

The software could be doing anything from identifying a pianist's ability to play two widely separated notes with one hand to their ability to quickly play notes at large intervals, he says. The AI has probably identified hundreds of small clues like these and taken them all into account in its assessment, he says.

Even without fully understanding how it works, Morris hopes the technique will eventually prove useful in tutoring, potentially reducing costs and lowering barriers to learning piano. ■

Quantum computing

Hyperchaos could help us build better quantum computers

Leah Crane

QUANTUM computing can be chaotic, but key properties of that chaos may actually help us develop useful devices. That is the finding of a study of the behaviour of quantum bits, or qubits, which has shown that their chaotic nature may be easier to predict than thought.

Quantum computers use qubits as the basic unit of memory, the same way regular computers use bits. However, while a bit can only be in one of two states – a 1 or a 0 – a qubit can be in a combination of the two, giving it an advantage over its classical counterpart. When

"Systems containing five or more qubits display not just chaos, but hyperchaos"

qubits are grouped together, such as on a quantum computer chip, they can display chaotic behaviour, each oscillating between different values. That can make changes in their final states hard to predict.

Alexandre Zagoskin at Loughborough University in the UK and his colleagues simulated this behaviour for certain types of quantum computing systems. They found that systems of five or more qubits display not just chaos, but hyperchaos, which makes their behaviour even more unpredictable.

"Chaos appears when a small difference in initial conditions causes a very fast-growing difference in the trajectory of the system's behaviour," says Zagoskin. "In hyperchaos, the trajectories run away from one another in many directions."

However, the chaotic dynamics of the system can be reined in by changing the properties of the energy

entering the system. That could make hyperchaos useful as a random number generator, one of the potential early uses of quantum computers.

More importantly, though, the researchers found that adding more qubits didn't make the hyperchaos in the system grow exponentially as they had suspected it would.

Instead, it grew linearly – each additional qubit added one more layer of chaos. This means the system is easier to describe mathematically – and hence simulate – than if adding qubits made chaotic behaviour shoot up (*npj Quantum Information*, doi.org/frvr).

"This system shows very non-trivial and new quantum phenomena which we have never seen before," says Shiro Kawabata at Japan's National Institute of Advanced Industrial Science and Technology. "In this sense, this system can be regarded as a new type of quantum simulator, a 'chaotic quantum simulator'."

Simulating quantum behaviour with classical computers is a challenge. If it

were possible to simulate lots of qubits precisely with a classical computer, there would be no need for quantum computers.

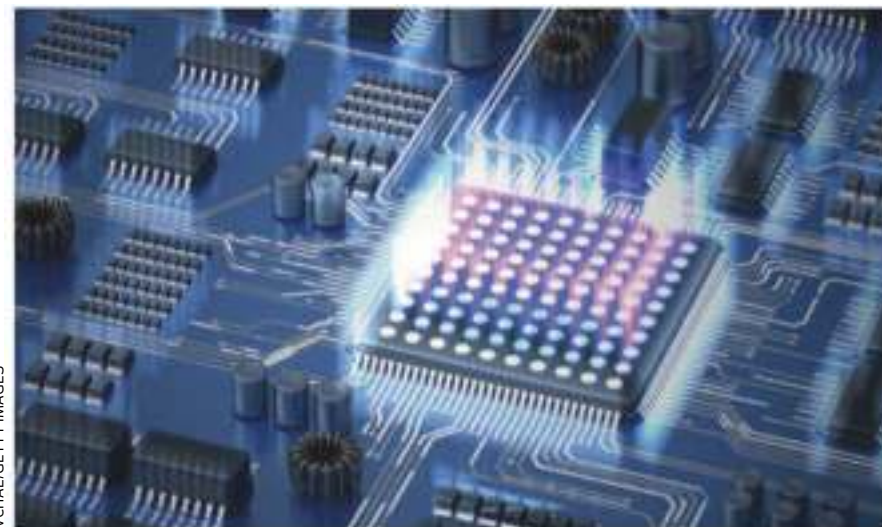
"We can calculate how a small group of qubits will behave, but we cannot extract from this information about how a realistic, large group of qubits will behave," says Zagoskin. "This is a bottleneck in quantum computing."

This work won't help us simulate the specifics of a large group of qubits, Zagoskin says, but it may help in figuring out their general behaviours, such as how to control a system to minimise chaos.

He likens it to building a model aeroplane in the process of engineering a real one: it won't behave exactly the same as if it were life-sized, but it can nevertheless help guide the final design.

Martin Weides at the University of Glasgow, UK, says that understanding how and when hyperchaos arises "will be extremely valuable for the design of future large-scale quantum simulators and computers". The researchers have already started the next step in this – to test the theoretical work in actual quantum computers. ■

A conceptual image of a quantum computer chip



VCAL/GETTY IMAGES

Medicine

Time for RNA editing

Altering RNA rather than DNA could be a safer approach for medicine

Michael Le Page

A METHOD for altering RNA that works similarly to the CRISPR DNA-editing technique has proven effective in animal tests and could be a powerful new tool for doctors.

The approach, created by a team led by Prashant Mali at the University of California, San Diego, is inherently safer than CRISPR because it doesn't alter the genome. What's more, it might be used to temporarily alter gene expression, which could treat conditions such as chronic pain.

"This is a clever and elegant approach," says Gaetan Burgio at the Australian National University in Canberra. "Overall, I believe this technique has great potential."

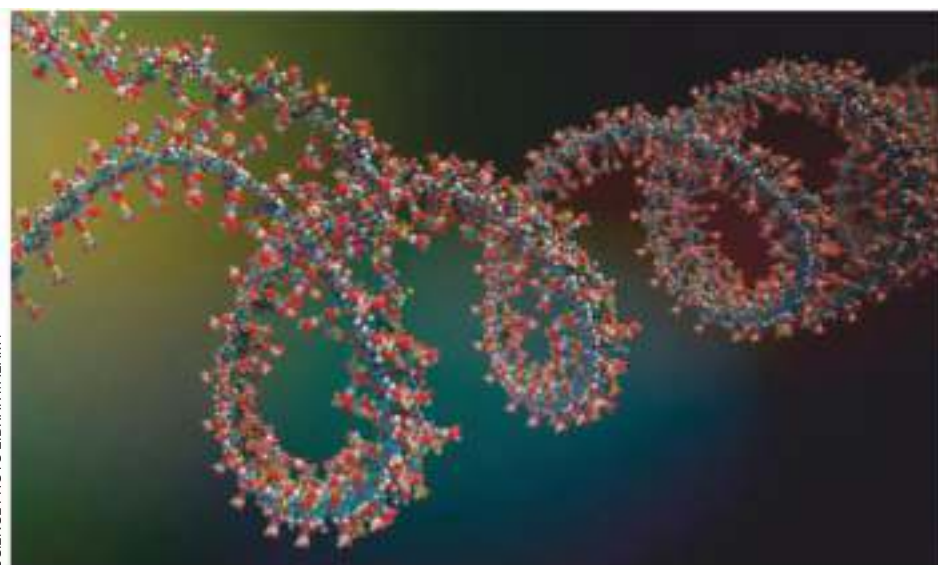
The recipes for making the proteins our bodies need are stored in the DNA inside cells. When we require proteins, our cells use DNA to make a complementary single strand of RNA. This "messenger RNA", or mRNA, is then sent to the cell's protein-making factories.

These mRNA strands aren't simple copies of the recipes, or genes. They can get changed in many ways before being used as protein templates. Cells have

complex RNA-editing systems, which do everything from cutting out the junk in our genes that gets transferred to RNA to changing the sequence itself.

Sometimes, two parts of a single RNA piece can bind to form a double strand. When this happens, so-called ADAR enzymes in our cells recognise the double-stranded section and edit the sequence by effectively changing the letter A

RNA, as illustrated here, acts as a messenger from DNA for making proteins



SCIENCE PHOTO LIBRARY/ALAMY

in the RNA code to a G at specific sites. Exactly why is unknown.

These bits of double-stranded RNA can be created artificially by adding "antisense RNAs", which are pieces of RNA whose sequence is complementary to part of a strand of mRNA. This method has been used before to edit RNA, but it doesn't work well, perhaps because antisense RNA rapidly breaks down.

Now, Mali and his colleagues have tried using circular pieces of antisense RNA, which are more stable. This boosted the

percentage of mRNA with the desired edit around fourfold, to as high as 90 per cent in human cells in a dish. The effect also lasted for several days.

Next, the team used the approach to treat mice with the same mutation that causes Hurler syndrome in people. This mutation disables an enzyme, leading to a build-up of harmful sugars. Mali's team managed to correct up to 20 per cent of the mutant RNA in the mice's livers, halving the sugar build-up (bioRxiv, doi.org/frvt).

For this experiment, a virus was used to deliver DNA coding for the antisense RNA to the cells. Although the DNA wasn't integrated into the genome, this means the effect lasts indefinitely. But antisense RNAs could also be delivered in fatty droplets, as is done in some of the new covid-19 mRNA vaccines, in which case the effects would last only weeks.

This approach is limited to changing an A to a G in the RNA code. But it might be possible to develop similar approaches that would enable a C to U change. ■

Animal behaviour

Physicists work out the best way for insects to jump

A MATHEMATICAL solution to a biological puzzle that might not actually exist could prove useful in the design of hopping rovers for space exploration.

Alberto Vailati at the University of Milan, Italy, normally researches the physics of fluid dynamics. But he was intrigued to read some lab studies in which insects, including fruit fly larvae and froghoppers, had been seen leaping with an average

take-off angle of about 60 degrees.

The idea that many types of insects should have independently evolved to leap at this angle seemed odd to Vailati: a 45-degree take-off angle is the natural choice, as this maximises the range of a jump.

Recently, one of his students, Samuele Spini, suggested an explanation: a 60-degree take-off angle may help the insects avoid obstacles mid-leap.

Vailati, Spini and their colleagues then built a mathematical model to test the idea. They found that a take-off angle of 60 degrees minimised the probability of striking

the side of a step-like or fence-like obstacle of random size and position lying ahead (arxiv.org/abs/2101.05133).

There is a hitch though: insects may not typically leap at a 60-degree angle. Malcolm Burrows at the University of Cambridge has spent much of his career studying insect neurobiology, including jumping behaviour, and is unaware of any research indicating that a

"A take-off angle of 60 degrees minimises the probability of striking an obstacle lying ahead"

wide range of insects typically leap at such a precise and unusual take-off angle.

The new study might nonetheless prove useful for engineers who are designing hopping rovers to explore astronomical bodies.

Gareth Meirion-Griffith at NASA's Jet Propulsion Laboratory in California is exploring this concept. He says this derivation of an optimum take-off angle of 60 degrees could be helpful for exploration robots jumping in places with very rough surfaces and low gravitational pull. ■

Joe Paul

Astronomy

Six-star system puts on a stunning display of eclipses

Jonathan O'Callaghan

ASTRONOMERS have spotted a bizarre stellar system in which six stars orbit and eclipse each other when viewed from our solar system.

Using data from NASA's Transiting Exoplanet Survey Satellite (TESS), which is designed primarily to find exoplanets, Benjamin Montet at the University of New South Wales, Australia, and his colleagues observed the system known as TIC 168789840, located 1900 light years away.

TESS searches for alien worlds by looking for the dip in a star's light when a planet passes in front of it. But this method means it can also spot so-called eclipsing binaries – in which stars in a double system pass in front of each other from our point of view.

"This system defied expectations at first, because there were lots and lots of eclipses," says Montet.

With the help of TESS, the team was able to piece together what was going on. Four of the stars are in two sets of two. These sets, A and C, each have two stars that orbit each other in 1.6 and 1.3 days, respectively, and the two sets orbit each other every 3.7 years.

Then another binary, labelled B, has two stars that orbit each other every 8.2 days. B orbits the A and C quadruple roughly every 2000 years (arxiv.org/abs/2101.03433).

What is most impressive about the system is that we see it almost exactly edge on, so all of the stars cross each other from our point of view. "There are a few [known] six-star systems, but this is the only one to have three sets of eclipses," says Montet.

Aside from being fascinatingly odd, the finding could prove scientifically useful. "We don't really understand why [some] stars become binaries and others don't," says Montet. "This system could provide avenues to help understand that." ■

Climate change

SUVs cancel out climate gains from electric cars

Michael Le Page



REUTERS/CHARLES MOSTOLLER

THE good news is that more people bought electric cars in 2020. The bad news is that SUVs continued to grow in popularity, too. The fall in oil consumption due to the first trend was completely cancelled out by the second, say Laura Cozzi and Apostolos Petropoulos at the International Energy Agency (IEA) in France.

The growing popularity of SUVs is making it even harder to cut carbon dioxide emissions and meet climate goals. "Policy-makers need to find ways to persuade consumers to choose smaller and more efficient cars," says Petropoulos.

Oil consumption by conventional cars – so excluding SUVs – is estimated to have fallen 10 per cent in 2020, or by more than 1.8 million barrels a day, Cozzi and Petropoulos say in a commentary published by the IEA on 15 January. Most of this fall was due to reduced travel because of the pandemic and is therefore likely to be temporary.

But a small part of the drop, around 40,000 barrels a day, was as a result of the increased

share of electric vehicles (EVs).

"We have seen a skyrocketing of global electric car sales in 2020," says Petropoulos.

Unfortunately, the number of SUVs increased as well. While overall car sales fell in 2020, 42 per cent of buyers chose SUVs, up around three percentage points from 2019.

280 million

Number of SUVs now on the road globally, up from fewer than 50 million in 2010

Globally, there are now more than 280 million SUVs being driven, up from fewer than 50 million in 2010. On average, SUVs consume 20 per cent more energy per kilometre than a medium-sized car.

The increase in SUVs in 2020 led to a rise in oil consumption that cancelled out the effect of electric cars, says Petropoulos.

Much the same is true over the past decade. Between 2010 and 2020, global CO₂ emissions from conventional cars fell by nearly 350 megatonnes, due to

SUVs give car-makers higher profit margins

factors such as fuel efficiency improvements as well as the switch to electric cars. Emissions from SUVs rose by more than 500 megatonnes.

"While the growth in EVs is encouraging, the boom in SUVs is heart-breaking," says Glen Peters at the CICERO climate research centre in Norway.

There are many reasons for the growing popularity of SUVs, says Petropoulos. Rising prosperity in many countries means more people are able to afford them, for instance. Some people see them as status symbols.

SUVs are also heavily advertised by car-makers, he says, whose profit margins are higher on these vehicles.

Some countries, including France, have introduced schemes under which more tax is paid on heavier cars. But Peters thinks that people who are rich enough to afford SUVs won't be deterred by slightly higher taxes.

There are now some electric SUVs available. "Hopefully, in time, you will see electric vehicles penetrating the SUV market," says Peters.

Even if it happens, switching to electric SUVs isn't an ideal solution. Due to their size and bigger batteries, it takes more resources to build electric SUVs, says Petropoulos, and they consume around 15 per cent more electricity.

That means higher emissions unless the electricity comes entirely from renewable sources, and higher electricity demand makes it harder to green the electricity supply. ■

Biodiversity

Quarter of all bee species not seen for three decades

THE number of bee species recorded worldwide has been sharply decreasing since the 1990s.

Eduardo Zattara and Marcelo Aizen at the National University of Comahue in Argentina analysed how many wild bee species are observed each year, as recorded in the Global Biodiversity Information Facility – a database where researchers and enthusiasts can record species sightings.

They found a quarter fewer species were reported between 2006 and 2015 compared with the records we have from before 1990 (*One Earth*, doi.org/frvc).

The decline is especially alarming considering the number of bee records in this database has risen by around 55 per cent since 2000, so it isn't due to a lack of observations.

"Our work is the first long-term

assessment of global bee decline," says Zattara. Previous bee research has been confined to a specific species or a particular location.

It doesn't necessarily mean that unrecorded bee species are extinct, but they are now rare enough that people who tend to report bee sightings aren't encountering them.

The destruction of natural habitats, pesticide use and climate change could explain this decline in species richness, says Zattara.

The global decline mirrors what has previously been reported in the UK. But the researchers note that studies in more remote areas are needed to gain a full picture.

"These declines are alarming for food security and the health of the natural world," says Gary Powney at the UK Centre for Ecology and Hydrology. **Karina Shah**



EDUARDO E. ZATTARA

Society

Data reveals racial bias in recruitment

PEOPLE from ethnic minorities are less likely to be contacted by job recruiters than people from the majority group, according to an analysis of users on a Swiss public employment website.

Dominik Hangartner at ETH Zurich in Switzerland and his colleagues studied the actions of more than 43,000 recruiters who conducted 450,000 searches of 17.4 million jobseeker profiles between March and December 2017. They tracked every click to see how recruiters interacted with the profiles, which include details of ethnicity, age and nationality.

How often Swiss nationals born in the country and from the majority ethnic group were contacted by recruiters was the baseline for the analysis. People from immigrant and ethnic minority groups were up to 19 per cent less likely to be contacted.

Recruiters spent only 0.3 seconds less, on average, on profiles of ethnic minority jobseekers, which the researchers say means the result can't be entirely explained by recruiters consciously discriminating against people based on ethnicity.

But the time spent on a profile varied depending on time of day: between 9am and 10am, it was 10.5 seconds on average per profile, and 12 per cent less on those from minority ethnic backgrounds. Between 5pm and 6pm, recruiters spent 9.5 seconds on the average profile, and 14.7 per cent less on ethnic minority accounts. Similar variations are found just before lunch breaks. For the average job, no significant difference was found based on the gender of applicants (*Nature*, doi.org/ghts9f).

"This kind of analysis shows racial discrimination is still deeply entrenched," says Safiya Umoja Noble at the University of California, Los Angeles.

Chris Stokel-Walker

Biomimetics

Swimming machine cracks squid motion

ROBOT squid that move with a certain rhythm can match the power efficiency of the real animals, a trick that could be used for designing new submarines.

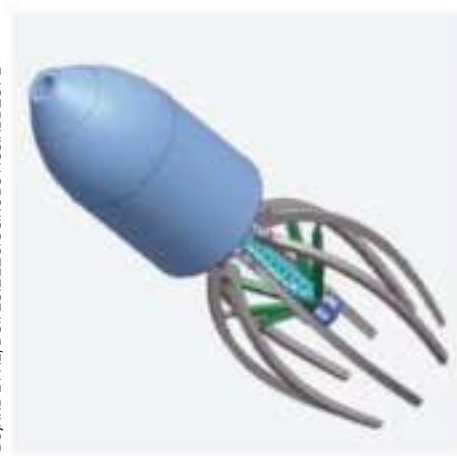
Real squid have small fins for slower manoeuvring, but when a big burst of speed is required, they suck in and expel water to propel themselves. Researchers have tried to build robots that mimic this jet-like behaviour, but now

a team led by Gabriel Weymouth at the University of Southampton, UK, has discovered a way to do so at high efficiency.

Weymouth and his colleagues created an umbrella-like robot with eight plastic ribs covered by a rubber skirt (mock-up pictured). This structure flexes out to suck in water and contracts to expel it, providing thrust.

The team tried the robot at a range of opening and closing rates, comparing energy in and out to measure its efficiency. Firing pulses of water at the natural resonance of the robot's propulsion mechanism resulted in an efficiency that was 100 times greater than at other frequencies, matching the most efficient squid (*Science Robotics*, doi.org/frj9).

This effect is similar to how pushing someone on a swing at just the right moment makes them swing slightly higher each time. Weymouth hopes the design could one day be adapted to power submarines. **Matthew Sparkes**



BUJARD ET AL, DOI: 10.1126/SCIROBOTICS.AB02971

Really brief



Calorie count higher on low-carb diets

People on a low-carb diet consume more calories on average than those on a low-fat diet. That is the finding of a study in which 10 people on each diet were tracked in a clinic for two weeks. However, both diets led to a loss of 1 to 2 kilograms on average over that time (*Nature Medicine*, doi.org/frh4).

Lynx question for people in Scotland

Conservationists are launching a consultation to assess knowledge of and attitudes towards lynx in Scotland. The survey is potentially a first step in the journey to reintroduce the medium-sized wildcats to the Scottish Highlands, an environment they occupied until 500 to 1000 years ago.

Male mantises fight to avoid being eaten

Female praying mantises often eat the male during or after mating, but it turns out some males can avoid this fate. A lab study shows that male *Miomantis caffra* mantises win the right to mate in peace if they fight and beat the female. Only if they lose the fight are they likely to be eaten (*Biology Letters*, doi.org/frjr).

Animal behaviour

Owner's personality rubs off on their dog

DOGS with certain behavioural issues are more likely to improve during training if their owners are extroverts and open-minded.

Traits like introversion and close-mindedness are linked to fewer changes in some types of undesirable dog behaviour, like aggression and fearfulness.

Knowing this could help vets identify dog-owner pairs that may need more help in training, says Lauren Powell at the University

of Pennsylvania School of Veterinary Medicine.

Over a six-month period, Powell and her colleagues followed 131 dogs and their owners attending training sessions with a vet. The dogs had various issues, such as aggression towards people.

Owners underwent personality testing and provided information about their dogs. The most important factor affecting success was how bad the dog's behaviour was to start with, says Powell, possibly because they had so much to gain from the training.

However, the research also

revealed that human personality plays a role in corrective training for some behaviours. For example, dogs that were fearful made more progress if their owners were extroverted (*Frontiers in Veterinary Science*, doi.org/frkg).

This makes sense, says Charlotte Duranton of Ethodog, a canine behavioural research facility near Paris. "When dogs are confronted with a new stimulus – like an unfamiliar human, dog or object – they're going to watch the reaction of their owner to know how they themselves should behave," she says. **Christa Lesté-Lasserre**

Palaeontology

JAKOB VINThER/UNIVERSITY OF BRISTOL & BOB NICHOLLS/PALEOCREATIONS



Extremely rare fossil reveals sex secrets of the dinosaurs

A RECONSTRUCTION of the only fossilised dinosaur cloaca in existence may help illuminate how the prehistoric animals mated.

The cloaca is an all-purpose bodily opening on many animals, including lizards, turtles and birds, that is used for mating, laying eggs, urinating and defecating.

Jakob Vinther at the University of Bristol, UK, and his team examined a fossil of a metre-long, horn-billed dinosaur called *Psittacosaurus* and noticed a surprisingly intact cloaca.

The researchers took the fossil, flattened by years of compacting, and turned it into a 3D digital model. The team then tried to compare the

cloaca with those of other animals.

Most birds, which evolved from dinosaurs, don't have a penis and reproduce using "cloacal kissing", in which cloacas touch. Vinther thinks *Psittacosaurus* didn't do this. Its cloaca had two flaps of skin over most of the cloacal vent, more like that of a crocodile rather than a bird (*Current Biology*, doi.org/frjp).

Male crocodiles have a penis that emerges from the cloaca and the team thinks *Psittacosaurus* did too. Vinther also reckons its cloaca may have had hidden glands producing sexually attractive scents and was pigmented to act as a visual signal to mates. **CS-W**

Solar system

Frozen world may contain rocket fuel

A MYSTERY on a distant moon may have been solved. When NASA's Cassini probe flew past Saturn's second-largest satellite Rhea in 2017, it spotted a puzzling compound. It turns out, it may be hydrazine, used in rocket fuel.

As Cassini passed Saturn's moons, it examined sunlight bouncing off their surfaces to determine what they are made of. On Rhea, as well as several of the other moons, something on the surface absorbed light in the ultraviolet part of the spectrum.

To try to identify the substance, Amanda Hendrix at the Planetary Science Institute in California and her team bounced light off various compounds and found two that seemed to match the Rhea signal: hydrazine and chlorine. Either could be a match, but it is hard to come up with a way for chlorine to be made on Rhea, says Hendrix.

Hydrazine, on the other hand, could be produced in reactions between chemicals known to exist on the icy world. It could also float over from neighbouring moon Titan (*Science Advances*, doi.org/frvs).

Even though Cassini used hydrazine as fuel, its thrusters weren't fired near Rhea, so it didn't come from the probe. **Leah Crane**

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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 **Care for Wild Rhino Sanctuary**



CHANTELLE MELZER

"The poaching of rhinos for their horns in South Africa has seen more than 8,400 of these iconic – and now endangered – animals killed in just the last ten years. Care for Wild Rhino Sanctuary was founded by Petronel Nieuwoudt in 2011 with the goal of rescuing and rehabilitating a range of wild animals, but she quickly identified the need for a specialist facility to focus on the orphaned and injured babies often left behind when their mothers were killed by poachers.

None of this is possible without the support and protection of the local community. Our sanctuary is located in Mpumalanga province,

an area of high unemployment and low educational achievement. Already, we provide valuable employment and training to many in the area and in the long term Care for Wild Rhino Sanctuary aims to become self-sustaining through the creation of jobs and enterprises both within the sanctuary and surrounding communities. One such project involves working with the local Lomshiyo

community to regenerate abandoned agricultural land to provide job security, income and food, ultimately ensuring that those who live nearby can see tangible benefits in conserving the sanctuary and the rhinos.

All of this is only possible through sponsorships and donations, and like many such causes we have seen these diminish in the current crisis.

Find out more

If you would like to help the survival of these iconic species and the economic security of the communities around the reserve then please donate at careforwild.co.za/donate or justgiving.com/careforwildrhinosanctuaryuk



The columnist

What is so great about native plant species, asks **James Wong** **p24**

Letters

Pandemic prevention will need some extra wisdom **p26**

Aperture

Rare images of collisions in galactic evolution **p28**

Culture

David Attenborough's dazzling new series *A Perfect Planet* **p30**

Culture columnist

Simon Ings says *Last and First Men* may break your heart **p32**

Comment

Formula wars

An overzealous push for breastfeeding has spilled over to hit food banks, worsening problems for the poorest people, writes **Clare Wilson**



Clare Wilson is a medical reporter at *New Scientist* @ClareWilsonMed

WITH many people enduring extreme hardship because of the covid-19 pandemic, food banks in the UK are providing a more important function than ever. These vital institutions, funded mainly through public donations, act as a safety net so those in financial crisis at least don't go hungry.

But there is one section of society who cannot always benefit from their support, and they are among the most vulnerable group of all: infants. In the UK, most babies are entirely or mainly dependent on formula milk.

Baby milk takes up a hefty chunk of a low-income family's food budget. It can cost up to £30 a week and most food banks don't stock formula milk because it is seen as clashing with breastfeeding promotion.

Some local authorities and health boards explicitly tell food banks not to supply it, often citing recent UN guidelines on the issue, according to a recent report from Feed, a Scottish-based charity that aims to provide impartial advice on infant feeding.

The resistance to providing formula milk stems from a long-running dispute over infant feeding. In the past, some manufacturers wrongly claimed that their formula milk was the healthiest choice. Today, we know that breast milk contains a range of beneficial substances like antibodies that fight off microbes and there is some evidence that



breastfed babies have fewer infections in their first year of life.

But many of the broader claims about the benefits that breastfeeding can lead to in later life, like protecting against obesity and asthma, and raising IQ, may not be true. Studies suggest that these apparent correlations arise because, in high-income countries like the UK, breastfeeding is more common among better-off families.

Child health organisations tend to say that if families have a baby that they can't feed, they need

specialist help, which is best given by referring them to health or social services. This can take time, however, and people are resorting to watering down formula or giving unsuitable milk alternatives, which risks babies' health, Feed's investigation has found.

It isn't as if families can simply switch from formula milk to breastfeeding if financial circumstances change. When someone stops breastfeeding, or doesn't start, milk production ceases. So saying that someone

ought to breastfeed when they are unable to is about as helpful as saying someone ought not to be poor.

Health benefits aside, not everyone can breastfeed. For example, a woman may not make enough milk or be on medication that would be harmful for their baby if they did breastfeed.

Breastfeeding can also be painful and take up a lot of time and effort. It is often said that breastfeeding is free, but that is only the case if you view women's time and labour as financially worthless.

In other words, breast isn't always best, and only the people involved can decide if the health benefits outweigh any toll to well-being to make that decision.

In the past decade or so, breastfeeding promotion has been overzealous, making some who use formula milk feel so guilty it threatens their mental health. It has triggered a backlash from groups, such as Fed is Best, that say the health system shouldn't try to control people's bodies in this way.

People who have so little money that they need handouts of food may be in no position to argue with health workers over their personal autonomy – but it is a disgrace that the often unscientific debate over breast milk versus baby formula is harming the most vulnerable. It has to stop. ■

#FactsMatter

What's so great about native anyway? There's a tendency among horticulturists to prefer native plant species, but we shouldn't assume they are better, writes **James Wong**



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

James's week

What I'm reading
These days? Mainly angry tweets.

What I'm watching
The Small Axe films.

What I'm working on
With a new BBC farming documentary going out and a houseplant course going online, I am hoping to take some time out... while stuck indoors!

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

IT ISN'T an exaggeration to say that in the world of horticulture "native" is frequently used as a byword for "better". Native plants are often considered easier to grow and better for wildlife, while also being less invasive and more resistant to pests.

This belief is so institutionalised that many local planning rules in the UK specify that a certain percentage of landscaping schemes must include native species. Indeed, this conviction runs so deep that some see sharing evidence to the contrary as being hugely controversial, even deeply irresponsible. But accuracy is what matters, so let's explore how well this entrenched dogma stands up to analysis.

First, it is important to clarify that, in many cases, native plants are great choices for a garden. What I am examining here is whether they are automatically a superior option for both garden performance and ecological value, in the context of Britain.

The problem with considering a group of plants to be inherently superior is that many measures of "better" are contradictory. For example, one of the key features that makes a plant invasive is it being so easy to grow that it overwhelms efforts to manage its spread, resulting in its escape into natural ecosystems where it can cause havoc. So the idea that native plants are both less invasive and easier to grow can only be maintained if you are very selective with your evidence.

You also have to ignore, for instance, that many native plants, such as bracken, are so invasive that they can swamp huge areas of land, with catastrophic effects on local biodiversity. So if we are concerned about biodiversity, we should also be concerned about

invasive native species. Unless, in reality, we are worried only about the "alien" part of "alien invasives", not the invasive potential or impact on ecosystems of all plants.

Likewise, the popular claim that non-native plants are far worse at supporting local wildlife, while also being less pest-resistant, requires doublethink. This is largely because the difference between pests and wildlife is cultural. Undoubtedly, the most important way that plants support wildlife is as a food source, but if an animal munches on them in an unaesthetic way, we label it a pest.

"This definition makes anything introduced by the Romans, such as olives, native to Britain"

This touches on a tricky reality. What does native even mean in the context of Britain? The island has been subject to waves of ecological annexation by giant ice sheets in a series of glacial periods, interspersed with successive waves of colonisation by species from further afield. As such, they cannot be realistically compared with highly specialised ecosystems like, say, those of Madagascar or the Galapagos.

To address this issue, many botanists and ecologists consider only species that we know were in Britain at the end of the last glacial period as worthy of the title native. But this in itself is pretty arbitrary. What is the exact date we are choosing for the glacial period to have finished, considering this process took millennia?

As one solution, others have picked an equally arbitrary cutoff for native plants: they must have

been in Britain 500 years ago, based on the idea that most trade in plants occurred after then. This makes anything introduced by the Romans, such as olives and pomegranates, native to Britain.

It is understandable if you think these examples are silly because such species require human-managed cultivation to survive in Britain, but then you must also accept that many of Britain's most-loved native meadowland and cornfield plants, such as poppies and cornflowers, are technically also exotic species, introduced by ancient humans and the agricultural methods they brought with them post-glaciation.

The arbitrary nature of the definition of native plants isn't just temporal, but also geographic. I could take delicate mosses and ferns from the remnant patches of temperate rainforest in the far south-west of England and plant them in south-east England, in areas with a similar rainfall to Rome or Jerusalem, and still claim them to be native and thus inherently better suited to the environment than Mediterranean plants. This once again shows that definitions of nativeness are really just arbitrary lines drawn on maps and dates picked on calendars.

Using this framework, it is frequently claimed that exotic plants from areas like southern Europe are automatically worse at supporting native British wildlife, despite many animals that are native to Britain also being native to vast swathes of the planet, as far east as Siberia and as far south as northern Africa. Just because they aren't native to British people, doesn't mean they aren't native to Britain's animal species.

So while these definitions of native can be useful pointers, we should really consider them in a more nuanced context. ■

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HEALTH SERIES
HERMAN PONTZER

Editor's pick

Pandemic prevention will need some extra wisdom

Leader, 16 January

From Nigel Tuersley,
Tisbury, Wiltshire, UK

Your excellent leader refers to the roll-out of effective coronavirus vaccines as "a stunning tribute to human wisdom".

A remarkable achievement it may be, but if humanity possessed even the rudiments of wisdom, it would already be eradicating the dangerous practices in intensive livestock production and wilderness destruction that are almost certain to be responsible for the next pandemic.

The fact that neither policy shift is even a possibility in the near future starkly illustrates the need for Robert J. Sternberg's call in the same edition for a radical redefinition of intelligence (p 36).

History may have forgotten coronaviruses

12 December 2020, p 22

From Tom Smith,
Basel, Switzerland

We should be cautious about casually linking the coronavirus pandemic to the devastation of biodiversity by people.

Lifestyle changes affect which diseases find their niche in the human population, but modernisation and urbanisation don't increase our exposure to zoonotic diseases above that of our ancestors, rather the opposite.

It is very likely that we don't see signs of some coronavirus epidemics in the historical record because our ancestors acquired immunity as children; the older people who were at highest risk of dying were, in any case, tiny proportions of the population.

In addition, referring to this pandemic as unprecedented ignores the fact that even current mortality rates are low compared with those of some diseases in the not-so-distant past, such as smallpox.

Maximum vaccine use is possible here too

16 January, p 10

From Jon Williams,
Ramsbottom,
Greater Manchester, UK

In your look at whether the UK will hit its vaccine target, you mention reports that Israel gets six doses from each vial of the Pfizer/BioNTech vaccine, whereas in the UK we only get five.

Having started as a vaccinator, I can assure you that in the online training module all UK vaccinators must complete before giving the Pfizer/BioNTech vaccine, it is clear that six doses per vial may well be possible, as long as each consists of 0.3 millilitres. In my first session giving this vaccine, I and most of the other vaccinators achieved six doses per vial in most or all cases.

Clarity needed over how fast we could change tack

9 January, p 8

From John Gordon,
Datchworth, Hertfordshire, UK

Regarding the new virus variants, several experts have said that it would only take a few weeks to tweak vaccines to cope with them.

What isn't clear is whether such a modified vaccine would require another lengthy programme of retesting, which may take months.

Lockdown policy may lead to a yo-yo effect

5 December 2020, p 9

From Tom Roberts, Derby, UK

The UK seems to be applying a lockdown approach to covid-19 that initiates an unstoppable swing between low and high levels of infection.

We must dampen this "motion". Having lowered levels of covid-19 during lockdown, we should

gradually reduce restrictions over an extended period, rather than rapidly, to the point at which an acceptably low death rate is reached and can be maintained.

Money for nothing may just end in higher prices

19 December 2020, p 25

From James Fleming,
Boston, Massachusetts, US

I have enjoyed your coverage of universal basic income (UBI) and its observed benefits on health and happiness. But I would like to see an analysis of whether its adoption could lead to inflation.

It is my understanding that in market-driven economies, supply and demand will govern prices, unless curbed by regulation. If everyone got extra money, won't the market raise prices? The UBI trials so far have been too small to reveal this potential problem.

Intelligence comes in many forms

16 January, p 36

From Tony Richardson,
Ironbridge, Shropshire, UK

Thanks to Robert J. Sternberg for his critical examination of the reliance on IQ as a guide to someone's potential.

At the height of the Rubik's cube craze, I taught a class of 14-year-olds – our "bottom set". They could rationalise a cube faster than I could follow them. No one had told them that they required the intelligence that society implicitly said they didn't have in order to solve the puzzle. Intelligence is more about motivation and confidence than some reductionist, abstract construct.

From Perry Bebbington,
Kimberley, Nottinghamshire, UK

I think my dad summarised your

article about how we view intelligence in one sentence. He said: "You go to university to learn more and more about less and less until you know everything about nothing."

The pollution solution is to just travel less

9 January, p 19

From Graham Jones,
Bridgham, Norfolk, UK

Regarding the idea of encouraging the use of public transport by making it free, the best option for the environment would be to reduce the need to travel at all. The pandemic has shown us that commuting is often unnecessary.

That's a yes to lowering carbs from me

9 January, p 32

From Alison Harvey,
Frome, Somerset, UK

Further to your article on the mixed evidence of the health benefits of low-carb diets, I have yet to see a creditable argument against cutting out processed sugar, limiting carbohydrates and consuming them only with proteins to avoid blood sugar spikes, and limiting or removing animal fats. The resulting diet is healthy, inexpensive and varied.

Stonehenge: try a fence instead of a tunnel

9 January, p 16

From Simon Cains, High Wycombe, Buckinghamshire, UK

There is a much cheaper solution than a road tunnel to avoid traffic on the road beside Stonehenge. Just build a fence to act as a sight screen at the edge of the road, and perhaps plant a hedge alongside it to take over the job when it grows high enough – a kind of wood-henge.

The congestion on the road seems to be due to drivers slowing down to look at Stonehenge, as though it has just miraculously appeared, instead of having been there for 5000 years. ■



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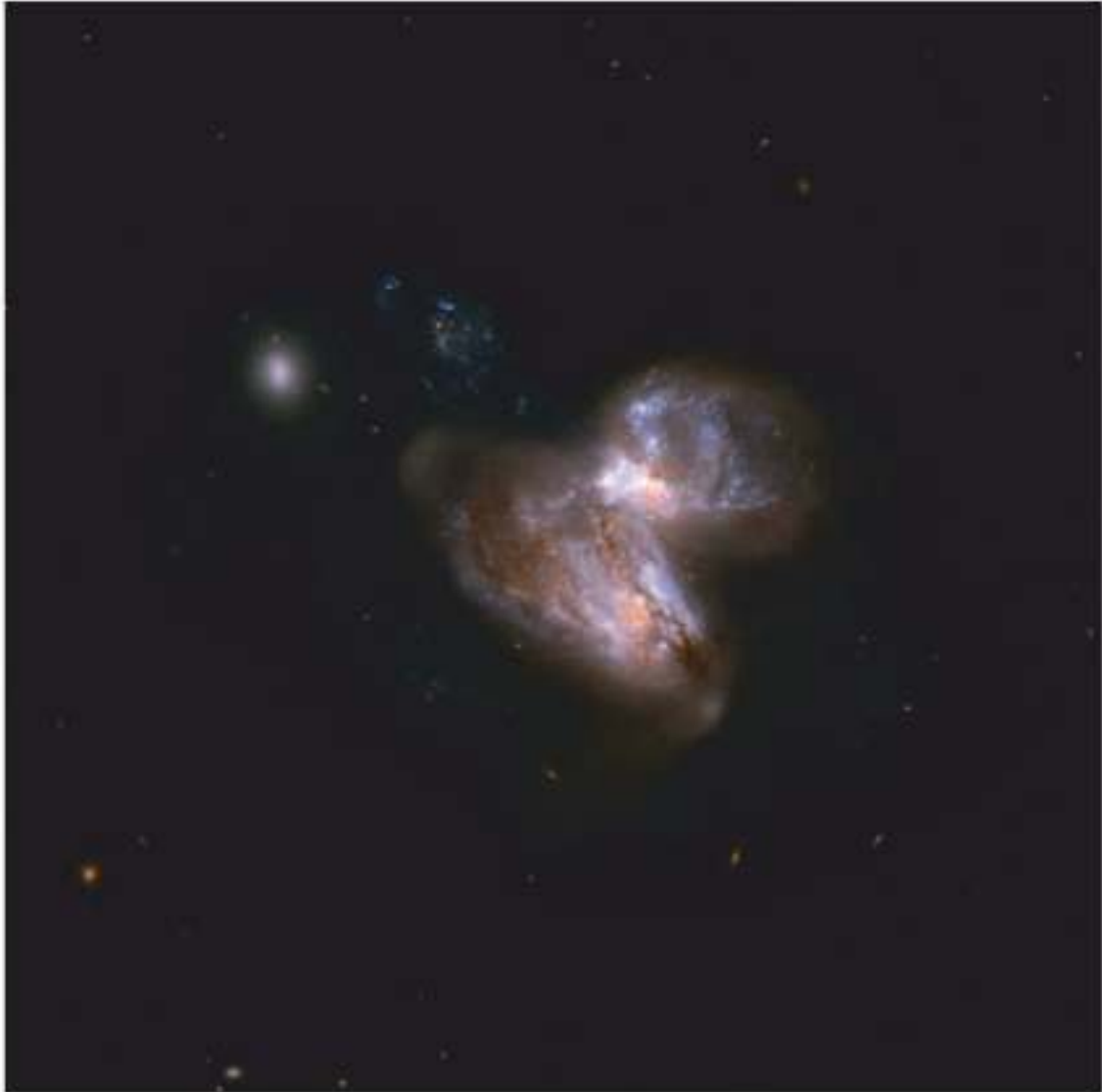
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NGC 3256: ESA/HUBBLE,NASA; NGC 1614 & NGC 3690: NASA,ESA,HUBBLE HERITAGE TEAM(STSCI/AURA)-ESA/HUBBLE COLLABORATION & A.EVANS(UNIVERSITY OF VIRGINIA,CHARLOTTESVILLE/NRAO/STONY BROOK UNIVERSITY; NGC 4194,NGC 6052 & NGC 34: ESA/HUBBLE & NASA, A.ADAMO ET AL.





Galactic growth



Agency NASA/ESA Hubble
Space Telescope

THESE rare and entrancing sights each shows an epic cosmic event: the merging of galaxies.

Taken by the Hubble Space Telescope, the six images capture what happens as galaxies collide and merge. As a result, clusters of stars form within them that can be millions of times the mass of the sun. Galaxy merging is thought to be one of the main driving forces of cosmic evolution.

These are unusual images since collisions, which drastically alter the appearance and composition of galaxies, are rare. The changes accelerate the birth of new stars during the merger as molecular clouds fall to the centre of each galaxy, where they collide with other molecular clouds, causing them to condense into new stars.

The exceptional resolution of the Hubble telescope can capture such changes, and home in on some of the features in the star clusters, such as ones that look like knots (actually, these are numerous compact young star clusters).

The Hubble imaging Probe of Extreme Environments and Clusters (HiPEEC) survey investigated these mergers and found that merged galaxies are among the most efficient environments to form star clusters. The largest clusters are created towards the end of the merger process.

Clockwise from top left, the images show six galaxy mergers: NGC 3256, NGC 1614, NGC 4194, NGC 34, NGC 6052 and NGC 3690.

Hubble, a joint venture between NASA and the European Space Agency, has been in low orbit around Earth for over 30 years, and may well continue operating for at least another decade. ■

Gege Li

The right place to be

David Attenborough's *A Perfect Planet* blends earth science with dazzling images to show how natural forces nurture life, says **Ibrahim Sawal**



TV

A Perfect Planet

BBC1 and on BBC iPlayer

CRYOGENIC frogs and blood-sucking finches are among the many remarkable animals to star in David Attenborough's latest series, *A Perfect Planet*, which examines what made Earth so suitable for life. How was it that everything about the planet – including its size, spin, tilt and distance from the sun and moon – was perfect for nurturing life? So much so that it may be the only planet to host life.

Working with the team that created Netflix's *Our Planet*, this new five-part series looks at some of the influential natural forces that create the ideal conditions to support life. It also shares fascinating stories about animals that benefit from them.

From the remote volcanic islands of the Galapagos to the clear blue waters of tropical atolls, and from the sand dunes of the Sahara to the frozen world of the Arctic, the documentary pushes the boundaries to capture previously unseen images.

The series starts with one of the most important of those creative or nurturing forces: volcanoes. They created land, brought carbon dioxide into the atmosphere, and, as Attenborough reminds us, life wouldn't have started without them.

Opening shots feature colourful footage of flamingos nesting around the corrosive waters that surround an active volcano in Tanzania. A haunting scene shows flocks of chicks, unable to fly, trying to avoid predators as they trek across muddy plains to meet their parents in the freshwater springs where they hunt for food.



SILVERBACK FILMS

Some of the most fascinating stories come from the Galapagos. There is a pregnant iguana making a perilous descent into a crater to lay eggs in the hot ash where they can incubate. Then there are vampire finches, one of the world's most recently discovered species, which feast on the blood

“Baby giant river turtles drown in the Amazon because the rainy season now comes too early”

of seabirds that treat the island as a pit stop, and are used to the behaviour, which may have its origins in a sort of symbiotic pact.

Opening with one of the most compelling scenes of the series, the second episode – focusing on the power of the sun – looks inside the world of figs in the tropical rainforest. We see the slightly disturbing and complex relationship between the fruit

and the fig wasps, some of which die inside a fig, while others die after they emerge from it.

Sun also brings the warmth of spring, even to the Arctic circle, where wood frogs “defrost”. After lying “frozen” in the ice during the winter, a frog’s blood is warmed by the sun, and it awakens.

In the intense heat of the Sahara desert, we see how one of the world’s fastest animals, the silver ant, avoids boiling in the sun, and in China, hungry golden snub-nosed monkeys fight for food to survive the winter.

The final scene is a real highlight as shearwaters from New Zealand prepare for a 16,000-kilometre flight across the Pacific Ocean to follow the sun to Alaska, as they chase summer around the globe. Warm waters allow plankton to thrive, making a welcome meal for millions of hungry shearwaters and the humpback whales that have also followed the warmth.

Perhaps the most dramatic scenes of the series are in the

The corrosive waters of Tanzania’s Lake Natron are paradise for flamingo

episode on the weather, which restates the message we can’t hear too often: climate change is disturbing the weather patterns that animals rely on. Baby giant river turtles drown in the Amazon because the rainy season now comes too early, and the dry seasons are too dry. Bee-eaters that nest in Zambia’s river banks now face the collapse of their nests as heat intensifies and dries them out, while many animals struggle to find water.

A Perfect Planet’s great blend of natural history and earth science makes it one of Attenborough’s best projects. It will make us think more about how natural forces shaped the planet to allow life to flourish and question the scale of human impact on it. ■

Ibrahim Sawal is an intern at *New Scientist*

Zero carbon, high costs

Demand for rare metals will increase as we move to a zero-carbon economy. A new book lays out the high cost, finds **Simon Ings**



Book

The Rare Metals War

Guillaume Pitron (translator
Biana Jacobsohn)

Scribe

WE REAP seven times as much energy from the wind and 44 times as much energy from the sun as we did a decade ago. Is this good news? Guillaume Pitron, a French journalist and documentary maker, isn't sure.

He is neither a climate sceptic nor a fan of inaction. But as the world moves to adopt a target of net-zero carbon emissions by 2050, Pitron worries about the costs. The figures in his book *The Rare Metals War* are stark. Changing the energy model means doubling the production of rare metals about every 15 years, mostly to satisfy demand for non-ferrous magnets and lithium-ion batteries. "At this rate," writes Pitron, "over the next 30 years we... will need to mine more mineral ores than humans have extracted over the last 70,000 years."

Before the Renaissance, humans had found uses for seven metals. During the industrial revolution, this increased to a mere dozen. Today, we have found uses for all 90-odd of them, and some are very rare. Neodymium and gallium, for instance, are found in iron ore, but there is 1200 times less neodymium and up to 2650 times less gallium than there is iron.

Zippering from an abandoned mine in the Mojave desert to the toxic lakes and cancer-afflicted areas of Baotou in China, Pitron weighs the awful price of refining the materials, ably blending investigative journalism with insights from science, politics and business.

There are two sides to Pitron's story, woven seamlessly together. First, there is the economic story of how China worked to dominate the energy and digital transition. It now controls 95 per cent of the rare earth metals market, making between 80 and 90 per cent of the batteries for electric vehicles, says Pitron, and more than half the magnets in wind turbines and electric motors.

Then there is the ecological story of the lengths China took to succeed. Today, 10 per cent of its arable land is contaminated by heavy metals, 80 per cent of its groundwater isn't fit for consumption and air pollution contributes to around 1.6 million deaths a year there, according to Pitron (a recent paper in *The Lancet* says 1.24 million deaths in China a year are attributable to air pollution – but let's not quibble).

China freely entered into this Faustian bargain. Yet it wouldn't have been possible had the Western world not outsourced its own industrial activities, creating a planet divided, as Pitron memorably describes it, "between the dirty and those who pretend to be clean".

The West's comeuppance is at hand, as its manufacturers, starved of rare metals, must take their technologies to China. It should have seen how its reliance on Chinese raw materials would quickly morph into a dependence on China for the technologies of the energy and digital transition.

By 2040, in our pursuit of ever-greater connectivity and a cleaner atmosphere, we will need to mine three times more rare earth metals, five times more tellurium, 12 times more cobalt and 16 times more lithium than we do now. China's ecological ruination and global technological dominance advance in lockstep, unstoppably, unless the West and others start to mine for rare metals in Brazil, the US, Russia, Turkey, South Africa, Thailand and Pitron's native France.

Better that the West attains some shred of supply security by mining some of its own land, says Pitron. At least there consumers can fight (and pay) for cleaner processes. Nothing will change if we don't experience "the full cost of attaining our standard of happiness", he says. ■



REUTERS/STRINGER

A man working at a rare earth metals mine in Nancheng county, China

Don't miss



Watch

Space Sweepers, a new South Korean blockbuster on Netflix from 5 February, follows a crew of misfits living among Earth's orbital space debris. Their luck changes when they discover a humanoid robot.



Read

Heartwarming's accounts of how different animals stay warm (and cool) on planet Earth lead us deep into evolutionary territory as social psychologist Hans Rocha IJzerman explains how temperature has shaped human behaviour.



Listen

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TOP: NETFLIX; BOTTOM: BULAT SILVIALAMY

The film column

How we end *Last and First Men* is big on brutalist architecture, with a sometimes chilly narrator, but this strange history of 2 billion years of humanity ranks with *Solaris* and *2001: A Space Odyssey*. It may even break your heart, says **Simon Ings**



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



STURLA BRANDTH GRØVLEN

***Last and First Men* uses eerie architectural shots to explore humanity's end**

was screened at the Manchester International Festival. Jóhannsson told the audience how Tito thought he was building a utopian experimental state that would unite Slavic nations. Because there were so many different religions, the architects looked to Mayan and Sumerian art, rather than religious icons. "That's why they [spomeniks] look so alien and otherworldly," he explained.

Swinton's regretful monologue proves an ideal foil for the film's explorations, lifting what would be a stunning but slight piece into dizzying, speculative territory: the last living human, contemplating the leavings of 2 billion years.

Last and First Men was left unfinished. The film was cut and Swinton had recorded the monologue by the time the film was presented at the Manchester International Festival. As far as Jóhannsson was concerned, there was still a lot to be done to finish the score. On his death, Yair Elazar Glotman was brought on board to arrange his notes and come up with a final performance for the soundtrack. No one hearing how the film was put together would imagine it could amount to more than a tribute, but sometimes the gods are kind. It is hugely successful, wholly deserving of a place beside Andrei Tarkovsky's *Solaris* and Stanley Kubrick's *2001: A Space Odyssey*.

Who knew that staring at concrete and listening to the end of humanity could wet the watcher's eye and break their heart? It is tragic that Jóhannsson didn't live to see that, in his own words, "we've taken all these elements and made something beautiful and poignant. Something like a requiem." ■



Film

Last and First Men
Jóhann Jóhannsson
Streaming on BFI Player

Simon also recommends...

Film

La Jetée (1962)
Directed by Chris Marker
This short black-and-white film, assembled mostly from stills, is a masterful tale of love, apocalypse and time travel. The story inspired Terry Gilliam's 1995 thriller 12 Monkeys.

Book

Summa Technologiae
Stanislaw Lem
The Polish parodist and sci-fi writer's only full-length philosophical work projects humanity into the future and explains why we are doomed to mess it up.

"IT'S a big ask for people to sit for 70 minutes and look at concrete," mused Icelandic composer Jóhann Jóhannsson about his only feature-length film. He was still working on *Last and First Men* when he died, aged 48, in 2018.

Admired for his keening orchestral pieces, Jóhannsson was well known for his film work: *Prisoners* and *Sicario* were made strange by his sometimes terrifying, thumping soundtracks.

Last and First Men is, by contrast, contemplative and surreal. It uses a series of zooms and tracking shots set against eerie architectural forms, shot in monochrome 16-millimetre film by Norwegian cinematographer Sturla Brandth Grøvlen.

The film draws its inspiration and script (a haunting, sometimes chilly, off-screen monologue performed by Tilda Swinton) from Olaf Stapledon's 1930 novel of the same name. His day job at the time of writing – lecturing on politics and ethics at the University of Liverpool, UK – seems of little moment now, but his sci-fi novels have barely been out of print and

still set a dauntingly high bar.

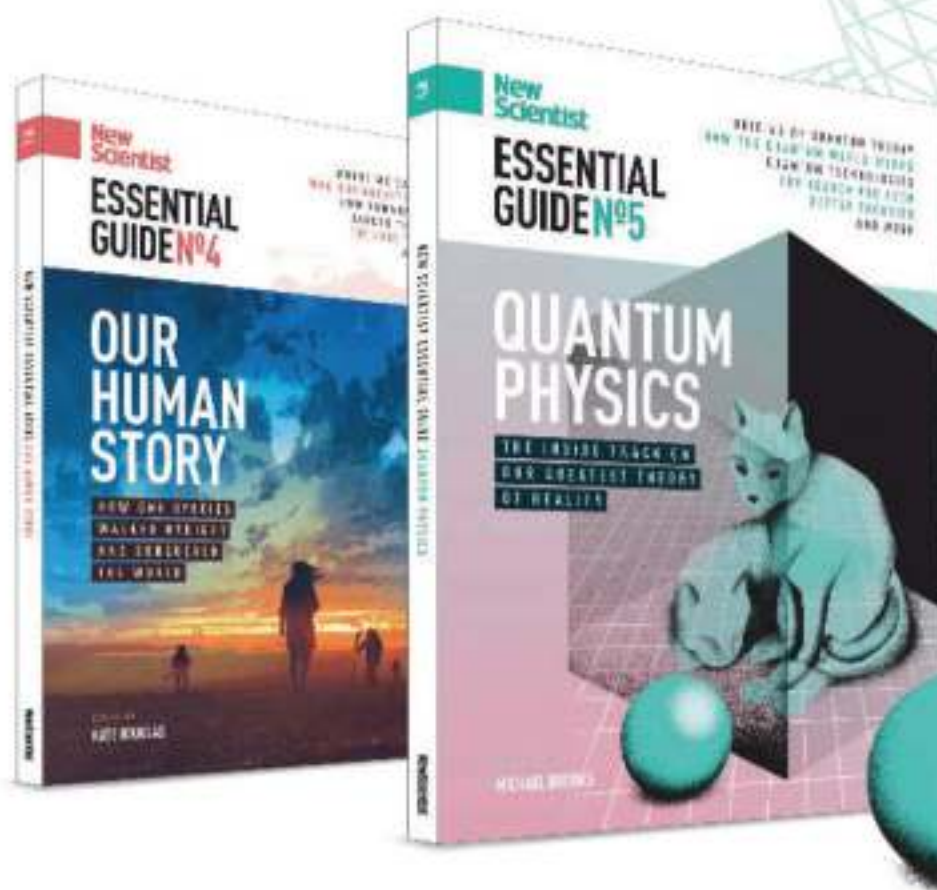
Last and First Men is a 2-billion-year history, detailing the dreams, aspirations, achievements and failings of 17 different kinds of future humans (*Homo sapiens* is first). In the light of an ageing sun, they evolve, blossom, speciate, die; the film is set in the moment of extinction.

"Who knew that staring at concrete and listening to the end of humanity could wet the watcher's eye?"

Stapledon's book isn't a drama. There are no actors or action. It isn't really a novel, more a haunting academic paper from the beyond. The idea to use the book came late in Jóhannsson's project, which began life as a film essay on Spomeniks, the huge, brutalist war memorials erected in the Socialist Federal Republic of Yugoslavia between the 1960s and the 1980s by dictator Jozip Broz Tito.

In 2017, the film, with a live performance of an early score,

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The other humans

A mysterious prehistoric people once known only from DNA they left behind are now emerging from the shadows, finds **Michael Marshall**

TODAY, there is only one species of human alive on the planet. But it wasn't always so. For millions of years, and until surprisingly recently, there were many types of human-like groups, or "hominins". They coexisted, perhaps they fought, and they interbred. It would be fascinating to know how these others lived, but understanding who they were and what they were like is extremely challenging. We cannot put ourselves into their minds, and we have only fragmentary clues from fossils and artefacts they left behind to reconstruct their lives.

That challenge is especially daunting for one of these extinct groups, the Denisovans. Discovered just a decade ago, the Denisovans have left us scant physical evidence. Instead, our knowledge of them comes almost entirely from their preserved DNA. It tells us that they are a sister group to the Neanderthals, that they lived in Asia for hundreds of thousands of years and that they interbred with our species. But we don't know what they looked like, how they walked or if they could speak.

Now, that is changing. In the past few years, archaeologists have alighted on a few fossils that seem to be Denisovan. They have also unearthed treasure troves of artefacts,

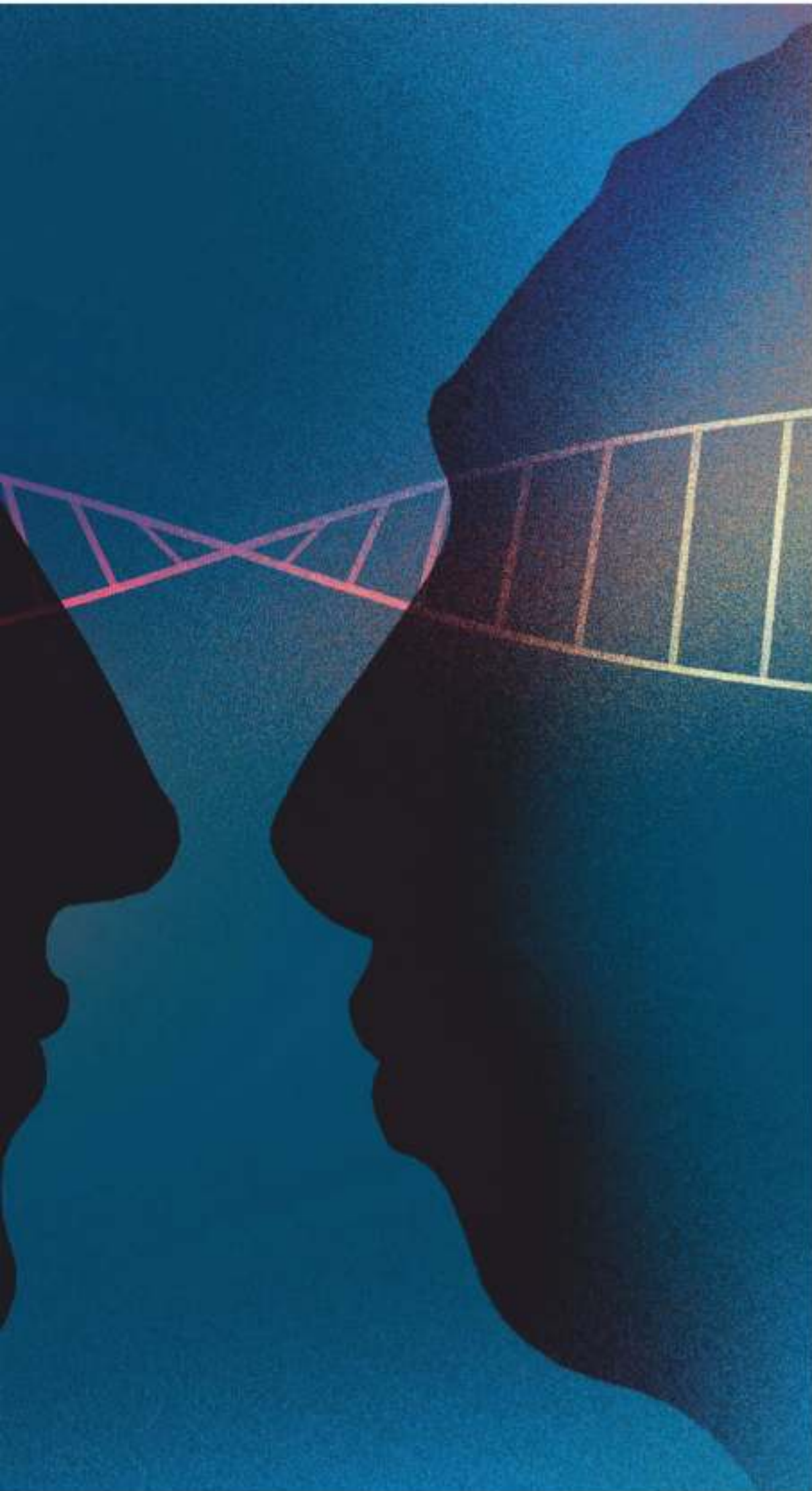
including tools, jewellery and even art, that they think were created by these mysterious people. These interpretations are potentially explosive, so it is hardly surprising that some dispute them. Nevertheless, we are starting to piece together a picture of the Denisovans, one of our closest cousins, and a group that still lives on in the DNA of many people today.

The discovery of the Denisovans came as a total surprise, partly because it played out differently from the uncovering of every other extinct human group. The story starts in the Altai mountains in southern Siberia, Russia. For decades, archaeologists have been excavating in Denisova cave – named after a hermit called Denis who lived there in the 18th century. Hominins have inhabited it on and off for hundreds of thousands of years. Most were Neanderthals who, although most prevalent in Europe and west Asia, sometimes made it as far east as the Altai.

In 2008, archaeologists led by Michael Shunkov at the Russian Academy of Sciences in Novosibirsk discovered a fragment of finger bone in the cave. Assuming it belonged to a Neanderthal, Shunkov sent it to Svante Pääbo at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. Pääbo's team extracted DNA from the bone and found it didn't match ➤



BRIAN STAUFFER



Where did the Denisovans come from and where did they go?

Genetically, the Denisovans are a sister group to the Neanderthals. The two diverged about 400,000 years ago from a shared ancestor, one that had previously split from the line that led to our species around 600,000 years ago. It isn't clear why the Denisovans and Neanderthals diverged, but a new idea suggests that as the Arctic ice sheet expanded southwards to the Black Sea, cutting Europe off from Asia, it divided the early humans into two populations, which became Neanderthals in the west and Denisovans in the east.

There is little evidence to indicate when and why the Denisovans died out. The most recent interbreeding episode with *Homo sapiens* may have been just 30,000 years ago. It is possible that there was so much interbreeding that Denisovans faded into the wider early human population. Alternatively, on arriving in Denisovan habitat, *H. sapiens* may have outcompeted or killed their cousins, or brought lethal diseases. Climatic events could have been crucial too. "If we accept Denisovans lived from Siberia to Indonesia, you have very different climatic and environmental circumstances in which they lived," says Bence Viola at the University of Toronto, Canada. "So I feel that there likely is not a single answer."

Neanderthal DNA – or modern human DNA. It was something never seen before. After initially referring to the individual as “X-woman”, Shunkov and Pääbo settled on “Denisovans” as a name for the group. The findings were published in 2010. Never before had a group of hominins been identified solely from its DNA. Another surprise was to come, however. Some of the Denisovan DNA sequences matched those found in people living on the islands of Melanesia, especially Papua New Guinea. The implication was that thousands of years ago, Denisovans and members of our species, *Homo sapiens*, had sex and produced children. As a result, today around 5 per cent of the DNA of Melanesian people is Denisovan, with many of these genes appearing to play key roles in immunity to diseases.

In itself, the interbreeding wasn’t too big a shock. Pääbo’s team had published the sequence of the Neanderthal genome earlier in 2010, revealing that *H. sapiens* and Neanderthals interbred, and that all humans today whose ancestral group developed outside Africa carry some Neanderthal DNA. But the Denisovan interbreeding was odd because their DNA was found thousands of kilometres away from Papua New Guinea in Denisova cave. The implication was that Denisovans were once widespread (see “How far did Denisovans roam?”, right). In fact, their “demographic and evolutionary core” was probably in south Asia, says Jean-Jacques Hublin, also at the Max Planck Institute for Evolutionary Anthropology.

This was all based on DNA from a single finger bone. There was no skeleton, and no artefacts. The Denisovan people themselves were a total mystery. A study published in 2019 sought to address this by using the Denisovan genome to deduce what they looked like. Researchers identified methyl “tags” attached to the genome, which reveal how active each gene was, and used that information to generate an image of a Denisovan face. However, the study was widely disputed, not least because nobody



Excavations at Denisova cave (above and below) have yielded few Denisovan remains, but thousands of artefacts including bone points and tooth pendants (left)

“Denisova cave in Siberia was probably the Denisovans’ northern limit”

T-B SHUTTERSTOCK/IGOR BOSHIN; KATERINA DOUKA; SPUTNIK/SCIENCE PHOTO LIBRARY



The oldest known bracelet, dated to 45,000 years ago, was found in Denisova cave

has ever even shown that methyl tags can “predict” the appearance of a known species.

If the genome cannot tell us what Denisovans looked like, we must find out the old-fashioned way – by excavating Denisovan remains. To that end, people have been exploring sites in China and nearby countries, and scouring old museum collections. For almost a decade, there was nothing. Now there is.

Bence Viola, a palaeoanthropologist at the University of Toronto in Canada, has found several skull fragments in Denisova cave. Details haven’t been published yet, but viewing a cast of one over Zoom reveals that the bone is unusually thick. To Viola, this suggests that Denisovans were big – perhaps more than 100 kilograms – with “American football player body build”. Analysis of their genome reveals it contains DNA from an unidentified older population: could they have interbred with the decidedly bulky *Homo erectus*, a species that lived on in east Asia long enough to have met them?

High society

These fragments are the best Denisovan fossil evidence found so far at the cave, but archaeologists have expanded the search. A crucial clue emerged in 2014. Emilia Huerta-Sánchez now at Brown University in Providence, Rhode Island, and her colleagues were studying a gene called *EPAS1*, which is involved in the body’s response to low oxygen levels. People living on the Tibetan plateau, more than 4 kilometres above sea level, have a modified version of *EPAS1* that helps them cope with the thin air. Huerta-Sánchez found that this came from interbreeding with Denisovans about 43,000 years ago.

Denisova cave is only 700 metres above sea level, so it seems unlikely that the mutation arose there. But it would have been a useful adaptation if Denisovans were living at high altitude elsewhere. Tentative evidence of this emerged in 2018. At Nwya Devu on the Tibetan plateau, a research team found

How far did Denisovans roam?

We have hard evidence of the Denisovans in two places: Denisova cave in Siberia, and Baishiya Karst cave on the Tibetan plateau. Most anthropologists think Denisova cave was their northern limit, because further north was too cold. Genetic results suggest that they also lived much further south than Tibet, however, roaming huge areas of Asia to Indonesia, which at the time Denisovans were alive was attached to mainland Asia because of low sea levels. Lands further south were still cut off, and there is no reason to think they were in Australia.

To the east, there are multiple potential Denisovan fossils from China. These include several bones from Xujiayao in north China and two craniums from Xuchang in central China. Like a jawbone found off the coast of Taiwan, none of these quite fits the profile of a known species, so are good candidates to be Denisovans. To the west, an arm bone from Sel’Ungur cave in Kyrgyzstan could be Denisovan too, but attempts to extract DNA from it have proved unsuccessful.

thousands of stone tools buried between 40,000 and 30,000 years ago that might have been left by Denisovans – or *H. sapiens*.

More compelling evidence comes from Baishiya Karst cave in Xiahe in the north-east of the Tibetan plateau. It is a sanctuary for Tibetan Buddhists and, in 1980, a monk meditating there found a jawbone. “Local people used to collect bones in this cave to grind, to make some kind of medicine,” says Hublin. “Luckily, this monk did not grind the fossil.” Instead, it was sent to Lanzhou University in China. It doesn’t contain any preserved DNA, but, in 2019, Hublin and his colleagues revealed that they had managed to extract protein from one of the teeth. This matched protein found in Denisovans. They also concluded that the jawbone was at least 160,000 years old.

Many people found it hard to accept that Denisovans were living in one of the harshest environments on Earth 160,000 years ago. But, in October 2020, researchers led by Qiaomei Fu at the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing, China, reported finding Denisovan DNA preserved in the sediments of Baishiya Karst cave. The DNA samples dated from 100,000, 60,000 and possibly also 45,000 years ago. Not only were the Denisovans there, it looks as if they were there for at least 115,000 years, plenty of time to evolve adaptations like the modified *EPAS1* gene. “I was a little more sceptical in the beginning,” says Viola. But the sediment DNA sealed the deal. “I’m really convinced.”

That means we now have another Denisovan specimen, with its own story to tell. The overall shape of the jawbone is typical for hominins of the time. Some features are quite Neanderthal-like, which Hublin says is to be expected of a sister group. What marks it as Denisovan are its enormous teeth. Ongoing excavations at Denisova cave have yielded three Denisovan teeth, all also whopping. “The Denisovans are really weird,” says Shara Bailey at New York University. Throughout human evolution, teeth have generally shrunk, but they bucked that

Were Denisovans a distinct species?

Studies of the Denisovans carefully avoid calling them a species. Whereas Neanderthals have the species name *Homo neanderthalensis*, Denisovans are referred to as a “population”. This partly reflects the fact that we know so much less about them, but there are other reasons.

Jean-Jacques Hublin at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, points out that species names are convenient labels we use to make sense of the world, and there is no hard dividing line between us and Denisovans. “We are connected by a chain of inter-fecundity that goes back 65 million years to a small sort of squirrel-like primate that lived in a tree,” he says. Moreover, *Homo sapiens*, Denisovans and Neanderthals could all interbreed, which by some definitions means none is a separate species.

A further complication is that there seem to have been two distinct groups of Denisovans: those whose genes are found in mainland Asia, and those whose genes are found in Melanesia. Lumping them together may be an oversimplification.



Tools found in Denisova cave show steady technological progress

trend. “Neanderthals and *Homo sapiens* both have small teeth, so I would suggest that their shared ancestor also had small teeth, which would suggest the big teeth in Denisovans is something they evolved later,” she says.

A likely explanation is that they had to chew tough or hard foods. Unfortunately, attempts to recover traces of food from the teeth have so far failed. However, if DNA in sediments at Denisova cave is anything to go by, Denisovans who lived there ate a range of large animals, such as deer and horses. They even seem to have tackled big carnivores including snow leopards, bears and hyenas, according to William Rendu at the National Centre for Scientific Research in Bordeaux, France, who led the analysis. Supporting this, stone tools from the cave have traces of animal fat on them. Rendu believes that the Denisovans probably hunted with spears, even though the wooden shafts haven’t been preserved in Denisova cave. Hominins appear to have been using spears for at least 300,000 years, so it wouldn’t be surprising that the Denisovans could make them.

Tech savvy

Meat can certainly be tough to chew, unless you cook it. “There is some evidence of fire in Denisova cave,” says Rendu. Indeed, controlled fire use became common in Eurasia after 400,000 years ago and Neanderthals probably used several cooking techniques. But the use of fire in Denisova cave looks intermittent, so it isn’t clear if Denisovans cooked too. If not, that might explain their unusually large teeth.

However, Rendu notes that there is almost no difference between what the Denisovans and Neanderthals living in Denisova cave ate. This suggests they had similar capabilities. “Clearly, we should expect the same levels of technology, same levels of thinking,” he says. Artefacts unearthed by Shunkov and his colleagues at the cave seem to back this up. Almost 80,000 objects, laid down over 150,000 years, reveal a steady progression from flat stone flakes to narrow blades and chisels. This is exactly the technological

progression that Neanderthals and *H. sapiens* were making at that time. Yet the researchers argue that Denisovans made all these tools.

Such claims are hard to prove and some people dispute this assertion. “You need to have the stone tools in the cold, dead hand of the hominin,” says Sheela Athreya at Texas A&M University. And provenance is especially difficult to establish at Denisova because habitation by Denisovans and Neanderthals overlapped. In 2018, geneticists reported discovering that a 90,000-year-old bone fragment belonged to a young girl they nicknamed “Denny”, who had a Neanderthal mother and Denisovan father. Finding such a child of the two types of early human would be astonishingly unlikely unless interbreeding, and thus population overlaps, were common.

Intriguingly, stone tools have also been found in Baishiya Karst cave. “They date back possibly around 190,000 years,” says Fu, suggesting that Denisovans made them. No details have been published, but according to Hublin, “it’s quite different from what they have in Denisova”.

Meanwhile, Shunkov has an even bigger claim: by around 60,000 years ago, the Denisovans were making jewellery. Artefacts his team has found in Denisova cave include bone beads, a marble ring, a button made of mammoth ivory and a polished bracelet of dark green rock. This claim is so hotly disputed that many researchers are unwilling to discuss it. But Viola notes that Neanderthals made jewellery out of feathers and eagle claws. He is comfortable with the idea that Denisovans made similar objects, but says that some of the finds look too advanced. “That polished stone bracelet, that’s a level of technology that we don’t even see modern humans doing till less than 10,000 years ago. I don’t think Denisovans could have done that.”

The other issue is the age. A 2019 analysis led by Katerina Douka at the Max Planck Institute for the Science of Human History in Jena, Germany, concluded that the most recent clear evidence of Denisovans in the cave is no younger than 52,000 years old,



**“Denisovans
inhabited one
of the harshest
environments
on Earth”**



**Excavations (top)
and a 160,000-
year-old jawbone
(above) show that
Denisovans lived
in Tibet (below)**



but tooth pendants and bone points found there are between about 43,000 and 49,000 years old. This suggests that *H. sapiens* made the most advanced artefacts.

The same problem bedevils claims of Denisovan art. In 2019, a team described two pieces of bone that had been carefully scratched with a sharp point and coloured with red ochre. They were found at Lingjing in northern China and are between 105,000 and 125,000 years old. That is early enough to be Denisovan, but also late enough to be made by *H. sapiens*. A beautiful Indonesian cave painting, showing human-like people hunting pigs and buffalo, is around 44,000 years old – an even more ambiguous date.

If some of these objects turn out not to have been made by Denisovans, it doesn't mean they weren't clever, says Athreya. “Not all societies have to have Western markers of civilisation to be smart.” In fact, symbolic behaviours like making art may not become established in small, isolated populations, which, genetic evidence suggests, is how Denisovans lived. “Symbolic thoughts, symbols like personal ornaments and art and body decoration, would be important when you're trying to identify ‘us’ versus ‘them,’” says Bailey. If most Denisovans rarely met other groups, art may not have been a priority.

Nevertheless, the Denisovans' apparent technological sophistication, hunting prowess and ability to survive in extreme environments are impressive. And they were clearly able to get along with other hominins when they did meet. The working hypothesis should be that they were intellectually on a par with Neanderthals, says Viola. Historically, Neanderthals were portrayed as stupid, but that stereotype has been overhauled. “Cognitively, they weren't that different from us,” says Viola. “If Neanderthals weren't that different, Denisovans shouldn't be either.” ■



Michael Marshall is a science writer based in Devon, UK, and author of *The Genesis Quest*

Mind control

Gaslighting is a form of psychological manipulation that warps your window on reality. There are ways to fight back, writes **Caroline Williams**





It's a really discombobulating thing to think, 'I know you're wrong, but you are now more confident in your lie than I am in the truth,'" comedian John Oliver told *The Hollywood Reporter* last year.

He was talking about a high-profile Twitter spat with Donald Trump, which began when Trump claimed that he had refused to appear on Oliver's "very boring and low-rated show". Oliver denied inviting Trump, who then upped the ante, claiming he had been asked several times and had repeatedly turned the show down. Trump was so adamant that Oliver wondered if he had forgotten something.

The argument has all the hallmarks of gaslighting, a form of psychological manipulation in which one person undermines another person's reality. When carried out over a long period of time, the target can begin to doubt their own thoughts and memories.

We might like to think that this couldn't happen to us, but the bad news is that it definitely could. This is because of a handful of psychological quirks that come as part of the package of the human mind. Although usually beneficial, these aspects of the way we perceive the world can be exploited by a gaslighter to control our reality. The good news is that by understanding them, it is possible to resist attacks and restore your faith in your own thinking – and reality.

Gaslighting became headline news in the UK in 2016 when a prominent storyline in BBC radio drama *The Archers* involved a character called Helen Archer being subjected to psychological abuse, including gaslighting, by her husband. A year earlier, England and Wales became the first places to introduce legislation regarding controlling or coercive behaviour. "Gaslighting could be considered a form of coercive control," says Evan Stark,

professor emeritus at Rutgers University in New Jersey, who helped shape the new laws.

The term has become so common in recent years that it is now bandied about in political discourse, as in the headline of a recent opinion piece in the *Boston Herald* newspaper, which asked: "Hey Democrats – who's gaslighting whom?" At the same time, there has also been a growing awareness of the serious psychological toll of living with someone who carries out this manipulative and undermining behaviour.

Your own world

One problem with any bid to hold on to your own reality in the face of a gaslighter is that, whether we like it or not, none of us sees the world as it is. Our brains only process a fraction of the incoming sensory information we detect. The gaps are filled in by the brain, which constantly makes predictions based on previous experience and then updates them in light of new information. "The perceptual world is a dialogue between what we're receiving from our senses combined with our experiences of weaving together a narrative reality that makes sense to us," says Mazviita Chirimuuta, a philosopher of neuroscience at the University of Pittsburgh in Pennsylvania.

Given that our experiences and memories are unique, that adds up to a bespoke personal reality that differs from everyone else's. It is no wonder that we sometimes disagree on how to interpret events. On top of this, memory can be notoriously unreliable. For example, studies of eyewitness testimony have shown that two people can form different memories of the same incident, including what was said and who did what. Our memories are far from a faithful recording of events.

So disagreeing with someone else's view of reality doesn't necessarily equal gaslighting. What distinguishes it is when coercion is used to make another person doubt the reality of their own experiences. In some instances, this is deliberate – driven by a desire to dominate or be in control. But it can also be the result of learned behaviour from someone's upbringing, or a reflection of certain ➤

"It could happen to any of us. Aspects of the way we perceive the world can be exploited to control our reality"

DANIEL STOLLE

underlying mental health conditions; they may not be aware of what they are doing.

Gaslighting can be subtle and insidious. Robin Stern, co-founder of the Yale Center for Emotional Intelligence at Yale University and author of *The Gaslight Effect*, gives an example from a previous relationship. Stern's ex would often arrive up to an hour late to dinner, which she found disrespectful. Yet when she confronted him, he insisted that it was her problem – that she was weirdly uptight about time. This, she says, turned a disagreement into gaslighting.

"It's a difference of opinion if I say, 'It's really important to me that you're on time', and you say, 'I can't understand why that's so important to you, but we don't have to agree on everything'. It becomes gaslighting if it's: 'There's something wrong with you for thinking the way you think.' In this case, you are questioning my take on reality," she says. "As a result, I question myself, asking: 'Is there something wrong with me?'"

Part of the problem is that this is a question we can't answer alone. "It's really hard to verify the reliability of yourself from the inside," says Andrew Spear, a philosopher at Grand Valley State University in Michigan. "You can't check whether you saw correctly by using your vision. You can't check whether your own memory is accurate. So, if I say, 'Are you sure you're not crazy? Prove to me that you're not crazy', it becomes circular quite quickly. There is this real fragility, right at the heart of ourselves."

Sticking to it

This fragility enables the manipulation. It allows a gaslighter to play on the fact that, in some situations, we should definitely trust a loved one who is telling us that we are forgetting things or acting strangely. If you are the one being gaslighted, it is almost impossible to tell the difference between manipulation and genuine concern, says Spear (see "How to spot a gaslighter", right).

On top of that, as a social species, we use our shared culture and language to compare our version of events to others and adjust our behaviour as necessary. "One reason why gaslighting is possible is because our sense of

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How to spot a gaslighter

The term gaslighting comes from the 1938 play *Gas Light* by Patrick Hamilton. In it, a man convinces his wife that she is losing her sanity by dimming the lights in their home and telling her she is imagining it, as well as moving things around and then persuading her that she did it but forgot. It can be hard to spot this kind of manipulation, but here are some clues from psychologist Robin Stern at Yale University.

- Gaslighters seldom admit they are wrong. They are more likely to tell you that you are "deranged" than change their mind.
- They often tell you that they don't like your friends and family, and find reasons to run them down and keep you away from them.
- A gaslighter may often question your mental well-being and your view of a situation, plus criticise your character.

reality is already influenced by people even when it's working fine and no one is trying to manipulate us," says Chirimuuta. We are constantly keeping an eye on whether other people are on the same page as us.

Gaslighters, however, don't take the view of the person they are manipulating into account, says Stern. They tend to be certain that they know what is right and wrong, and make a point of sticking to their guns.

For the rest of us, though, even the most entrenched views can change when group norms shift. The Black Lives Matter movement is a good example. Groups that say they experience racial discrimination commonly have that reality denied by those who are inflicting the abuse, says Chirimuuta. The May 2020 killing of George Floyd when a Minnesota police officer knelt on his neck was a catalyst for society as a whole to re-examine the reality of what black people continue to experience.

The influence of groups can easily be turned against us, however, particularly when we don't have all the facts to hand. And the more credibility we give to outside sources, whether they are individuals, news sources or social groups, the easier it is to believe that they know best and the more vulnerable we are to being controlled. And when groups wildly disagree on an interpretation of events, each side can accuse the other of gaslighting. After the recent US election, both sides accused the other of lying to citizens for political gain. In situations like these, it can be difficult to know who to believe.

That is the challenge, says Spear. "Who should you assign credibility to?" This dilemma is behind arguments over fake news, the loss of trust in journalism and situations in which "alternative facts" start to take hold, such as the current misinformation around climate change or the outcome of the US presidential election. It also explains how people can have their entire world view reshaped by religious cults, which convince members that everything they think they know is a lie. There may be other incentives for believing other people's perceptions over your own: when someone is torn between their own reality and that of a person they rely on to help pay the bills, for

instance, it makes it more likely that they will opt for financial security over an inconvenient truth.

With so many loopholes in our psychology, how can we avoid the gaslighter's traps? The most important thing is to trust your feelings, says Stern. "When you feel like there's something wrong in the conversation, it's usually because there is."

A surprisingly powerful way to tune into our emotions is to pay attention to what is happening from the neck down. We have known since Charles Darwin noted it back in 1872 that physiological changes are an integral part of what it means to have emotion, but recent research has shown that having a better sense of interoception – the awareness of internal bodily signals such as heart rate – may help people to better recognise and manage their emotions.

Nick Medford, a neuropsychiatrist at South London and Maudsley National Health Service Foundation Trust, says that in his work with cult survivors, this bodily awareness is a key part of recovery. "When people describe a process of realising that a toxic or abusive relationship isn't right, they

Fighting back

Here are some tips for countering gaslighters:

- **Guard your self-trust. Don't give up your faith in your perceptions without strong evidence to the contrary, says Andrew Spear at Grand Valley State University in Michigan.**
- **If in doubt, check things with more than one other trusted person. "The strategy of the gaslighter is to discredit those other people," says Spear. "But if you can get external, independent validation, you're in a better place."**
- **Check for power imbalance. Do you believe someone rather than yourself because you rely on them for emotional or practical support, says Spear.**

A gaslighter can make us doubt our own thoughts and memories

talk about it in very physical terms," he says. "[They say:] 'I just started to feel that something wasn't quite right.' There is some kind of physical message coming through which is very primal, and it's often very, very hard to put into words."

Malicious intent

Once you identify that something is wrong and begin to trust that feeling, it is time to take away the gaslighter's monopoly on being right. "The only way to get yourself out of the trap of gaslighting is to stop worrying about which one of you is right," says Stern. It might be tempting to try to prove the gaslighter wrong, but changing their opinion doesn't actually matter, says Stern. "What matters is that you feel uncomfortable and manipulated, and that is not OK."

All of this is further complicated by just how difficult it can be to identify gaslighting to begin with. Sometimes, what looks like manipulation may simply be someone revealing an uncomfortable truth about another person's behaviour or challenging their point of view or memory of events.

"My view isn't that you should always be stubborn. It's not just dig in no matter what, because that in itself would be irrational," says Spear. There are plenty of circumstances where we should listen to another person's perspective, but it becomes manipulation when there is an intention – often malicious – to mislead. Spear says that when someone is so unwilling to consider your point of view that they double down harder when challenged, that is a red flag.

Gaslighting is often a slow and stealthy process. Shining a light on it is a major step towards reclaiming reality. ■

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Caroline Williams is a consultant for New Scientist. Her book *Move! The new science of body over mind* will be published in April





How to spot an alien megastructure

Intelligent extraterrestrials may have built vast power plants, known as Dyson spheres, around stars. The search for their telltale glow is hotting up, finds **Mordechai Rorvig**

THERE comes a point at which any advanced alien civilisation worth its salt has to dismantle a neighbouring planet for spare parts. This isn't an act of vandalism, you understand, but rather a precursor to building an enormous solar power plant that surrounds its entire host star. What else would an ambitious alien society do to continue its expansion? How else would it meet its ever-increasing demand for energy?

This scenario, or something like it, is the founding principle of the search for alien megastructures, which in this case would look something like dark embers when viewed through infrared telescopes. The search began in 1960, when physicist Freeman Dyson proposed it as a way of finding alien life. More than 60 years later, the hunt for Dyson spheres, as they are now known, remains a minority sport among those involved in the search for extraterrestrial intelligence (SETI), an enterprise that has focused primarily on listening for radio signals from other worlds.

But astronomers are still prospecting for evidence of alien engineering. In particular, they have been working to put the pursuit of Dyson spheres on a rigorous scientific footing. Now, they are poring over the most precise cosmic cartography ever produced to try to find stars that could be surrounded by swarms of solar panels and distinguish them from naturally occurring infrared herrings. They are already narrowing down candidates. They have even begun to think seriously about the final hurdle: how to tell the difference between an infrared herring and a genuine alien megastructure.

Dyson's original proposal was quite broad. In a one-page paper, he suggested simply that advanced extraterrestrial civilisations, should they exist, would be likely to convert the light from their stars into energy on an epic scale, leaving observational clues for those who cared to look. Since then, others have developed the argument. Jason Wright, an astrophysicist at Pennsylvania State University, for instance, concluded in a 2014 paper that "long-lived civilizations with large energy supplies might... be expected to rely almost entirely upon starlight for their energy needs".

In terms of engineering, theorists say there are no serious obstacles to building giant solar power plants around stars. "There is nothing really weird about the physics of a Dyson sphere," says Anders Sandberg at the Future of Humanity Institute at the University of Oxford. Any such structure probably wouldn't be a simple monolithic sphere. More likely, a Dyson sphere would consist of a collection of orbiting solar panels that only partially cover the star.

In any case, there would be clear observational signatures for astronomers here on Earth. Dyson spheres would inevitably give off heat and energy that would make them extremely difficult to conceal. Indeed, Dyson sphere hunters need only make one key supposition – that the structure would get warmed by starlight to a moderate temperature, somewhere above the background temperature of space. All warm matter produces an infrared glow, and a massive megastructure would produce a great deal of it. The structure would therefore

effectively reprocess incoming starlight into outgoing infrared light, creating a substantial excess of infrared light compared with what you would see from the same star uncovered.

In 1960, Dyson thought these megastructures would stick out because strong sources of infrared light seemed rare in space. The first proper surveys of the cosmos at this wavelength began with the Infrared Astronomical Satellite (IRAS), a space telescope launched in 1983. The problem was that it revealed a teeming multitude of objects radiating in the infrared. Some were stars that are bigger and brighter than our sun. Others were stars surrounded by clouds of gas and dust, which become heated and radiate infrared light – just like a Dyson sphere would. The implications for the search for Dyson spheres were confounding. "The huge and unexpected abundance of infrared sources made the search harder than people thought it would be," says Wright.

Spectral signatures

Richard Carrigan was among the first to try to sort through the clutter, completing a landmark search in 2009. A particle physicist at the Fermi National Accelerator Laboratory near Chicago, Carrigan pored over the spectroscopic data from IRAS. Like a prism, spectroscopy splits the light from a source into its constituent wavelengths, telling a remarkably full tale about the nature of the object that emitted the light. He identified a handful of stars with the sorts of spectral signatures one would expect if they were surrounded by Dyson spheres. ➤

One star looked particularly promising. In the end, however, it was impossible to distinguish it from an ordinary type of star called a red giant. These are old, bright and emit a great deal of infrared. Worse, they are often shrouded by dust, meaning they mimic a Dyson sphere's optical dimness. Carrigan didn't see signs of dust in his candidate's signature, but that only sufficed to make it an unusually undusty red giant. "Not anything you'd say eureka about," he says.

The experience was instructive, though. It demonstrated the difficulty in distinguishing a Dyson sphere from a natural phenomenon that has a similar spectral signature. Many of these phenomena turn out to be associated with stellar age: newborn stars form within a cocoon of dense gas and dust, for example, while old stars can blow out a dense shell of carbon dust that looks a bit like a megastructure. For Dyson sphere searchers, the full list of mimics is long and sobering. "Confirming whether something is really due to extraterrestrial intelligence and not just some very unusual astrophysics, it's hard," says Erik Zackrisson, an astronomer at Uppsala University in Sweden who is heading the largest ever Dyson sphere search.

The challenge is to weed out these mimics, and we already have a few ideas of how it can be done. Though IRAS was revolutionary for its time, it couldn't tell how far away the infrared sources it detected were: it only measured brightness, not distance. A star that seemed bright in infrared could just be a star that was nearby, rather than an unusually infrared bright Dyson sphere. Conversely, an optically dim-seeming star could just be far away, rather than having its visible light blocked by a megastructure. Carrigan realised that measuring the distance to a candidate would help pinpoint its identity.

"The idea is to release a list of interesting objects for the whole SETI community"

But distance can also help to identify stars that are less likely to have dust in the first place. The distance to a star can be used to deduce its true intrinsic brightness, or luminosity. This in turn correlates with its age; old stars like red giants burn bright, for instance. Age then speaks to the presence of dust – which is more common around very young or very old stars. Through this chain of reasoning, Zackrisson and his colleagues

figured, we can identify middle-aged "main sequence" types of stars that are less likely to be mistaken for dusty impersonators.

The recent releases of data from the European Space Agency's Gaia space telescope give Dyson sphere prospectors exactly what they need to narrow their search. Gaia was launched in 2013. Its mission is to measure the distances to more than a billion stars in the Milky Way and beyond. In the process, it has identified precisely the main sequence stars SETI researchers are looking for – the least dusty candidates. All of which explains why Zackrisson and his team are so keen to make use of the Gaia data, which has been released in three tranches so far, the latest coming in December 2020.

Fresh search

Zackrisson's first study using Gaia results came out in 2018. He and his colleagues looked for stars that seemed too dim in visible light for their distance, suggesting they might be shrouded. The distance was given by Gaia, with an independent estimate of dimness acquired from ground-based telescopes. The trouble is that spectroscopic data takes a long time to collect. Gaia won't be providing much of it, and that limits the number of stars you can scour for signs of Dyson spheres with this approach.

Now, Zackrisson, along with Wright and others, is experimenting with a new method that allows them to scour many more stars. The researchers are combining the Gaia data set with observations from the Wide-field Infrared Survey Explorer (WISE) space telescope, launched in 2009 as a kind of supercharged successor of IRAS. They are focusing on undusty main sequence stars, readily identifiable thanks to Gaia, and

looking exclusively for infrared brightness over and above what you would typically expect, rather than combing through the details of each star's spectroscopy. "While they are on the main sequence, you don't expect them to have a very strong infrared excess," says Zackrisson.

Their first goal is to estimate the possible prevalence of Dyson spheres in the galaxy. To do this, the researchers take every main



Artist's impression of the Gaia satellite, which helps us hunt alien engineering

sequence star from the Gaia/WISE data set and look at how its infrared emissions would change if it was surrounded by a Dyson sphere that covers a given percentage of its surface. A sphere with a more complete swarm of solar installations would build up more heat and therefore generate more infrared light. Zackrisson and his team then compare these emission signatures with the actual emissions from stars in the Milky Way to see how many match. This way, they can calculate the prevalence of possible Dyson spheres with various covering fractions.

Initial results, presented last year by Zackrisson's colleague Matías Suazo showed that Dyson spheres covering 90 per cent of their star seem to occur around at most 1 in 10,000 stars in the Milky Way. The results served as proof of the principle for this sort of analysis. Well, sort of. Closer attention revealed something of a hiccup in that the candidates that they identified weren't main sequence stars after all, let alone Dyson spheres: Gaia had been tricked by binary star systems and other stellar objects like planetary nebulae, which can be closer or further than they appear. But Suazo is in no doubt that, as the team analyses the data more closely, such wrinkles will be ironed out.



Traces of technology

Glowing megastructures aren't the only "technosignatures" alien civilisations might leave behind

POLLUTANTS

Intelligent extraterrestrials are likely to have transformed their planet with industry. SETI researchers have proposed that we could look for their non-natural waste products such as chlorofluorocarbons (CFCs), which can persist in the atmosphere for tens of thousands of years.

PARTICLE COLLIDERS

If intelligent aliens are curious about the fundamental forces of nature, they might have built a particle collider that makes our Large Hadron Collider look puny. A black-hole-powered accelerator, for instance, would produce super-high-energy neutrinos, particles that could be detected from Earth.

APOCALYPSE

Any advanced alien civilisation runs the risk of destroying itself, and the fallout might be visible to distant observers. Nuclear bombs would release flashes of gamma rays, but they would be fleeting and the resulting dust would be hard to distinguish from that produced by an asteroid strike.

The next stage is to whittle down however many possibilities the team ends up with to the most promising. One way to do this is by scrutinising the spectroscopic information for each star of interest, which provides a wealth of insight on the presence and nature of dust. If a star is surrounded by a common form of dust known as polycyclic aromatic hydrocarbon (PAH) dust, for instance, then ultraviolet light is absorbed and re-emitted at specific infrared wavelengths, says planetary astronomer Carey Lisse at Johns Hopkins University Applied Physics Laboratory in Maryland. See extra light at those wavelengths and you know there is PAH dust.

Crucially, a smooth distribution of light over many wavelengths indicates an absence of dust – and the possibility that the star in question is surrounded by a Dyson sphere. “An optically thick Dyson sphere or swarm should be spectrally featureless,” says Lisse.

It is going to be extremely difficult to rule out every natural explanation for what appears to be a vast solar plant around a star. “This is a problem for many types of SETI,” says Zackrisson. But he expects his highly targeted search to generate at least 100 to 1000 potential candidates, all of which will have to be further scrutinised to see if they can be explained with natural phenomena. “We will have our list of weird objects at the end of the day, and I think it will be substantial,” says Zackrisson.

The idea is that follow-up spectroscopy

observations will be able to tease out the answers to many questions, including a candidate's shape, temperature and material composition – including the presence or absence of dust. The precision with which these questions can be addressed will be enhanced by the upcoming James Webb Space Telescope (JWST) – that is, if Dyson sphere searchers can gain precious observing time. “If we find an interesting candidate, we will need to argue that it is interesting enough for JWST regardless of its nature,” says Wright.

But even the best spectroscopy will have

trouble making an indisputable ruling. Nowhere in the wavelengths is it likely to state unequivocally ALIENS WERE HERE. The only way to know for sure if there is an artificial megastructure around a star would be to detect an alien radio signal coming from it. Zackrisson's team plans to hand its list of candidates to radio SETI colleagues for follow up observations. “The idea is to release a list of interesting objects for the whole SETI community,” says Zackrisson.

Then again, there remains the possibility that we might actually see an alien structure, rather than rely on infrared inferences. Interferometers, which combine the light from multiple telescopes to enhance resolution, have already demonstrated the ability to take startling images of faraway solar systems. The Atacama Large Millimeter/submillimeter Array (ALMA) interferometer in northern Chile has revealed natural megastructures around nearby stars with high clarity, such as phenomena known as debris disks – left over from planet formation.

Using earlier instruments, “all the disks would look like blobs”, says Mark Wyatt at the University of Cambridge. Now, with ALMA, disks have been clearly observed as vast belts of rocky debris, like the rings of Jupiter, but a thousand times larger. Would a Dyson sphere look truly distinctive? “It's harder to say,” says Wyatt. “We don't know what those look like.”

Wright, Zackrisson and Lisse recently argued that the search for Dyson spheres has matured to the point that the biggest obstacle is now funding. There is precious little money devoted to such pursuits. But there are signs this is beginning to change. Last year, NASA awarded its first ever grant to search for non-radio alien “technosignatures”, including solar arrays on the surface of exoplanets.

When it comes to finding Dyson spheres, no one is under any illusions about the scale of the challenge. “It's going to continue to be hard for a long time,” says Zackrisson. And yet as they learn more about the natural phenomena that can shroud stars, astronomers are building up a formal framework by which they could, should the opportunity ever present itself, objectively distinguish between a mere dusty shroud and an alien megastructure. ■



Mordechai Rorvig is a science writer based in Massachusetts

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The background of the entire advertisement is a dense, three-dimensional arrangement of purple cubes of various sizes. Some cubes are in sharp focus, while others are blurred in the background, creating a sense of depth. The lighting is soft, highlighting the edges of the cubes.

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Try our crossword, quick quiz and logic puzzle **p52**

Almost the last word

How does lichen survive on roofs in the summer? **p54**

Tom Gauld for New Scientist

A cartoonist's take on the world **p55**

Feedback

Sustainable whales and feline frenzy: the week in weird **p56**

Twisteddoodles for New Scientist

Picturing the lighter side of life **p56**

Science of gardening

Feed your garden for free

Good compost is free nourishment for the garden. But it takes science to stop it turning into a slimy mess, says **Clare Wilson**



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

What you need

A compost bin

Kitchen waste

Plenty of waste

low in nitrogen,

such as cardboard

or sawdust

WE ALL like to get something for nothing, and one way to do that in gardening is to make your own compost from kitchen and garden waste. If all goes well, you end up with an earthy, fine brown crumb within a couple of years, which adds nutrients and structure to your soil. But get things wrong, and it turns into a slimy, stinking mess. So what are the dos and don'ts of composting?

The process is all about exploiting the animals and microorganisms that break down organic matter, recycling nutrients through successive plant generations. Storing it in a pile or compost bin retains more heat to speed things up.

For raw materials, think in terms of greens and browns. This relates not to colour, but to the relative nitrogen and carbon content of the materials. Green waste is relatively richer in nitrogen and comprises things like grass clippings and fruit and vegetable scraps. Too many greens suppress the desired microbial processes, releasing smelly ammonia gas. Brown waste, which is richer in carbon, includes cardboard, sawdust and autumn leaves. Aim to dilute nitrogenous green waste with three-to-four times as much brown material.

For those like me, who are chiefly looking for ways to dispose of food scraps, it can be hard to get enough browns. I used to use all my household cardboard waste, but food packaging is often covered with thin films or labels and I got fed up picking bits of



ANNIE OTZEN/GETTY IMAGES

plastic out of my compost. Now I stick to cardboard I'm sure is uncontaminated, like the tubes in toilet rolls, or shredded corrugated cardboard boxes. Sawdust works particularly well if you can lay your hands on any.

You also need to manage the oxygen and moisture levels of your heap. The better you do this, the faster it will make usable compost. Improve aeration by turning things over a few times a year. I do this by lifting the container off the heap and forking the contents into another bin.

You may also need to water your compost heap if it looks too dry. But don't let it get too waterlogged or anaerobic decomposition will leave the heap smelling like rotten eggs. "Most composters learn through a process of trial and

error," says Danielle Purkiss at University College London.

Purkiss is running an experiment to see how long "biodegradable" plastics rot down in home compost heaps. Paradoxically, these cause more of a problem for expert composters' heaps. The label "biodegradable" is given if a substance rots in 12 months, but experienced hands may achieve a faster compost life cycle than this.

Although I'm not an expert, I can vouch for how satisfying it is when your hard work results in a finished product you can use on your garden. "It's a kind of alchemy," says Purkiss. ■



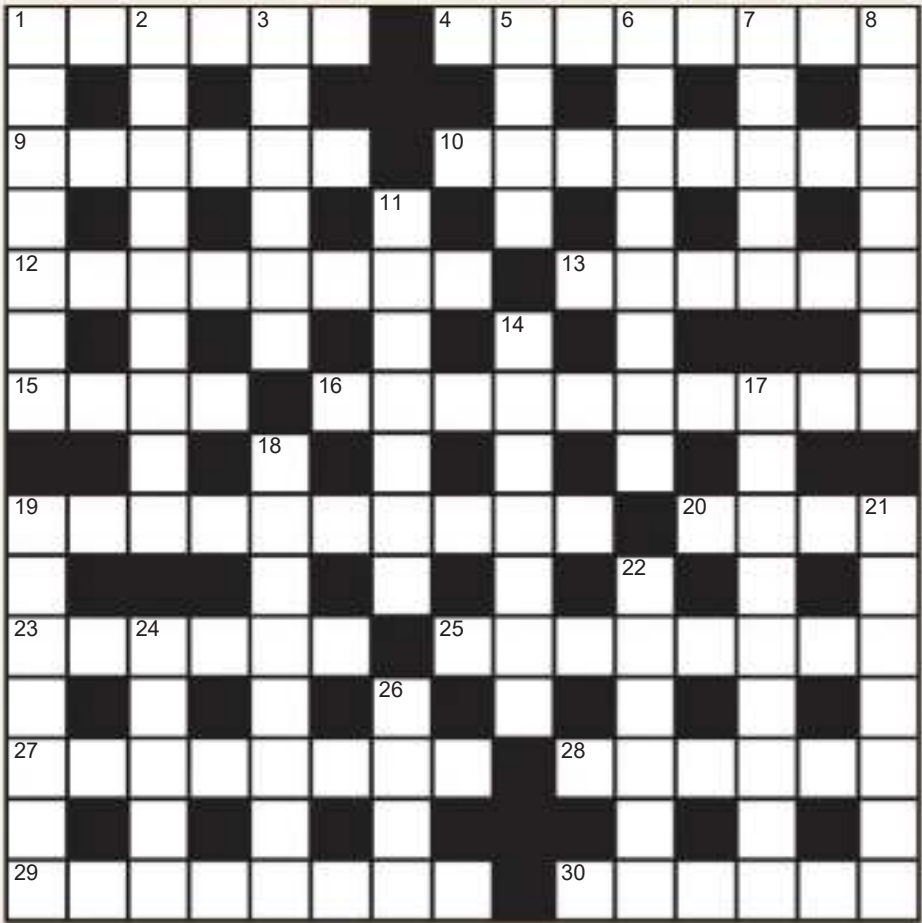
These articles are posted each week at [newscientist.com/maker](https://www.newscientist.com/maker)

Science of gardening appears every four weeks

Next week

Citizen science

Quick crossword #75 Set by Richard Smyth



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

- 1 Omnivorous mustelid (6)
- 4 1992 hacker caper (8)
- 9 Quantum flavour also called bottomness (6)
- 10 Term for an autostereogram (5,3)
- 12 Lu (8)
- 13 Lubricant (6)
- 15 NaCl (4)
- 16 Misaligned eyes (10)
- 19 Speed up (10)
- 20 4047 square metres (4)
- 23 Discard; throw out (6)
- 25 1984 comedy-horror film (8)
- 27 Process of acquiring new information, skills or values (8)
- 28 Bird in the order Columbiformes (6)
- 29 Series of small waterfalls (8)
- 30 Catalytic protein (6)

DOWN

- 1 Gas globules in liquid (for example) (7)
- 2 Referring to part of the cardiac cycle (9)
- 3 Thing (6)
- 5 Of a tide, at its minimal range (4)
- 6 Low-pH precipitation (4,4)
- 7 Injection of fluid into the lower bowel (5)
- 8 German engineering and electronics conglomerate (7)
- 11 Scavenging bird of prey (7)
- 14 Electrochemical power source (7)
- 17 Mechanical structures (9)
- 18 Foetal organ, in mammals (8)
- 19 Synthetic fibre (7)
- 21 Fundamental attributes; quiddity (7)
- 22 Membrane surrounding an embryo (6)
- 24 Sir James ___, English astronomer and mathematician (5)
- 26 On a single occasion (4)

Quick quiz #86

- 1 Zymology, also known as zymurgy, is the study of which process?
- 2 Animals that enter hibernation when cold-stressed or food-deprived are what kind of hibernators?
- 3 How many mountains in the US are 5000 metres or higher?
- 4 Bromelain is an enzyme extract derived from which fruit?
- 5 What is the only country to have completely banned the cultivation, harvesting, production and sale of tobacco?

Answers on page 55

Puzzle set by Zoe Mensch #98 Puppies galore!

Dog breeder Harriet Hound's prize pooch has just had 10 puppies. She is particularly pleased, because there are only nine puppies in the latest litter of her arch-rival, Matilda Mutt.

However, for Harriet, it isn't just the overall quantity that counts, it is the number of female puppies, because females earn her a premium. On average, 50 per cent of puppies are female. "What is the chance I've got more female puppies than Matilda?" wonders Harriet.

You might think she needs to use sophisticated probability maths to work this out, but in fact there is a way to figure out the solution with some relatively simple reasoning.

Answer next week



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Sun-baked lichen

The tiles on my roof are covered in lichen. In summer, the roof is baking hot and dry as a crisp. How does the lichen survive?

David Muir

Edinburgh, UK

Lichens have the ability to shut down, allowing them to tolerate extreme desiccation in a dormant state. They recover quickly when conditions improve, restarting photosynthesis and growth.

Two lichens took a trip on a Russian Soyuz rocket in 2005. They were exposed to the vacuum environment and cosmic radiation of open space for 15 days. On their return to Earth, their ability to photosynthesise was unaffected. It would be a fair bet for lichens to be one of the last living life forms on a dying Earth.

Mike Follows

Sutton Coldfield, West Midlands, UK

Lichens are fascinating. They are a symbiotic partnership between a fungus and either an alga or cyanobacterium, and there are about 15,000 species. This symbiosis allows both parties to extend their geographical range so that lichens can survive at a bigger range of latitudes and altitudes than most other organisms.

“Lichens survived 15 days in space and it would be a fair bet for them to be one of the last living life forms on a dying Earth”

The fungus provides the accommodation and anchors the lichen to whatever it is living on, while the alga or cyanobacterium harnesses photosynthesis to provide food for both parties.

Generally, a lichen has at least three layers. The top layer, called the cortex, is essentially a roof, made of fungus, complete with a water collection system. Beneath this is the symbiont layer, with a looser structure to accommodate

the photosynthetic partner and allow air to circulate. Beneath this is a fungal layer that acts as the foundations and attaches the lichen to its substrate.

The cortex acts a bit like a malfunctioning sunroof that opens – or rather becomes more transparent – when it rains. This way, the alga can photosynthesise when the moisture is available.

When there is insufficient water, the lichen goes into suspended animation in a process called poikilohydry. This is one reason they take so long to grow. Their longevity and regular growth rate mean that they can be used to work out how long bare rock or roof tiles have been exposed, for example, in a method called lichenometry.



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This week's new questions

Feline fix Is it possible, or desirable, to produce a genetically engineered cat that doesn't have an urge to kill wildlife?

Geraint Day, Swindon, Wiltshire, UK

On that note When two musical notes are an octave apart, one has double the frequency of the other yet we hear them as the “same” note – a “C” for example. Why is this?

Jon Dickinson, Sevenoaks, Kent, UK

Could cats be genetically engineered to stop their urge to kill wildlife?

warming and get hot in the sun. Desert lichens can reach temperatures up to 70°C, yet in the dry state they can survive for long periods. Heat denatures proteins leading to cell death, but many lichens contain abundant sugars and alcohols called polyols.

During desiccation, it is thought that these substances become concentrated within the cells and eventually form a glassy material that protects the complex cellular machinery from damage.

Hop to it

In our local bush in Australia, there are two types of birds: those that walk, such as magpies, and those that hop, such as kookaburras. Is one of these groups more advanced than the other? (continued)

Anick Abourachid

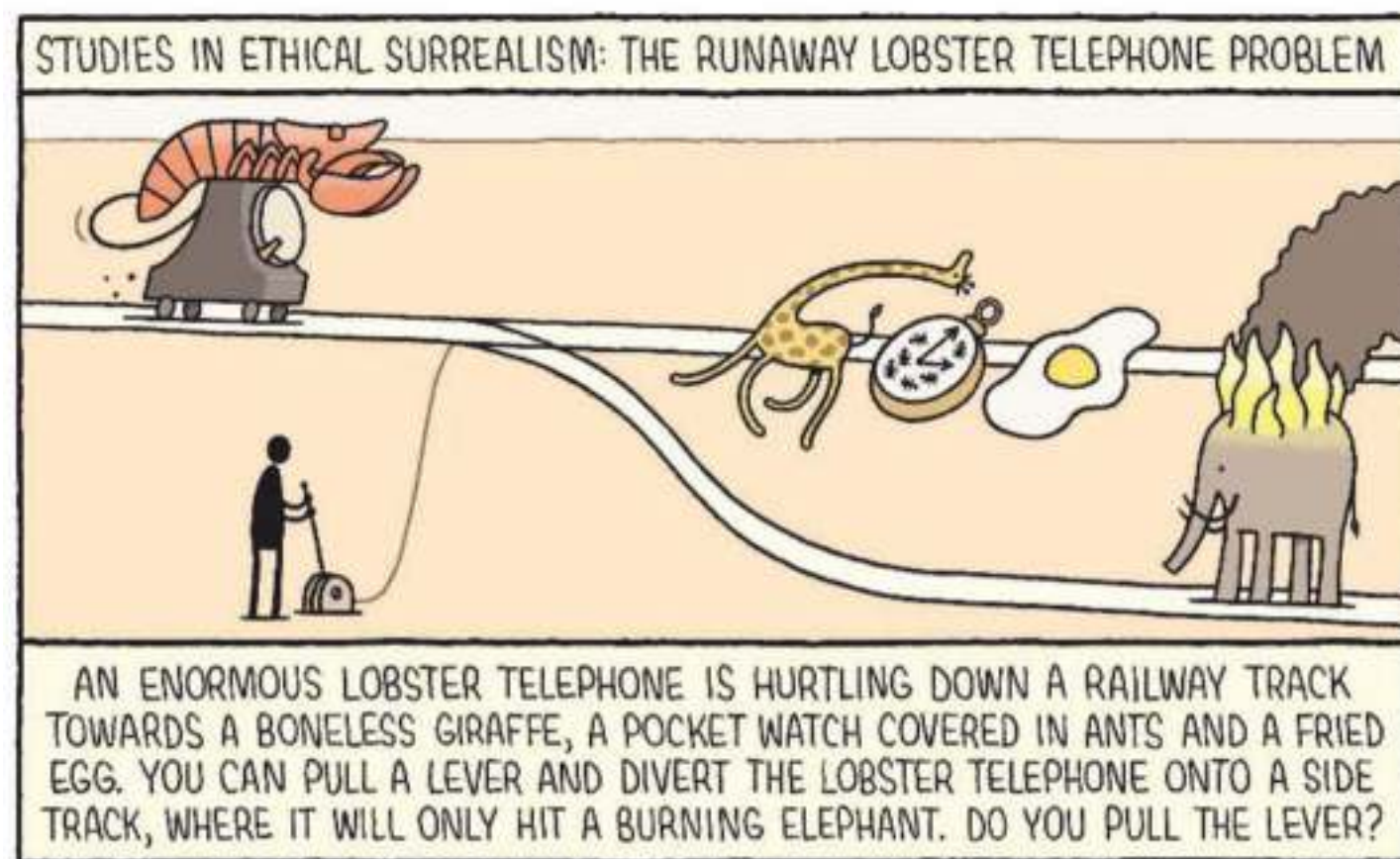
National Museum of Natural History, Paris, France

Birds are flying animals, but it is their legs that allow them to live in most places on Earth. Under the feathers, all bird species share a similar shape, related to flight, but they have very different ecologies, thanks to their legs.

Different legs and feet are suited to different terrains, whether it be flat ground or in trees, where surfaces can be thin or wide, flexible or solid, vertical or horizontal. Thus, perching birds have legs with toes like pincers, which allow them to cling on, and most tend to hop, such as kookaburras.

Birds that live mainly on the ground have longer feet at the front than at the back and tend to walk, such as chickens. Many species of bird live both on the ground and in trees, and often walk, but also jump when they accelerate, such as magpies. Only large ratites like ostriches are specialised in running. Most birds fly away instead.

Tom Gauld
for *New Scientist*



The birds' legs give them two advantages: allowing them to take off from or land on many surfaces, and moving in a wide variety of environments to find all kinds of food and shelter for their nests.

Chris Feare

Haslemere, Surrey, UK

In a previous answer to this question, Linda Phillips contemplated why crows like to stroll on roads (24 October 2020). One answer was given in *New Scientist* in the early 1970s.

Some researchers in the UK had asked the same question about rooks, highly sociable members of the crow family. At that time, rooks commonly fed on motorways and the researchers hypothesised that vibrations caused by traffic simulated those of rainfall, which encouraged worms to come to the surface, providing an attractive food source for rooks.

I had my doubts, because I had never seen a worm with a tarmac-piercing nose! So I began my own research. On motorway journeys, I counted all the rooks I saw and

“In car parks, the birds scanned the front number plates of parked vehicles to pick off dead insects that adhered to them”

recorded where they were feeding: main road surface, hard shoulder (or breakdown lane) or the verge.

Sadly, the data disappeared with the demise of a computer. However, the birds' preference was to feed at the boundary of the hard shoulder and verge. Further investigation revealed that insects killed by passing vehicles accumulated here and provided a bounty of nutritious morsels that didn't require chasing or digging.

Incidentally, many of my journeys were related to my research on starlings. Motorway service stations provided a restaurant for these birds too, with starlings parading around car parks, scanning the front number plates of parked vehicles and picking off the dead insects that adhered to them.

Rooks are seen much less frequently on motorways now, possibly reflecting a decline in UK insect populations.

Recycling racket

Why is the noise so deafeningly loud when I empty a bag of empty bottles into the glass recycling hopper?

Peter Peters,

Sherborne, Dorset, UK

Glass is hard, and rings for some time when bottles clash because it is a very stiff material. This effect is cumulative in the short term, so the sound intensifies. A good example of this effect is when two wine glasses, held by their stems and very gently clashed, ring with a surprisingly loud sound.

Additionally, recycling hoppers made from sheet steel will vibrate on impact, and their conical shape focuses the noise of the clashing glass on your ears.

Pete Lloyd

Torremolinos, Spain

Could it be embarrassment? ■

Answers

Quick quiz #86

Answers

1 Fermentation

2 Facultative

3 Four, all in Alaska: Denali, Mt St Elias, Mt Foraker and Mt Bona

4 Pineapple

5 Bhutan

Cryptic Crossword #49

Answers

ACROSS 1 Nori, **3** Albacore, **9** Bear hug, **10** Plain, **11** Lemon, **12** Alexia, **14** Single, **16** Cosset, **19** Amoeba, **21** Okapi, **24** Olive, **25** Nurture, **26** Migraine, **27** Vent

DOWN 1 Nebulise, **2** Realm, **4** Logjam, **5** Ample, **6** Ovaries, **7** Etna, **8** Phenol, **13** Strident, **15** Numbing, **17** Odours, **18** Tannin, **20** Enema, **22** Azure, **23** Zoom

#97 Cabinet reshuffle

Solution

The Ruritanian PM reshuffled the five senior ministers as follows:

Anerdine: Health to defence

Brinkman: Chancellor to education

Crass: Defence to chancellor

Dyer: Home secretary to health

Eejit: Education to home secretary

We were told Dyer goes to health, so only Crass or Eejit could take Dyer's job (which isn't chancellor).

From this starting point, you will find that the only cycle of moves that works is ACBED, resulting in the jobs listed above.

Feline frenzy

"Are you a cat or a dog person?" Feedback is often asked. To which we reply, "no".

Catty? Perhaps. Yet even our heart is softened by the unbounded joy expressed by a feline rubbing against a catnip plant (*Nepeta cataria*, to get in there before our ever-vigilant subeditors do). The suspicion that hardcore drugs are involved has now been confirmed by a study pinning down how nepetalactol, an organic compound first isolated from catnip, activates the feline opioid reward system.

Reiko Uenoyama at Iwate University in Japan and her colleagues reached this conclusion by testing the effect of nepetalactol on 25 laboratory cats, 30 feral cats, an Amur leopard, two jaguars and two Eurasian lynx. We hope the claw marks are on their way to healing.

We also appreciate the further insight from the study that, besides an opioid rush, self-anointing with nepetalactol has the practical effect of repelling mosquitoes. "Our findings suggest that nepetalactol may be a new natural candidate repellent to help reduce mosquito problems in human society," the authors write. We can think of a few potential drawbacks – especially if you're not a cat person.

Sustainable whales

The Australian High Court has recently asserted a "right to reuse", allowing third parties to refill and resell expensive patented printer ink cartridges. Despite living in a stationery cupboard at a resolutely northerly latitude, we can only approve. No more night-time visits to the backstreet cartridge retrofitter, desires wordlessly expressed in a series of faded A4 printouts.

Quite how big a deal this is takes some working out, discovers reader Michael Paine. The website choice.com.au informs him that, including printer cartridges, "in 2019, Australia produced about 539,000 tonnes of e-waste, which is more than the estimated weight

Twisteddoodles for New Scientist



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of all of the northern hemisphere's blue whales combined".

We screw up our eyes, 10 per cent in confusion at the familiar blue whale measure resurfacing in a more complex guise, 10 per cent in perplexity at the strangely globetrotting nature of the comparison, and the remainder in a strained attempt to envision what all the blue whales living in the northern hemisphere look like.

The weight of these blue whales, it turns out, is a majestically large number multiplied by a lamentably small one. But, we muse, this comparison has a lot going for it as a measure of sustainability. We can imagine no better future than one where the mass of our waste diminishes as the mass of an imperilled species rises, with the one expressed as progressively smaller multiples of the other.

Bring coffee

A mildly jittery colleague clutching a homeschooled infant in one arm and a quadruple espresso in the other draws our attention to a new paper in the journal *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, titled "Coffee effectively attenuates impaired attention in ADORA2A C/C-allele carriers during chronic sleep restriction".

Pausing only to note that this paper, dated 13 July 2021, appears to come from what we hope is a happier, less sleep-deprived future, we turn to an accompanying press release. "Drinking coffee may help temporarily offset the negative effect of chronic sleep loss on working memory, attention and reaction-time," it trills. "The study explored coffee's effects during a simulated busy work week, in

which the 26 participants involved underwent sleep restriction, sleeping a total of only five hours each night for five days."

This, apparently, is what goes on behind the closed doors of the "state-of-the-art Institute of Aerospace Medicine, in Cologne Germany". Sadly, while positive effects of caffeination were observed during the study's first three to four days, by the fifth day, no difference was observed compared with a control group being fed decaffeinated coffee.

Feedback is tempted to growl "tell us something we didn't know". But it was a disturbed night, no one's been round to service the office coffee machine since March 2020, and... sorry, what were we talking about?

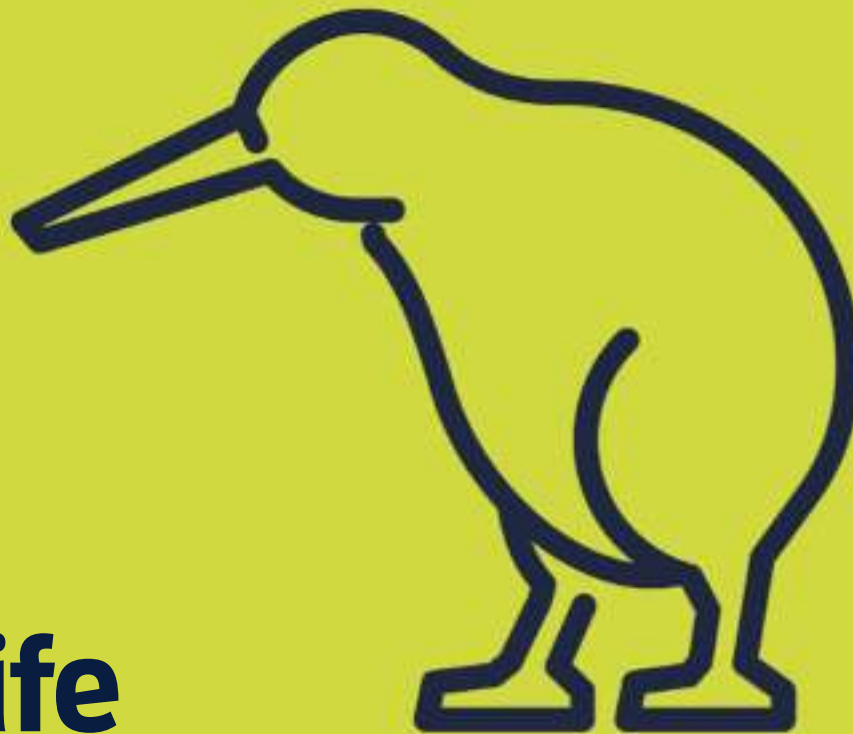
Blockchain blues

We probably weren't talking about blockchain. Reuters reports that two UK hospitals are "using blockchain technology to keep tabs on the storage and supply of temperature-sensitive covid-19 vaccines".

Blockchain, Feedback readers will no doubt be aware, is a distributed ledger technology designed such that any attempt by one party to explain what it is or how it works causes the eyes of a second party to glaze over, thus ensuring total security about what's actually going on.

Accordingly, opinions about this new development are divided in the windowless basement of New Scientist Towers housing our technology staff. "There's literally nothing blockchain can do that a spreadsheet can't," says one. Another points out that at least a blockchain can't run out of rows – a snafu that caused Public Health England to lose some 15,000 records of positive covid-19 tests last year (24 October 2020, p 56).

If you say so. Feedback is inclined to shrug: what, after all, is the worst that can happen? Actually, don't answer that. Better still, answer it on a blockchain. ■



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