New Scientist

SPECIAL ISSUE

WEEKLY September 26 – October 2, 2020

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Why the virus isn't from a lab, and why you didn't have it in December

NUCLEAR BATTERIES
The forgotten power source that could fuel an energy revolution

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How to keep your brain healthy (even in a pandemic)

Psychologist Kimberley Wilson reveals how lifestyle habits can make a difference. Discover the science behind this and get practical advice. Thursday 15 October at 6pm BST/ 1pm EDT/on-demand.

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The race to find life on Venus; coronavirus set to claim the lives of 1 million people; the extinction crisis; how the brain slows time.

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Newsletter

Health Check

Our free newsletter rounds up health and fitness news. This week: what the pandemic's future may look like.

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Video

Life on Mars?

This week's *Science with Sam* explains how Perseverance, NASA's latest Mars rover, will look for signs of ancient life.

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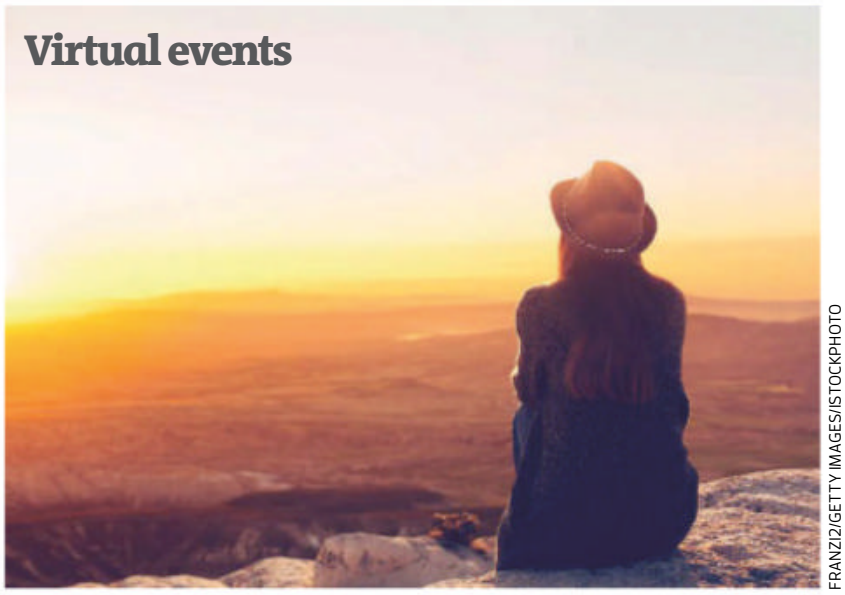
Online

Covid-19 daily briefing

The day's coronavirus coverage updated at 6pm BST with news, features and interviews.

newscientist.com/coronavirus-latest



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Get some headspace Expert tips on keeping your brain healthy

Down in the dust Sam Wong explains how rovers hunt life on Mars

YANDONG LIU /ALAMY

The fourth dimension The way your mind manipulates time

A note from the editor

THE sharp-eyed among you will have already noticed a few changes to the Back Pages section of the magazine.

In the last issue we welcomed back Abigail Beall's *Stargazing at home* column, in which she explained how to see a SpaceX Starlink satellite. Her column will now appear every four weeks, on a rotation with three other columns, two new ones and another returning favourite.

This week it's the turn of a fresh offering, *Science of gardening*, written by medical reporter/allotmenteer Clare Wilson. She begins with a trend in architecture to cover walls with plants to help insulate buildings, soak up rain and give wildlife more space. However, this usually requires complex structures to support the soil. There is another way to get these benefits, though, which Clare tells you about on page 51.

Next week will be Layal Liverpool's turn with another new column, *Citizen Science*, in which she investigates the most interesting collaborative science projects and explains how to get involved. Her first instalment will look at a scheme that has recruited millions of people to help us fight covid-19.

The final part of the quartet will be a return of Sam Wong's very popular *Science of cooking*. We hope you enjoy!

Emily Wilson
New Scientist editor

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Episode 33
The healthy-eating revolution, China's cosmic ambitions, Russia's pursuit of gene-editing technology and the world's greatest mammal

Episode 32
Billionaire plan to geoengineer the planet, how the moon affects your health and Neuralink's telepathic pigs

Episode 31
Widening the search for alien life on habitable planets, why unconscious bias training might not work and the microbiome of cancer tumours

Hosted by *New Scientist*'s Rowan Hooper and Valerie Jamieson, new episodes are out each Friday. Follow us on Twitter **@newscientistpod**

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Darwin was right

The glorious theory of evolution by natural selection has seen off all comers

THE theory of evolution is one of the greatest accomplishments of the human intellect. Some might argue that it is the greatest, although quantum theory or relativity would have their supporters too. But in the biological sciences, it stands unrivalled. It is no less than the grand unified theory of life.

It is also a theory in the truest sense of the word: an interlocking and consistent system of empirical observations and testable hypotheses that has never failed scrutiny. Nothing has even been discovered that falsifies any part of it, despite strenuous efforts by detractors. It all stacks up.

Yet we should resist the temptation to think that evolution is carved in tablets of stone. The radical but irresistible ideas put forward by Charles Darwin and Alfred Russel Wallace in 1859 remain the core of the theory, yet it has constantly accommodated new knowledge. This happened most conspicuously about a century ago, when the new science of genetics was melded with natural selection to create what became known as the "modern synthesis".

"The voices of evolution's detractors have largely fallen silent, worn down by the patient drumbeat of reason"

Today, we are arguably in the midst of another upgrade. Over the past 30 years, discoveries in developmental biology, epigenetics and elsewhere have needed to be brought under the wing of evolution. As our special report on page 38 shows, they largely have been. Only hindsight will be able to judge whether what emerges is Evolution 3.0, or merely Modern Synthesis 1.1. If nothing else, the flurry of activity is proof that evolution – and hence biological science – is a vibrant, living-and-breathing entity still in its prime.

Evolution has also achieved something that is arguably more important: it has seen off its culture warrior detractors. A decade ago, it was on the front line of the war on science, under attack from creationism and its pseudoscientific alter ego, intelligent design. Those voices have now largely fallen silent, worn down by the patient drumbeat of reason.

Sadly, that remains an isolated victory in the wider anti-science culture war. But it shows that victories aren't impossible. Evolution won because it is true. Eventually, truth will out. ▮

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CONTACT US

newscientist.com/contact

General & media enquiries
US PO Box 80247, Portland, OR 97280
UK **Tel** +44 (0)20 7611 1200
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Australia 418A Elizabeth St, Surry Hills, NSW 2010

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New Scientist Newsletter

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Get the most essential health, diet and fitness news in your inbox every week

Hundreds of new studies about our physical and mental well-being are published every week, but the results can be conflicting and confusing. Our weekly newsletter gives you the health and fitness news you can really trust – which, amid the coronavirus pandemic, is more important now than ever.

Get a digest of the week's most essential health stories, including the latest covid-19 news, in your inbox every Saturday, carefully curated by *New Scientist* health reporter Clare Wilson.

Clare Wilson

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REUTERS/ALASDAIR PAL

Global spread

India is catching up with the US

The number of reported coronavirus cases in India is surging, and the true figure is likely to be even higher, reports **Nilanjana Bhowmick**

INDIA is on track to overtake the US as the country with the highest number of coronavirus cases worldwide. With more than 5.56 million recorded cases, India set a new record with 97,859 daily cases on 16 September. It took just 11 days for the total number of cases so far to rise from 4 to 5 million, and it is likely to be just a matter of weeks before the country passes the US, which has some 6.85 million cases.

Given India's population of about 1.38 billion, however, the number of cases is comparatively low. On 22 September, for instance, the seven-day average of daily confirmed cases in the US was 131 per million people, compared with 65 per million in India. Deaths, too, currently totalling about 89,000 in India, are much lower than in the US, which is nearing 200,000.

Cases have soared since India eased a strict national lockdown in May, and some are worried that the spread of the virus into rural areas will increase case counts and fatalities. Two-thirds of the population lives in rural regions, which have only about a third of the country's hospital beds.

"We will have to gear up our services to delay the spread of the virus to rural areas," says K. Srinath Reddy, president of the Public Health Foundation of India. "That's going to be absolutely critical."

Even states like Kerala, which won global praise for its handling of the virus in the initial months of the pandemic, are now seeing a rise in case numbers.

Much of the surge is ascribed to migrant workers returning to their home states since restrictions eased. "That's when it became difficult to control," says Reddy.

On 14 September, India's health minister Harsh Vardhan said that 1 million tests are being conducted daily. "You do need some testing, but it cannot be the only public health strategy," says Reddy. "We will also have to boost heathcare systems and improve connections with local communities."

There are fears that testing is inadequate and many cases are going undetected. Research published earlier this month by the Indian Council of Medical Research looked at the prevalence of antibodies in the population. It suggests that 0.73 per cent of adults in India had been infected by early May, equating to 6.4 million people.

Despite the rising number of cases, it is unlikely that India will impose another lockdown. The economy contracted by 23.9 per cent in the April-June quarter, its worst decline since 1996.

On 21 September, the Taj Mahal opened its doors to tourists after six months of closure, just one of the measures the government has taken since June to revive the economy, along with opening up state borders, domestic flights, malls and gyms.

These measures are sending a wrong message that "the worst is over", says Reddy. "Only when the daily death rates are falling steadily for 10 days can we feel assured that the epidemic is coming down. Before that, if we start opening up, we are inviting trouble." ▮

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

Testing strategies

How to get a grip on testing

The UK has grand ambitions for testing, but is struggling to get it right. There are solutions, reports **Clare Wilson**

THIS month, UK Prime Minister Boris Johnson announced an ambition to increase the country's capacity for coronavirus testing to several million tests a day.

Billed as Operation Moonshot, the idea was received with widespread incredulity. The UK is currently failing to meet demand for coronavirus testing, with roughly half a million daily requests outstripping supply by up to fourfold.

Yet there are also reports of new technologies in development that could make testing faster and cheaper. If the UK had the capacity to test not just those with symptoms of covid-19, but to regularly test symptomless people too, it could be a game changer in the ability to control the disease.

From the beginning of the pandemic, many countries have struggled to provide enough coronavirus tests for all those who need them. A lack of tests is disruptive because anyone with symptoms that resemble those of covid-19 has to stay at home and isolate, and must also be treated as infectious within hospitals.

Insufficient tests also make it impossible to accurately track how the epidemic is progressing in a region, whether cases are rising or falling. "Without testing, which is our eyes and ears, we don't understand where this is going," says Stephen Griffin at the University of Leeds in the UK.

The UK faced this problem initially in its first wave of covid-19, when even hospitals were going short of tests. To expand capacity, five large facilities known as Lighthouse Labs were set up to process polymerase chain reaction (PCR) tests, a well-established technique. In this case, the tests are used to compare samples from a nose or throat swab to the genes of the new coronavirus. The labs are dotted around the UK and, for a few months, capacity seemed largely sufficient.

ANDREW MILLIGAN/POOL/AFP VIA GETTY IMAGES

QR codes are used to scan in samples at a new testing centre in Glasgow

10m

The number of daily tests the UK government reportedly plans to carry out by 2021

"Without testing, which is our eyes and ears, we don't understand where the outbreak is going"

As UK cases have begun to increase again in recent weeks, though, demand has risen. The drivers seem to be people socialising and returning to work and school. Although children are generally less affected by the coronavirus, schools are known hotbeds for spreading coughs, colds and flu, which have similar symptoms to covid-19 and so can trigger test requests.

Media reports have been full of stories of testing centres with empty car parks, while people trying to book online are being offered appointments hundreds of kilometres away.

The bottlenecks aren't at the testing centres where swabs are taken, but at the Lighthouse Labs where they are sent. If labs fall behind on processing, they tell testing centres not to release more appointments.

Although the UK's current capacity for tests is around 250,000 a day, some are reserved for hospitals, so only about 160,000 are available to the public. Based on estimates of phone requests and website usage, about three or four times as many people are seeking tests as are able to get one, according to comments made to members of parliament by Dido Harding, head of England's test-and-trace scheme.

Two further Lighthouse Labs are opening in the next few weeks, which should increase testing capacity to 500,000 a day by the end of October. However, Harding admitted to MPs that, by then, it

still won't be enough to meet rising demand.

Official documents leaked earlier this month suggest that Operation Moonshot is aiming for a capacity of 10 million tests a day by early next year. This is around the same number that would be needed to eliminate the virus from the UK, by testing everyone in the country once a week, although the government hasn't stated that elimination is the goal. Instead, it has focused on testing as a means for people to return to regular activities.

New testing methods could help. One option is a small machine called NudgeBox that can process a sample on the spot and give a result in 90 minutes, instead of it having to be sent to a lab.

Developed by UK biotech firm DNANudge, the device is already being used in eight hospitals, and the UK has ordered 5000 more. Recent research shows it is almost as sensitive as standard lab testing. "It allows you to start therapy much more quickly," says Graham Cooke at Imperial College London, who led the study.

While this kind of machine can help in hospitals, it can only process one sample at a time and so turn around at most 16 samples a day. That means it can't raise testing capacity enough to screen millions of people daily unless hundreds of thousands of devices are manufactured. What is needed are mass-testing devices that process multiple samples at once.

Various other kinds of PCR tests are in use or in development around the world that could help. Some of these are cheaper or easier than the standard lab tests, or use different chemicals to get round any shortages of the commonly used ones. But if testing capacity is to be boosted to the levels mooted in Operation Moonshot, other approaches may be needed.

ALEX KRAUS/BLOOMBERG VIA GETTY IMAGES

Travellers queue at a covid-19 testing centre at Frankfurt Airport, Germany

Earlier this year, Julian Peto at the London School of Hygiene & Tropical Medicine proposed a plan in medical journal the *BMJ* to use mass testing to eliminate the coronavirus from the UK. To achieve the necessary level of testing, he proposed commandeering all the PCR equipment in research labs at universities and hospitals.

Peto now says that increased capacities for other tests – for example, a genetic test called RT-LAMP – could make mass screening easier. Unlike PCR, this doesn't need sophisticated lab equipment, but merely a heater to warm the sample to about 65°C. It gives a result in 20 to 45 minutes.

It might be possible to speed up testing further by switching from looking for the virus's genes to hunting for molecules on its surface, known as antigens. These can be detected using artificial versions of the antibodies of our immune system that normally recognise viral antigens. This is the same mechanism as home pregnancy tests and, like these, coronavirus antigen tests can produce fast results.

Antigen tests aren't generally as sensitive as genetic ones, but that has both pros and cons. They can fail to spot some people whose infection is waning and so have relatively few virus particles in their nose or mouth, but still have enough viral genetic material to be picked up by PCR. However, such people are less likely to be spraying virus into the air from their lungs, so antigen tests might be good for quickly picking out only people who are infectious.

For now, UK mass-testing schemes are sticking with genetic tests. There are two large trials combining saliva testing with the fast RT-LAMP method in two cities. In Salford, screening of people at indoor and outdoor venues is due to begin next month. In Southampton, children at several schools are starting weekly checks.

It was initially thought that saliva tests wouldn't catch as many positive cases as swab tests because mucosal fluid from inside the nose or the back of the throat should in theory contain more virus particles. So the first tests approved were swab ones.

But it now seems that testing people's saliva is effective. The US Food and Drug Administration granted emergency approval last month to two saliva tests. Such tests would be especially useful in schools because administering the invasive swab tests is particularly hard with small children.

A ready supply of tests to enable mass screening would allow for a radical new containment strategy, as testing would include people who are infected but have no symptoms and so can spread the virus unknowingly. If enough people are reached and all infected individuals self-isolate, it should reduce the virus's prevalence.

There are big questions around false positives (see box, left) and who would pay for the tests, and it would also be vital to test visitors and returning travellers, as is happening in Germany. But done properly, these two strategies together might be able to more or less eliminate the virus from a nation without a vaccine in sight. ▮

False positives

Any mass screening of people who don't have symptoms can hit the problem of "false positives".

Imagine a test that is 95 per cent accurate when it produces a positive result. It is important to remember that very few of the screened group really are infected – say about one in 1000 at any time. Of the 999 people without the coronavirus, 949 would correctly test negative, and 50 would wrongly test positive.

Assuming that the one person out of the 1000 who really has the virus correctly tests positive too, then for every 51 positive test results, 50 would be wrong. Across the population, that would lead to thousands of people unnecessarily staying at home and self-isolating.

There is a solution, says Julian Peto at the London School of Hygiene & Tropical Medicine. With fast tests that give a result in an hour or two, anyone who gets a positive result could have another test, reducing the number of people wrongly told to isolate. "The idea of false positives is a complete red herring," he says.

Transmission

Virus probably didn't take hold in the US and Europe last December

Michael Le Page

WHEN did the coronavirus first reach Europe and the US?

No cases were reported outside China until January 2020, but a study published on 10 September claims that cases in the US began to rise by 22 December. Many people there and in Europe suspect they had coronavirus around this time. Yet overall, the evidence suggests there were few cases outside China this early on.

Covid-19 was first recognised as a new disease in Wuhan, China, over the course of December. On 13 January, the first case outside China was reported in Thailand. On 21 January, the US reported its first case and on 24 January, France reported three, the first in Europe.

This, at least, is what was known at the time. But it can take up to two weeks for covid-19 symptoms to appear and many infected people don't have symptoms at all.

In addition, when countries did start testing, many initially limited it to people who had come from China recently. If the virus had already begun spreading, any early local cases would have been missed. "It is certain there were many cases we did not see," says Lauren Ancel Meyers at the University of Texas at Austin.

But how many and how soon? One team says it found viral RNA in sewage in Barcelona, Spain, as early as March 2019, but others have dismissed this. "It is highly likely to be contamination," says Kristian Andersen at the Scripps Research Institute in California.

The 10 September study is based on the number of people going to a group of hospitals and clinics in the Los Angeles area with a cough, but just because people had symptoms resembling covid-19 doesn't mean they had it. "It's extremely unlikely," says Dominik Mertz at McMaster University in Canada. "I think we can be pretty sure it was something else."

In fact, it is very unlikely that anyone was infected by the virus before November. Several teams tracing its evolution by looking at changes in RNA of samples of the virus sequenced so far have all concluded that the pandemic strain emerged around November.

"While it's possible lots of people in the West had covid-19 then, it is more likely it was another virus"

On the flip side, this does mean that people in Italy may have been infected by 18 December, as another sewage study claims, and that a man in France could have been infected as early as 14 December, as testing of stored hospital samples suggests.

Based on two studies that found missed cases by testing stored hospital samples in Wuhan and Seattle, Meyers's team estimates that there could have been 10,000 cases in Wuhan by 23 January when only 400 had been detected, and 9000 in Seattle by 9 March, when only 245 had been reported.

However, even if Meyers's estimates are right, it doesn't mean lots of people outside Wuhan had the coronavirus as early as December. "While it is possible, it's much more likely they had some other respiratory virus," says Meyers.

REUTERS/MANUEL SILVESTRI

Venice Carnival in February before festivities were cut short due to coronavirus

Virus origins

Still no evidence the coronavirus was made in a lab

A RESEARCH paper claiming to prove that the coronavirus was cooked up in a lab has been widely dismissed by scientists.

The paper, which was posted online last week and hasn't been peer reviewed, says that "unusual features" of the virus's genome suggest "sophisticated laboratory modification rather than natural evolution" (zenodo.org/record/4028830). The authors allege that the modification of one or more bat viruses was carried out in a laboratory in Wuhan, China.

Experts poured scorn on the claim. The paper "does not provide any robust evidence of artificial manipulation and is highly speculative", said Gkikas Magiorkinis at the National and Kapodistrian University of Athens, Greece, in a statement.

"This preprint report cannot be given any credibility in its current form," said Andrew Preston at the University of Bath, UK, in a statement.

The paper was co-authored by Li-Meng Yan, a self-styled whistle-blower from Hong Kong whose current affiliation is the non-profit Rule of Law Society and the Rule of Law Foundation, both in New York. They were co-founded by US president Donald Trump's former chief strategist, Steve Bannon.

Yan did media interviews before the preprint was posted. She told UK daytime TV show *Loose Women* that last year she was a medical doctor and PhD student at the University of Hong Kong (HKU) Medical Centre School of Public Health.

In December, she was assigned to a secret investigation of the new disease that we now know as covid-19, she said. She claimed that in the course of her investigation, she discovered that it was caused by an unnatural coronavirus created in a Chinese government laboratory in Wuhan. She said she fled Hong Kong for the US in April after the Chinese government tried to make her "disappear".

HKU has confirmed that Yan was a postdoctoral fellow and has since left the university. In a statement, it said that Yan didn't conduct research into the coronavirus at HKU, and distanced itself from her comments.

Graham Lawton

Diary from the covid-19 front line

The coronavirus has posed many challenges to doctors, the latest being "long-tail" symptoms, says doctor **Selma Stafford**

THE first confirmed case of covid-19 in Brighton was around 1 February. I know this because I had been to a friend's 50th birthday party that night. Having left early, I didn't know anything was wrong until I received a cryptic text from the host, something about us meeting up "when this is all over". I disregarded it.

I later discovered that somebody at the party had been in contact with this first confirmed case, so several guests had to self-isolate. Many were doctors.

It soon became clear that letting "hot" patients – those with a potential covid-19 infection – see their general practitioner (GP) might take many surgeries out of action, and money was made available for new solutions.

That is how my organisation was tasked with setting up a "hot-hub" for the area. The challenge was: how can you see patients who aren't sick enough to go to an accident and emergency department but who might have covid-19, yet make it as safe as possible for healthcare workers?

What if someone has covid-19 symptoms, for instance, and is OK, but also has appendicitis? Our idea was to keep a patient in their car. You could recline them in the passenger seat and carry out a basic examination.

So we decided to set up the hot-hub in a car park, inside a huge drive-in marquee. We paid scrupulous attention to infection control and conversations took place on the phone before and after the physical assessment, to minimise face-to-face contact. All the practices in the area were signed up, covering about 350,000 people.

When we started, it felt as though every person we spoke to had covid-19. We didn't have access to testing, but would advise patients on the basis of the phone call and physical examination. I became adept at recognising the "covid cough" over the phone.

Some days were especially difficult. I remember one 60-year-old man in particular. He had driven himself in, with his wife, but when we measured his oxygen levels, they were surprisingly and dangerously low. I asked why he was driving, and he told me that he was fed up with his wife missing the turning so had taken over at the wheel. He was clearly unwell, so we called an ambulance, and 19 minutes later he was taken away.

ANDREW AITCHISON/IN PICTURES VIA GETTY IMAGES

A patient being assessed at a drive-in clinic in Dover, UK

I suddenly became very aware of his wife in the passenger seat. She wasn't allowed to accompany him to the hospital, but had to drive home alone with the very real possibility that she wouldn't see her husband again.

During my career, I have seen many patients very ill and dying, but this sudden aloneness without any ability to say goodbye or accompany the loved one affected me more than usual. After that, we made someone responsible for staying with the person accompanying the patient, to make sure we could respond to their needs as much as possible.

After a few weeks, the number of patients like this fell and we started to see people who had finished self-isolation but were still unwell. The common feature was a residual lethargy, with some people reporting a persistent dry cough or intermittent high temperature. Their managers expected them back at work and they simply felt unable to go, or they worked for a few days then were incapacitated afterwards. GPs had little to offer – encountering patients who continue to have physical symptoms where there is no clear course of treatment can make doctors feel uncomfortable and impotent – and were unable to see them in person anyway, so we would assess them at the hot-hub.

We would check their breathing rate, oxygen saturations, temperature and pulse. These were usually normal, but the patient was still effectively disabled by symptoms. We don't have any medicine to offer, so all we can give is reassurance that this isn't unusual, advice to rest and hope that it will pass as the weeks go by.

This is a new illness, so we lack the evidence that is available for other areas. This long-tail disease seems similar to chronic fatigue, but can also have a periodicity like a tropical disease – some people feel better for a while, and then it hits them again.

"They used to go on 30-kilometre bike rides. Now they get breathless going up the stairs"

It also seems as though those with prolonged disease are more likely to have initially had milder symptoms. In fact, the majority of people I have seen in this camp are fit, active people in their 20s and 30s. Some of them would go on 30-kilometre bike rides three times a week. Now they get breathless going up the stairs.

It isn't clear whether this will become a chronic illness or get better over months rather than weeks. We are very far from understanding the long-term consequences of covid-19 and now need to support and advocate for people who are affected. ▮

Profile

Selma Stafford is a GP and educator in Brighton, UK, and clinical director of the Sussex MSK Partnership

Space exploration

Venus fly-by may confirm potential signs of life

Leah Crane

ON 14 September, researchers announced that two telescopes had spotted signs of phosphine in Venus's clouds, and no known non-biological processes could have made the gas in such large amounts. The BepiColombo spacecraft may be able to confirm that the phosphine is indeed there.

BepiColombo, a joint mission by the European Space Agency and the Japan Aerospace Exploration Agency, launched in 2018. Before it arrives at Mercury in 2025, it will pass near Venus twice, using the planet's gravitational pull to adjust its trajectory.

The first pass should occur on 15 October, and the team had already planned to test the craft's instruments by observing Venus. Now, the researchers are working out how to use them to check the phosphine finding.

This is important because the phosphine discovery isn't entirely certain. When light goes through gas in Venus's atmosphere, some of its wavelengths are absorbed, leaving dark lines in the light's spectrum called absorption lines. Phosphine absorbs light at thousands of wavelengths, but the telescopes that spotted the gas only caught it absorbing one wavelength in Venus's skies.

"The discovery was like getting a partial fingerprint and we want lots of fingerprints"

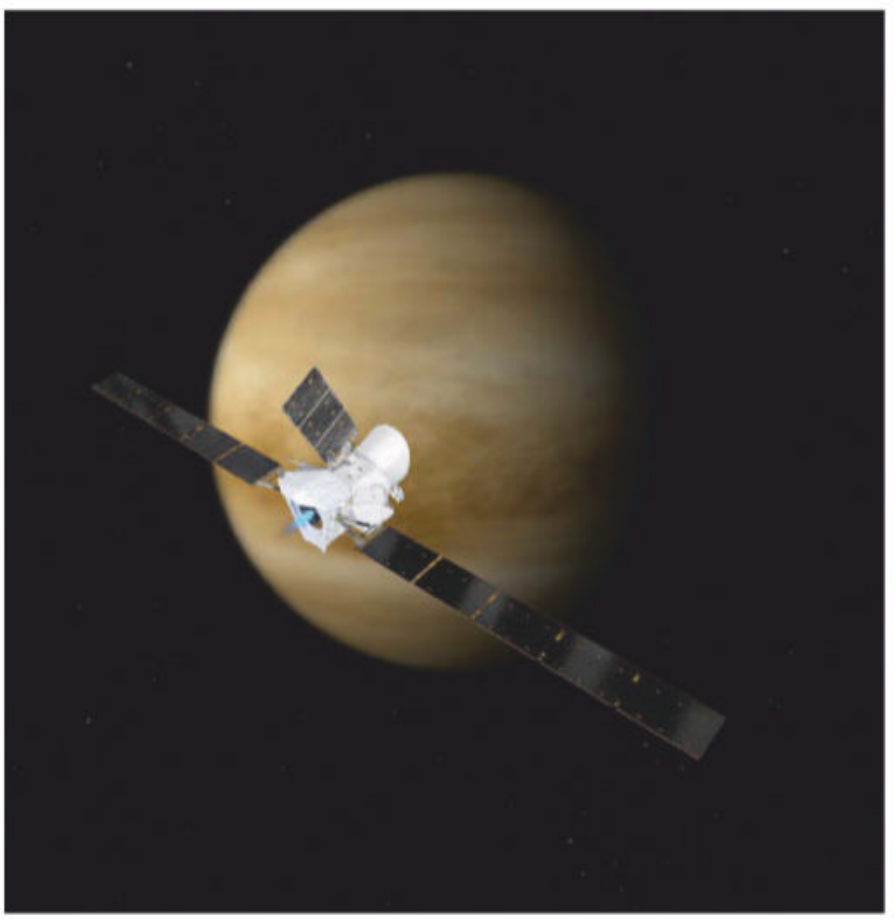
"The discovery was only one line – that would be like getting a partial fingerprint, and we want lots of fingerprints," says Sara Seager at the Massachusetts Institute of Technology, who is part of the team behind the detection. The researchers are now working on plans to examine the light further with Earth-based telescopes and potentially even new missions to Venus.

BepiColombo may be equipped to get a phosphine fingerprint before the planned observations. Preliminary calculations have shown that two of phosphine's absorption lines are in the wavelength range of one of the instruments, the Mercury Radiometer and Thermal Infrared Spectrometer (MERTIS), that was already due to take images of Venus as the spacecraft hurtles by, says team member Jörn Helbert at the German Aerospace Center.

MERTIS has two cameras, but their configuration may complicate efforts to get a good shot of Venus: during its voyage to Mercury, the main camera is folded inwards and unable to capture images. The second MERTIS camera is a calibration tool designed to take images of space to capture ambient light and remove its effects on the main camera's data. As BepiColombo passes Venus, this poorer quality calibration camera might be able to search for phosphine, says David Rothery at the Open University in the UK.

Luckily, there will be another chance. "We have a second fly-by coming up in August 2021 where we are even closer to Venus," says Helbert.

Without the main MERTIS camera and with no time to alter the October fly-by plans, it isn't certain whether BepiColombo can confirm there is phosphine in Venus's atmosphere next month. If it does, we will then be left to figure out whether the gas is truly is a sign of life. ▮



ESA/ATG MEDIALAB

The BepiColombo spacecraft depicted passing Venus

Environment

Air pollution may be behind millions of deaths in China

Donna Lu

UP TO 30.8 million adults in China and Taiwan are estimated to have died prematurely as a result of air pollution during a 17-year period.

Yang Liu at Emory University in Atlanta, Georgia, and his colleagues used satellite imagery to quantify the amount of air pollution over mainland China, Hong Kong, Macao and Taiwan between 2000 and 2016. The team used imagery taken by NASA satellites to estimate the concentrations of PM2.5 – particulate matter of less than 2.5 micrometres in diameter.

One measurement the team used is the amount of sunlight scattered or absorbed by particles in the air. Combining these readings with PM2.5 measurements from ground monitoring stations, as well as information about meteorological conditions and road networks, the researchers trained a machine-learning algorithm to predict PM2.5 exposure.

To estimate the total mortality linked to air pollution, the team then used historical data from a study of 116,821 adults in 15 Chinese provinces, which quantified the link between long-term PM2.5 exposure and non-accidental death. There was a roughly linear relationship between PM2.5 exposure and mortality, up to a certain point (*PNAS*, doi.org/d9n5).

"The people who live in the most polluted regions get disproportionally harmed," says Liu.

The highest per-capita deaths due to air pollution were found in the north-eastern Chinese provinces of Hebei, Henan, Shandong and Tianjin.

To date, most air pollution monitoring has been done from stations on the ground. In China, these are concentrated in urban areas, which doesn't account for some 600 million people in rural areas. In addition, measurements before 2013 are scarce. ▮

Technology

Most fertility apps are unreliable, but free ones work best

Jessica Hamzelou

FERTILITY-TRACKING apps can provide misleading information and shouldn't be relied on to help people conceive or as a contraceptive tool, according to an analysis of mobile phone apps available in the UK and Canada.

There are hundreds of apps that offer to track periods in order to help people either achieve or avoid pregnancy. To find out how reliable they are, Joyce Harper at University College London and her colleagues considered all 200 of the fertility-tracking apps offered on Apple's mobile iOS app store.

The team removed apps from the list if they were faulty, hadn't been updated within three years or didn't offer to predict a user's "fertile window". This left 90 apps. Just over half of those predicted this window based on when a user has their period.

This "calendar method" is based on the idea that ovulation typically happens on day 14 of the menstrual cycle and fertility is highest in the days before this. But this method is flawed, says Harper. "Not every woman has a 28-day cycle, we don't all ovulate on day 14," she says. Harper's recent research, based on the data from another fertility app, suggests ovulation occurs on day 17, on average.

CHEE GIN TAN/GETTY IMAGES/ISTOCKPHOTO

"In our study, women ovulated anywhere between day 10 and day 26," says Harper. Apps that rely only on dates provide inaccurate information, and could, say, result in some users missing their fertile window, she warns.

22%

Proportion of period-predicting apps with "serious inaccuracies"

Many fertility-tracking apps give imprecise ovulation predictions

The more robust apps took into account other markers of fertility based on user input, such as body temperature, which rises during ovulation, and information about the changing state of cervical mucus. Harper says she was surprised to find that, on the whole, the free apps used more of these biomarkers than paid-for apps did (*Reproductive BioMedicine Online*, doi.org/d9bj).

Still, no prediction will be perfect, and only 57 per cent of apps provided any disclaimer to this effect. Just five advised against using the app to avoid getting pregnant. "They shouldn't be relied on for contraception," says Rhonda Zwingerman at the University of Toronto in Canada, who wasn't involved in the study.

That doesn't mean apps can't be useful. Apps that track period dates can help those who want to be reminded when their period is due, or could indicate if periods seem unusually far apart, which might signal ovulation problems.

Yet they aren't always accurate. In other research, Harper has entered the same dates into 10 apps, and they gave varying dates of the next period. And Zwingerman has shown that about 22 per cent of such apps had "serious inaccuracies" in information they provided. "Almost all of those claimed to be able to predict the gender of your child based on when you had intercourse in the cycle," says Zwingerman. "Just to be clear, that's not how it works." ▮

Health

Nut allergies spike on Easter and Halloween

EACH year, severe allergic reactions to nuts spike in children around Easter and Halloween, according to an analysis of data from emergency rooms across Canada.

"I'm not so surprised," says Moshe Ben-Shoshan at McGill University in Montreal, who led the study. As a paediatric allergist who regularly works in the emergency room, he noticed that severe allergic reactions among children tended to go up at certain times of the year.

Ben-Shoshan and his colleagues used records of emergency room visits to analyse the incidences of nut-induced anaphylaxis – a severe allergic reaction – in children across Quebec, Ontario, British Columbia and Newfoundland and Labrador.

In 1390 cases between 2011 and 2020, they saw that rates of peanut-triggered anaphylaxis were 85 per cent higher than average on Halloween and 60 per cent higher during Easter. They saw a similar trend for anaphylaxis in cases where it wasn't clear if the child had eaten tree nuts or peanuts (*Canadian Medical Association Journal*, doi.org/d9mg). The team didn't find a significant increase in nut-induced allergic reactions during other holidays, such as Christmas, Diwali, Chinese New Year and Eid al-Adha.

SHUTTERSTOCK/AS FOOD STUDIO

Halloween treats can trigger dangerous reactions in children with nut allergies

"Halloween and Easter involve social gatherings with other children in the presence of a lot of candy. These holidays may include interactions with other adults who may not be aware of the child's food allergies," says Tina Sindher at Stanford University in California. She adds that "a lot of fun-size candy may not be labelled appropriately".

Children with food allergies should always carry an epinephrine autoinjector, such as an EpiPen, and parents should make other adults aware of allergies, says Sindher. ▮

Layal Liverpool

Science in the media

US science coverage is biased against people with names not of British origin

Donna Lu

NEWS coverage in the US of scientific work is biased against researchers whose names aren't of British origin.

Hao Peng at the University of Michigan and his colleagues analysed more than 230,000 news stories from 288 US outlets, which reported on around 100,000 different research papers across all scientific fields.

The team looked at whether the first authors of papers were mentioned in news coverage. Very often, these are junior researchers who have contributed most significantly to the work. Peng and his colleagues found that first authors who had names that weren't of British origin were significantly less likely to be mentioned or quoted than first authors with names that were.

On average, the probability of featuring in a news article was up to 6.4 per cent less for researchers with names of non-British origin. The greatest decreases were for people with names of Asian or African origin compared with those whose names were of European origin. The greatest disparity was seen in general news outlets, such as certain newspapers, where researchers with names of African and Chinese origin were 10 per cent less likely to be mentioned (arxiv.org/abs/2009.01896).

To perform the analysis, the team used Altmetric, a database that aggregates media and online coverage of scientific papers.

"Most people who work in journalism have personal anecdotes that support these findings," says Marcus Ryder at Birmingham City University, UK. "There is no doubt that the media confers legitimacy and authority to deciding who the voices we should be listening to are."

"People with names not of British origin were significantly less likely to be mentioned or quoted"

When examining possible factors contributing to the bias, the team found that geographical location was a major component, but that this alone didn't account for the disparity. Authors with names not of British origin based outside the US were even less likely to be mentioned, potentially because of perceived difficulties in interviewing them due to time-zone or language-fluency issues, according to the study.

"[Media coverage] not only affects public perception about who is a scientist, it also affects new scientists when they enter the academic world – who they choose to be advised by, who they choose to collaborate with," says Peng.

The researchers noted a small, gradual increase in the number of times scientists with names of Chinese or Indian origin, as well as those in languages derived from Latin, were mentioned. They predict that scientists in these groups may reach parity with colleagues who have names of British origin in five to 12 years, but that the gap will persist for other minority ethnicity authors.

The team also found a gender imbalance across the news coverage, but it reflected existing disparities between the numbers of male and female researchers in those scientific fields. ▮

MB PHOTO/ALAMY

A news stand in the New York subway in Manhattan

Human evolution

People in Cape Verde have evolved better malaria resistance

WE ARE still evolving, and one of the best examples of recent evolution in people has been found on the Cape Verde islands in the Atlantic. There, a gene variant that confers a form of malaria resistance has become more common over just 550 years.

Amy Goldberg at Duke University in North Carolina and her colleagues analysed data on gene variants in 564 Cape Verdeans. They found that around half the people on the outer islands have a variant of a gene called *DARC* that protects against malaria.

However, on the more densely populated main island of Santiago, where there have been many malaria outbreaks over the centuries, about 80 per cent of people have the variant. On Santiago, there has been strong selection for the malaria-protecting variant: in other words, the population has evolved.

The Cape Verde archipelago was uninhabited before Portuguese voyagers arrived in the 15th century, bringing slaves from Africa with them. This explains why the *DARC* gene variant is present in the Cape Verdean population today, because it is also seen among many people of West African origin.

The strength of selection for a particular gene variant – how fast it spreads per generation – can be calculated, and is called the selection coefficient. "We estimate the selection coefficient is approximately 0.08, one of the highest inferred in humans," the researchers write (bioRxiv, doi.org/d9mh).

By comparison, selection coefficients are estimated to be between 0.02 and 0.14 for the lactase tolerance variants that allow adults to digest milk, says Sharon Grossman at the Broad Institute in Massachusetts, who wasn't involved in the research. For the sickle cell variants that also convey malaria resistance, they are between 0.05 and 0.18. ▮

Michael Le Page

New Scientist
Newsletter

Fix the Planet

Overwhelmed by climate change? You're not alone

Fortunately, there are reasons for hope in science and technology around the world. Sign up to our weekly climate newsletter and every Thursday we'll email you a dispatch about an idea, project, person, company or breakthrough that could speed us up on the road to zero emissions.

Join *New Scientist* chief reporter Adam Vaughan as he brings you scientific reasons to be optimistic that catastrophic climate change isn't inevitable.

Adam Vaughan

Get a weekly dose of climate optimism, delivered straight to your inbox. Sign up at **newscientist.com/fix**

Space exploration

Astronauts are mainly men and are getting older

Joshua Rapp Learn

THE average age of people sent to space has been on the rise since Yuri Gagarin first blasted off in 1961, and the vast majority of the 566 people who have left Earth are male, according to a new analysis.

Svetlana Komarova at McGill University in Montreal, Canada, wanted to understand more about how space flight affects bones, but found that data on spacefarers wasn't in any central scientific database. Such lists have only been put together by space enthusiast websites. "Only fans care," she says.

Her team began to gather information from space agencies around the world and decided to analyse the demographics of spacefarers. It found that the average age of crew has increased from 34 in the 1960s to 45 in the 2010s (*Life Sciences in Space Research*, doi.org/d9fd).

Komarova said this may reflect the fact that in the early days, we sent younger, stronger types as we were mostly interested in how space might affect humans. Once we understood it was relatively safe, the cost of launches meant an increased desire for experience and knowledge. "The demands of space travel now require very highly educated people," she says. "The requirements for astronauts are driven by what they do in the [space] station, and the requirements are going up and up."

Only 64 of all space travellers have been female – about 11 per cent – though the proportion has increased since the 1980s. The average age of women in space hasn't increased as much as that of men, which Komarova speculates could be due to the impact of the menopause on older women. This can lead to bone loss, and since space travel also weakens bones, older women may present a higher risk than sending younger women or older men, she says. ▮

Conservation

World falls short on all its biodiversity goals

Adam Vaughan

A GLOBAL push to protect biodiversity has failed to fully meet any of the targets set by governments a decade ago, leading conservationists to condemn nature protection efforts as a "massive failure".

A United Nations report reveals only six of the "Aichi targets" for 2020 have been partially achieved. The other 14, such as eliminating subsidies that are driving biodiversity loss or halving the rate at which natural habitats are being lost, have been completely missed.

The goals were agreed by almost 200 governments at a 2010 meeting of the UN Convention on Biological Diversity (CBD) in Nagoya, Japan. They aimed to stem the destruction of species and habitats, but the CBD analysis shows that countries have failed to address the structural problems driving nature's loss, such as land use change and the current state of biodiversity itself, mostly show worsening trends, he adds.

destruction, such as economic growth that can lead to forests being converted to farmland.

Richard Gregory at the UK's Royal Society for the Protection of Birds says the number of missed targets means the report makes for grim reading. "This represents a massive, if not catastrophic, failure at all levels," he says. Significantly, there are positive signs when it comes to policies supporting biodiversity protection, but the drivers of

20

targets were agreed in 2010 to tackle major threats to wildlife

Felicia Keesing at Bard College in New York says that despite the shortcomings, the analysis shows "global coordination can make a real difference in protecting biodiversity".

The report makes clear the situation would have been even worse without conservation efforts. Up to four times as many birds and mammals would have gone extinct without action in the past decade, the authors estimate.

Tim Hirsch at the Global Biodiversity Information Facility in Copenhagen, Denmark, one of the report's authors, admits the scorecard is a "big disappointment", but says that doesn't detract from progress. Bright spots include work on stopping invasive species, the growth in protected areas of land and ocean and the doubling of financing for biodiversity projects.

David Cooper at the CBD rejects the idea efforts have been a failure, but says there is only so much conservationists can do. "We can do things that are specific for biodiversity, like protected areas, but they're being overwhelmed by the more society-wide, economy-wide pressures that have not changed enough."

The analysis follows a warning that a million species are facing extinction and comes ahead of a CBD summit in China in May 2021, originally due this October. The aim is for governments to hash out new biodiversity targets that conservationists hope will be more successful than those agreed in Japan. "If the covid-19 pandemic doesn't motivate us to make the changes we need to make, I don't know what will," says Keesing. ▮

HOTLI SIMANJUNTAK/EPA-EFE/SHUTTERSTOCK

Forest cleared for oil palm plantations in Aceh, Indonesia

Weather

Storming the Atlantic

A rare cluster of cyclones was captured by a satellite

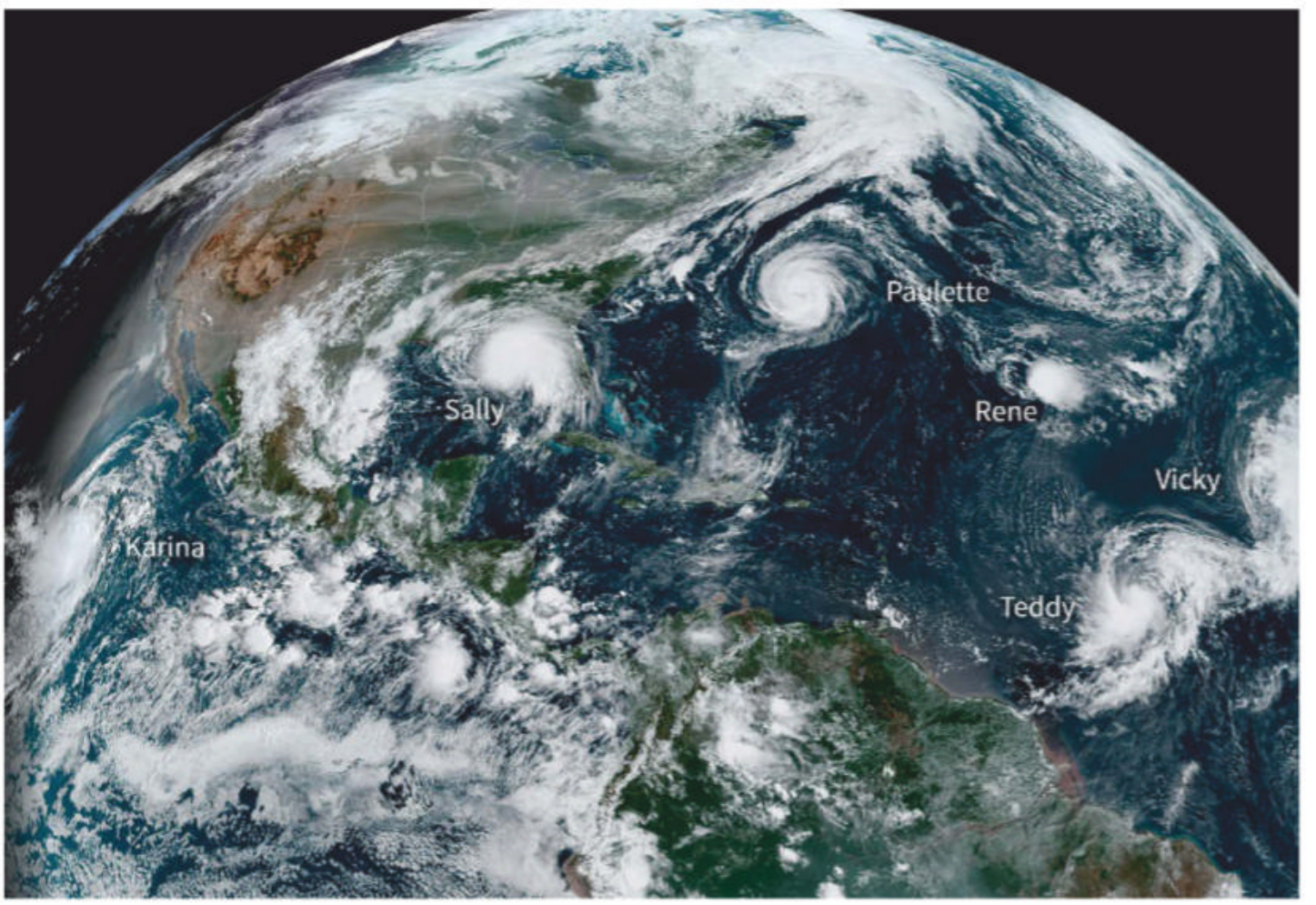
Michael Le Page

FIVE named tropical storms were present in the Atlantic on 14 September – only the second time this has happened since records began. The image here shows all five, plus tropical storm Karina in the Pacific. Most remained at sea, but Sally, which intensified into a category 2 hurricane, caused damage across the US Gulf Coast.

The 2020 hurricane season has been so active that all 21 names on the list for this year have been used. After storm Wilfred, which formed after this picture was taken, the US National Hurricane Center will use the names of Greek letters.

The number of tropical storms varies each year. High wind shear – the difference between wind speeds at the surface and higher up – can rip potential storms apart.

Global warming may not increase the number of hurricanes, but there is evidence that it makes them stronger and more damaging.



NOAA

Physics

Clearest signs yet that water is two liquids

SUPERCOOLING liquid water to record low temperatures has revealed new evidence that it can exist as two different liquids simultaneously.

Supercooled water – liquid water chilled below its freezing point without being allowed to freeze – has been baffling chemists for decades. Previous studies found that the extent to which water molecules pack together, known as their density, starts to fluctuate as water is cooled to extremely low temperatures.

Since then, evidence has been mounting that these fluctuations may indicate the presence of two different liquids in one, with some water molecules packed more closely together and others spaced further apart.

But researchers have struggled to study these two different liquids, because supercooled water usually freezes nanoseconds after it is formed.

By firing lasers at an extremely thin sheet of ice, Greg Kimmel and Bruce Kay at the Pacific Northwest National Laboratory in Washington were able to briefly generate and analyse supercooled liquid water at much lower temperatures than had been possible previously.

During the fraction of a second in which the water was in its supercooled state, the team took a snapshot of its structure using infrared spectroscopy, a method that takes advantage of the way infrared light is transmitted through molecules. Repeated experiments revealed fluctuations in the density of the supercooled liquid consistent with the two-liquid hypothesis.

The researchers could identify a temperature range within which supercooled water transitions between its two liquid forms: between about -93°C and -33°C.

By increasing or decreasing the temperature within the critical range, the team also discovered that you can tip the ratio of the two liquids one way or the other, suggesting that the two-liquid phenomenon can't simply be explained by water crystallising into ice. "We noticed that there was something funny happening early on before it was really crystallising," says Kimmel (*Science*, doi.org/d9d7).

"Water has many strange properties," says Anders Nilsson at Stockholm University in Sweden. But this is the clearest experimental evidence of two-liquid structures, he says.

Understanding water's unique chemistry could help us predict how it might behave under unusual conditions, such as in outer space, says Paola Gallo at Roma Tre University in Italy.

Layal Liverpool

Marine biology

Triggerfish jumps out of the water to catch crabs

Jake Buehler

A TITAN triggerfish, which can grow to a length of 75 centimetres, has been seen beaching itself to feed on crabs along the shoreline.

In 2018, Matthew Tietbohl at King Abdullah University of Science and Technology in Saudi Arabia was surveying a beach on the Red Sea's Mar Mar Island for sea turtle tracks when he and his team heard loud splashing at the water's edge.

"We turned to see this triggerfish launching itself into the shallows and stranding itself," says Tietbohl.

It soon became clear that the fish was attempting to feed on ghost crabs that were grazing on algae-covered rocks at the water's edge. The triggerfish would stalk the crabs from the water, turn on its side and lunge out of the shallows like a crocodile. At one point, the fish gripped a crab and pulled it back into the water (*Journal of Fish Biology*, doi.org/d9d6).

75cm

The maximum body length of an adult titan triggerfish

The determined diner was about 35 centimetres long, but titan triggerfish (*Balistoides viridescens*) can be more than twice that length.

Tietbohl says the feeding strategy may help avoid competition with other predatory fish. Supplementing a diet with terrestrial prey "would open up a whole new food source that other fishes just can't [exploit]", he says.

Tietbohl wants to know if the hunting style is used by related species or is widespread among titan triggerfish. The team did see other triggerfish "patrolling" the island's shallows.

Because water and air refract light differently, Tietbohl thinks it is intriguing that triggerfish are able to spot and track terrestrial prey from below the water. ▮

Analysis Health technology

New Apple Watch monitors blood oxygen – is that useful?

The tech firm says its watch isn't meant for medical purposes, so what is its oxygen monitoring good for, asks **Clare Wilson**

APPLE

Lights on the back of the latest Apple Watch measure blood oxygen

APPLE'S recently released Series 6 smart watch has a new feature: it can measure blood oxygen levels. The tech must have been years in the making, but the timing of its release worked well given that we are in the middle of a global respiratory pandemic.

The amount of oxygen in the blood is important medical information. In hospitals, it is usually measured with a device called a pulse oximeter, which shines a light through the finger or earlobe. Blood carrying more oxygen absorbs light differently.

It is already possible to buy a fingertip pulse oximeter for use at home for about £20. Now Apple says it has replicated this function in its high-tech watch, which shines a light onto the back of the wrist and measures the light reflected back with embedded sensors. The user must keep their arm still for 15 seconds. The device also takes periodic readings when the person happens to be still, day and night.

In a press statement, Apple was vague about the purpose, saying it offers "insight into overall wellness", and didn't answer *New Scientist*'s requests for further details. A spokesperson couldn't share any published research showing how oxygen monitoring would help a typical healthy person.

But tools to track personal health may come to the fore as the coronavirus pandemic continues. Home oxygen monitoring is in no way a test for covid-19, yet it could help those who have already been diagnosed and are not sick enough to be in hospital but want reassurance about their condition. Some UK clinics are piloting

"If we knew the device was absolutely robust and accurate, then there would be a place for it"

"virtual wards", where people who might otherwise be admitted to hospital stay home and do phone check-ups, and pulse oximetry is a key part of their monitoring.

Other conditions could benefit from home oxygen monitoring, such as chronic obstructive pulmonary disease, a long-term lung condition that can cause a need for supplementary oxygen.

It could also help when people use the electrocardiogram (ECG) function that was introduced with the Series 4 watch, launched in 2018. This can detect if electrical activity in the heart is disturbed. The criticism of that feature was that it might detect harmless small changes that have no effect on the body, but if someone finds they have low oxygen levels as well as heart rhythm problems, that becomes more useful.

The night-time monitoring could help to alert people about sleep apnoea, when they have problems breathing at night, usually due to being overweight. This can cause people to wake up when their blood oxygen gets too low, although they may not be aware of how much their sleep is being disturbed.

Because most pulse oximeters are applied to the finger or earlobe, it is unclear how well this new method will compare. Even highly accurate devices sometimes give erroneously low readings when people's hands are cold, says Andy Whittamore, clinical lead for Asthma UK and the British Lung Foundation. "There are a few gaps there in terms of how we interpret this device," says Whittamore.

Even Apple says in the small print on its press statement that the oxygen measurements are "not intended for medical use, including self-diagnosis or consultation with a doctor, and are only designed for general fitness and wellness purposes". Until the firm releases data on the accuracy of the watch's readings, it is hard to know how useful it will be. "If we knew the device was absolutely robust and accurate, then there would be a place for it," says Whittamore. ▮

Animals

SHUTTERSTOCK/MITCHELL KROG

The knobs on a giraffe's head can prove deadly

DURING a rainstorm on 29 February, two giraffes were killed by lightning in Rockwood, a conservation area in South Africa. While it may seem unsurprising that the world's tallest animal faces this risk, scientists had never described this occurrence in any detail until now.

"It came as a bit of a surprise to me because the whole day was quite quiet in weather, and suddenly there was this big storm," says Ciska Scheijen, a conservation scientist at Rockwood who had been following a group of eight giraffes in the area.

Scheijen says she immediately suspected something was wrong with the herd after the storm, as she could only see six of the animals.

Rockwood ranger Frans Moleko Kaweng went out to investigate and found the oldest and tallest giraffe of the herd, the matriarch, lying dead with a wound on top of her head. It appeared as if one of her ossicones – the horn-like knobs on a giraffe's head – may have acted as a lightning rod in the storm. "It looked like the ossicone broke off," says Scheijen.

The body of a younger female lay 7 metres away. She was probably killed by a side flash from the strike – in which the lightning jumped from the matriarch – or by ground current, as she was standing close to the other giraffe (*African Journal of Ecology*, DOI: 10.1111/aje.12785).

"It's possible that this happens more often to giraffes than other species because of their height. But I think more research is needed to see if this has an effect on the natural selection of giraffes," says Scheijen. **Joshua Rapp Learn**

Neurology

Sleep's role seems to change in toddlers

WHY do we sleep? The answer may depend on your age, according to research that suggests the main role of sleep shifts at the age of around two-and-a-half.

Newborn babies sleep a lot, and this gradually reduces as they get older. To find out why sleep alters as the brain develops, Van Savage at the University of California, Los Angeles, and his colleagues collected published data on brain activity and size and sleep duration across different age groups.

They used this information to build a model of how these aspects might be expected to change as we grow. This allowed them to swap in different figures to test various ideas. For example, if the brain is learning during rapid eye movement (REM) sleep, this would lead to a prediction that the duration of REM sleep is linked to aspects of brain development, which can then be tested against published findings.

The group found that most of the brain processes associated with learning occur during REM sleep, and that this appears to be the most important function of sleep generally in young infants, who get much more REM sleep than adults (*Science Advances*, doi.org/ghb7x7).

But there seems to be an abrupt shift in toddlers. "Before two-and-a-half, sleep is mainly about… rewiring the brain to learn and grow," says Savage. But after this age, the main function of sleep appears to be the repair of any damage to the brain. "I was surprised that it was such a sharp transition point," says Savage, who likens the sudden change to water freezing into ice.

The findings need to be confirmed by studying how children's brains change over time, says Rebecca Spencer at the University of Massachusetts Amherst. **Jessica Hamzelou**

Pollution

The heavy cost of clothes washing

MILLIONS of tonnes of tiny microplastics have been shed from our clothing into the environment over the past seven decades or so, according to an analysis of the impact of clothes washing. Between 1950 and 2016, an estimated 5.6 million tonnes of such particles have been emitted – half in the past decade (*PLoS One*, doi.org/d9d5).

"By mass, the amount of microfibres that has been emitted to the ocean is equivalent to about 7 billion fleece jackets just being thrown into the ocean," says Jenna Gavigan at the University of California, Santa Barbara. Similar amounts of shed microfibres have ended up on land, mostly cropland.

PLAINPICTURE/GLASSHOUSE/DERRICK GOMEZ

Microfibres – strand-like particles of microplastics – come from washed clothes, particularly synthetic fabrics. Researchers are only beginning to learn how these particles might effect ecosystems, but they can be ingested by small marine organisms, such as plankton, and work their way through the food chain.

Microplastics often act as "sponges" for toxins, says Gavigan, and are able to transport a variety of chemicals into an animal's digestive tract, some of which are likely to be harmful. The particles are also thought to cause physical damage once ingested by animals. We don't yet know how detrimental these tiny fibres might be to humans. **JH**

Really brief

BORIS KOZLOV/ALAMY

Bees trained to prefer sunflowers

Honeybees that have been coached to prefer feeding from sunflowers have boosted seed production on Argentinian farms by 60 per cent. Being given sugar with a sunflower-like scent encourages the bees to seek out and feed from similar flowers in their environment (*Current Biology*, doi.org/d9d2).

Emergency sirens and wolf howls

A sound analysis suggests the wail of an emergency siren is similar to a wolf howl. This may be no coincidence, say biologists: wolves are dangerous, and so early humans may have evolved to recognise howls as an alert signal. Sirens may exploit this adaptation (*Acta Biotheoretica*, doi.org/d9d3).

100-million-year-old fossilised sperm

A 0.5-millimetre-long female shrimp mated just before becoming trapped in tree resin 100 million years ago – and its body still contains about 50 sperm within its reproductive tract. They are the oldest animal sperm cells ever found (*Proceedings of the Royal Society B*, doi.org/d9d4).

Health

Your shoes may raise the risk of foot pain

SHOES that push up the toes make walking easier, a small study shows. The downside is that this may weaken the foot, increasing the risk of a common and painful condition called plantar fasciitis.

When Freddy Sichting at the Chemnitz University of Technology in Germany went running with Daniel Lieberman of Harvard University – whose work helped popularise barefoot running – the pair discussed the way that the soles of most shoes curve upwards under the toes, a feature called a toe spring.

"It is such an obvious feature of nearly every shoe," says Sichting. Despite this, no one had studied its effect on the foot before, he says.

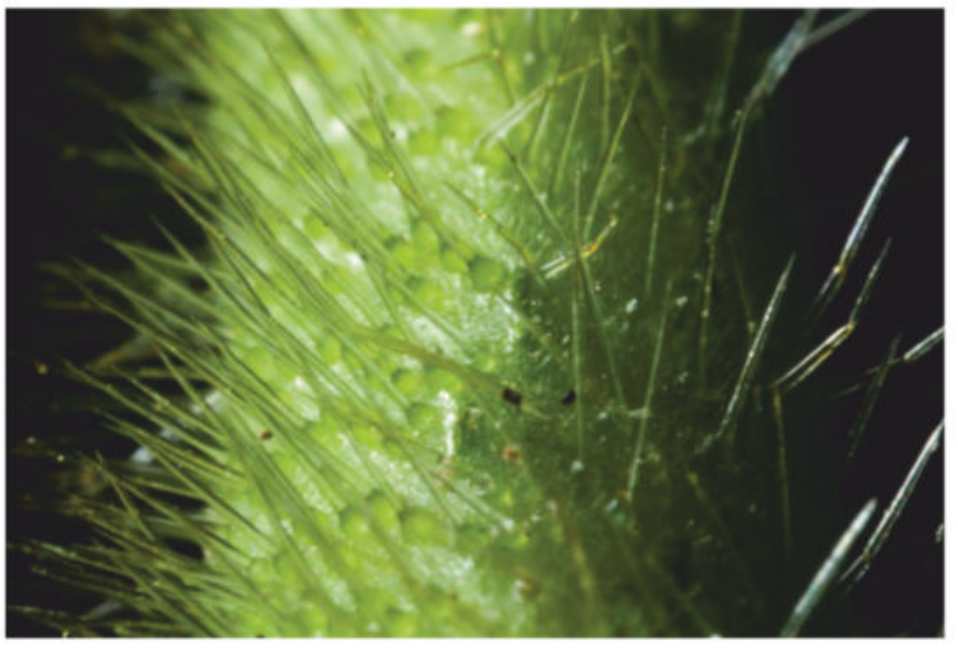
So Sichting, Lieberman and their colleagues got 13 volunteers aged between 19 and 33 to walk on a treadmill while barefoot or wearing sandals with a toe spring angle of 10, 20, 30 or 40 degrees.

Using sandals rather than shoes allowed them to record the foot's 3D motion. From this, they could work out how active the muscles of the foot were during walking.

The results show that footwear with a toe spring means the muscles have to do a little less work per step to stabilise the foot, says Sichting, with higher toe spring angles boosting the effect (*Scientific Reports*, doi.org/d9fb).

This could weaken the muscles and place stress on other tissues such as the plantar fascia, a layer of connective tissue running under the foot. Putting the foot under a lot more stress than normal raises the risk of damaging this tissue and developing plantar fasciitis, says Sichting. **Michael Le Page**

Botany



JURGEN FREUND/NATUREPL.COM

Stinging tree injects animals with spider-venom-like toxin

AUSTRALIA may be notorious for its venomous animals, such as snakes and jellyfish, but the country is also home to dangerous plants. Some produce toxins that look very similar at the molecular level to spider and scorpion venom.

Irina Vetter at the University of Queensland in Brisbane and her colleagues examined the toxins produced by the giant Australian stinging tree (*Dendrocnide excelsa*, pictured above), which can reach 35 metres in height, and the shrub-sized gympie gympie (*Dendrocnide moroides*), the most toxic of the six *Dendrocnide* species in Australia.

Both these species, commonly found in rainforests in eastern Australia, are covered with felt-like hairs that can penetrate human skin and deliver the toxin, which can hospitalise people. "The pain can last for such a long time," says Vetter.

The team identified the trees' main pain-causing toxins as a group of peptides consisting of 36 amino acids. The toxins have a knot-like structure that resembles the venoms found in spiders and scorpions (*Science Advances*, doi.org/d9fc).

Stinging trees may have developed these animal-like toxins as a defence mechanism against mammals. Donna Lu

Machine learning

AI can tell what surfaces feel like

AN AI linked to a camera can tell the physical properties of surfaces without touching them.

Matthew Purri and Kristin Dana at Rutgers University in New Jersey have trained an algorithm that can determine the tactile traits of an object when presented solely with a photograph or series of images of it.

They took photographs of more than 400 materials, including cloth, plastic, leather and wood surfaces. The pair took 100 images of each surface using a device with an arm that can be moved to take photos at exact camera angles.

These images were linked to an existing data set about the materials. For each material, 15 physical properties were logged in categories including friction, adhesion and texture.

Using all this, they trained a deep-learning algorithm and tested it on surfaces it hadn't seen before. Given a single image taken from directly above an object, the algorithm could reliably estimate 14 of its 15 surface properties (arxiv.org/abs/2004.14487).

The researchers believe the algorithm could be used in robots and in cars to improve road safety by estimating the surface properties of roads. **DL**

Views

The columnist
Annalee Newitz takes the long view amid a year of disasters **p22**

Aperture
Beautiful but deadly, California's wildfires caught on camera **p24**

Letters
Views on the "fuzzi-verse", the pandemic and much more **p26**

Culture
Incredible stories of the human brain's ability to adapt **p28**

Culture columnist
Simon Ings on *Hope Frozen*, a journey into cryogenics **p30**

Comment

Let's get back to Venus

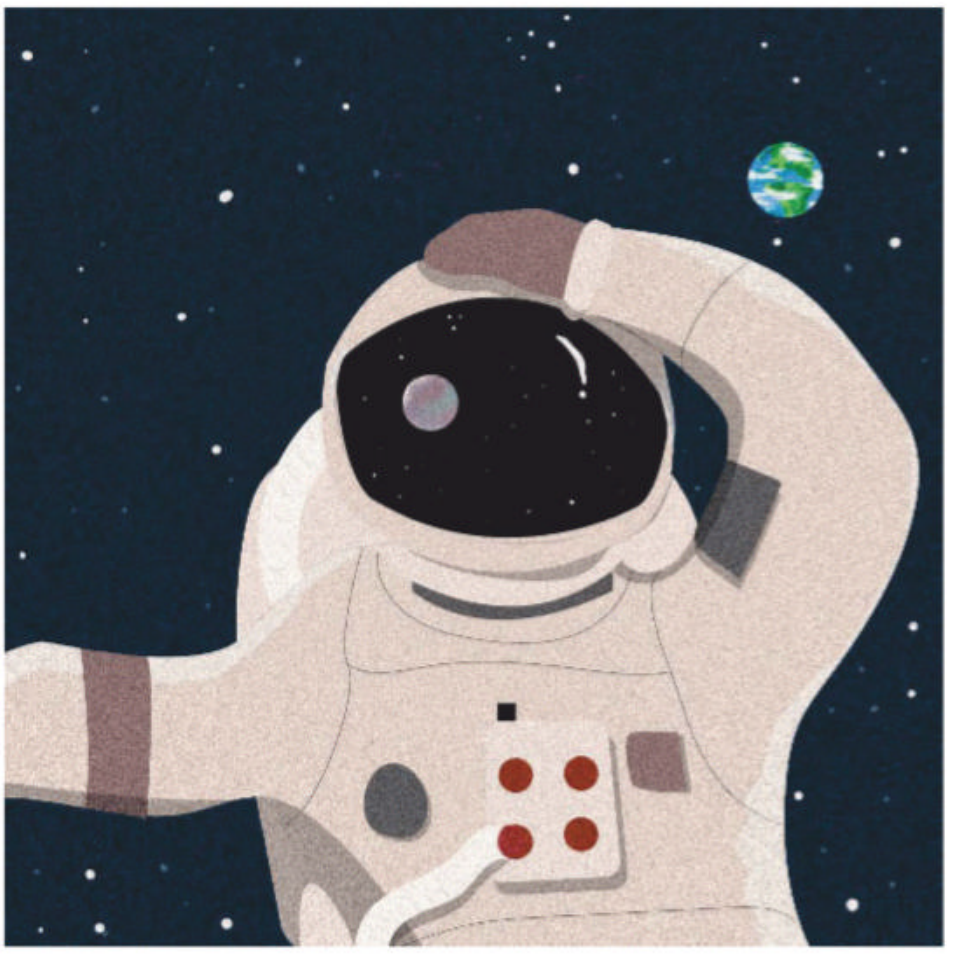
Phosphine in Venus's atmosphere could be a sign that life is there. The only way to find out for sure is to go have a look, writes **Peter Gao**

IF MARS were the popular kid in school, Venus would be the nerd sitting in the corner, largely ignored. Despite its image, Venus is the brightest object in the sky after the sun and the moon, its orbit taking it closer to Earth than any other planet in the solar system. It has nearly the same mass and size as Earth, but being closer to our star, it gets nearly twice as much heat from the sun.

However, instead of having a climate that is just a warmer version of Earth's, Venus's surface and atmosphere are hellish: clouds of sulphuric acid blanket the planet, while at ground level it is hot enough to melt lead. Despite this, there is now a sign that Venus may harbour life.

Jane Greaves at Cardiff University, UK, and her colleagues recently detected phosphine in Venus's atmosphere, with one potential explanation that it is the by-product of biology. That is because the only way this gas is made on Earth is in laboratories or by microbes. Though this doesn't mean it was produced by life on Venus, attempts to find non-biological explanations for its presence have so far fallen short.

Our best hope for confirming or rejecting the possibility of life on Venus is to go and have a proper look. During the cold war, the USSR sent more than a dozen missions to Venus, including several landers and a pair of balloons, but these ended well before the dawn of the 1990s. Likewise, NASA hasn't launched a mission dedicated to Venus since the late 1980s. What's more, no US mission has plumbed the depths of its atmosphere and probed its surface since the Pioneer Venus missions that departed Earth in the 1970s.



MICHELLE D'URBANO

Other countries have had more recent efforts: the European Space Agency's Venus Express orbited the planet throughout the late 2000s and early 2010s, while Japan's Akatsuki orbiter is exploring Venus right now. But these missions were ill-equipped for detecting phosphine or life.

While Mars has been the focus of interplanetary exploration efforts of late, with some space agencies focusing on landing more craft and even people on its surface, the phosphine discovery has people looking at Venus in a new light. As NASA administrator Jim Bridenstine tweeted: "It's time to prioritize Venus."

In the months and years to come, computer simulations will be used to further study the possible chemistries of the atmosphere on Venus. More observations will be made (and the old ones reanalysed) and laboratory experiments will be conducted to try to identify other ways the phosphine there could be produced. However, there is no guarantee that these efforts will reveal the true nature of this substance on Venus.

A new mission to directly sample the atmosphere and surface would be a watershed moment in planetary science. It need not only look for signs of life, but also answer some of our many questions about Venus, such as why it became so different to Earth and whether it was once habitable.

Some options to do this already exist. There are two NASA missions currently vying for approval, India aims to send an orbiter to Venus in 2023 and private company RocketLab also has plans to visit in that year, hopefully with a probe passing through the planet's atmosphere.

By sampling the chemistry in the Venusian air, we would be able to take direct measurements of phosphine and see how it varies with height, capture any other chemicals that contribute to its formation and potentially detect any life that may be there.

The discovery of phosphine in Venus's atmosphere is a great accomplishment. The scientific endeavour it has set in motion is as if a sleeping giant has awakened and it may be just what we need to finally refocus on this neglected world. The quiet kid in the corner may yet get the last laugh. ▮

Peter Gao is a Sagan Postdoctoral Fellow at the University of California, Santa Cruz

This changes everything

California's burning

With wildfires raging, the outlook looks bleak from San Francisco. Thinking about the future in terms of "hope horizons" can help, writes **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest novel is *The Future of Another Timeline* and they are the co-host of the Hugo-nominated podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is **techsploitation.com**

OUTSIDE my window, the skies are brown and the sun is a deep reddish-orange. Unfortunately, that isn't because I've moved off-world to a beautiful alien planet orbiting a red dwarf star.

This is simply what "outside" looks like in San Francisco when vast swathes of the western US are on fire. Even the light itself is alarming. Its Mordor-esque gloom makes everything seem like it is the wrong colour. (For a striking image of California's Bidwell Bar Bridge against the backdrop of the state's wildfires, see page 24.)

It has been a bad year for California. After years of drought, we started getting record high temperatures that were coupled with fierce winds.

Back in 2018, our doddering old power lines, mismanaged and neglected, sparked a deadly fire that was supposed to be a once-in-a-lifetime Armageddon. It turns out that was merely a beta test.

This year, the southern California desert reached 54.4°C. If verified, this is the hottest temperature ever reliably recorded on Earth. Then a rare lightning storm zapped the coast. The resulting wildfires have already burned more land than they did in all of 2018 – and the fire season has only just started.

All this devastation comes on top of the coronavirus pandemic, which means that people fleeing the heat and fires can't huddle in shelters together without risking a superspreader event. So, the future here is looking a little uncertain.

At times like this, I find myself contemplating something I call a hope horizon, or how many years it might take before everything becomes alright again. My definition is deliberately open-ended. It raises questions like "What is 'alright'?" and "What do you mean by 'everything'?"

That's the point. Teasing out the answers reminds us of two important facts. The first is that nothing is ever "alright" for everyone. The second is that "everything" is actually a bunch of unrelated stuff, some of which matters to you and some of which matters to me, and the sum of which cannot be fixed by either of us, ever.

It is a useful way to put our problems into perspective and it is also a good method for figuring out what to tackle next. For example, looking into the hellish light of my smoky city, my hope horizon is set at roughly 10,000 years. That's because I'm thinking about climate change and how long it might take before we see an end to these intense heatwaves and lightning storms.

"I'm contemplating something I call a hope horizon, or how many years it might take before everything becomes alright again"

At the same time, I see another hope horizon of 10 to 20 years, which is about how long I think it will take for California to deploy fire-reduction strategies like controlled burns and housing codes that mandate firebreaks around cities and houses.

That's something policy-makers could actually work on right now, and fixing it will help to improve the outlook on the 10,000-year problem too. Which brings me to a more important question: "Alright for whom?"

Plenty of people have never been "alright", if by that we mean having some meaningful degree of autonomy and control over their lives. Maybe they grew up in war-torn regions or in devastatingly poor families. Or perhaps their futures have been blighted by systemic prejudice, xenophobia or genocide. We can imagine a million reasons – some of them political, some of them personal – why one person's idea of "alright" might be the opposite of another's.

As we face a terrifying future, we have to keep in mind that our problems won't be solved all at once. We might stabilise our imperilled democracies just in time to watch places like California burn so catastrophically that it is no longer possible for people to live in them anymore.

Or we might finally have enough tests and protective equipment to cope with the next coronavirus pandemic, but only because we are vastly underpaying the workers who make all of that stuff. What good is a face mask if you cannot actually afford to buy one?

The best strategy is to pick the problems whose hope horizons are within reach, while also keeping the rudder steering us towards those distant millennia when humans might be able to bring our planet's runaway carbon cycle back under control. Most importantly, we need to remember who could be harmed by such efforts as well as who they could benefit.

Every single catastrophe I am watching unfold in front of my eyes was caused by a combination of natural disaster and political failure. That's why we are going to need more than science and technology to fix this. We are going to need better political systems, too. ▮

Annalee's week

What I'm reading
The Hidden Persuaders, *a 1950s book by Vance Packard about subliminal advertising that feels strangely relevant in our social media world.*

What I'm watching
Lovecraft Country, *a series about how sci-fi nerds fight monsters and white supremacy.*

What I'm working on
A podcast about how we'll survive climate change (or not).

This column appears monthly. Up next week: James Wong

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Red for danger

Photographer **Josh Edelson**
Agency **AFP/Getty Images**

THIS is what a US wildfire looks like up close. Trees and embers burn on the other side of the Bidwell Bar Bridge, which spans California's Lake Oroville in Butte county. These appear white in the image, while the lights to the right are from a small boat.

Thick smoke from the fire is responsible for the red hues. Smoke particles filter out shorter wavelengths of light, such as blue and yellow, while allowing longer, redder wavelengths through.

Its peculiar beauty is a dire warning about the power and spread of wildfires in the region. The Bear Fire in Butte County is part of a major crisis in the western US, where the most severe wildfires in two decades are destroying homes, landscapes and livelihoods.

The first wildfires started in California and Colorado in August. So far, more than 10 states have been affected, including Washington and Oregon. Collectively, some 18,000 square kilometres have been scorched.

The smoke could also have serious effects on health. The risk of lung infections from inhaling the smoke is made worse by the other pressing threat, covid-19.

Wildfires serve as a stark reminder of climate change. Longer and drier summer seasons coupled with strong winds are largely to blame for the unprecedented size and scale of the fires.

Gege Li

Editor's pick

A bit of fuzziness isn't a big problem for physics

5 September, p 36

From Rachael Padman, Cambridge, UK

In "Welcome to the fuzzy-verse", philosopher Eddy Keming Chen misstates the relationship of physics and mathematics. The universe is what it is, and the fundamental laws of physics are really just expressions of the patterns we observe there – they don't explain anything. What they can do is help us predict what else we might see if the pattern extends to areas we haven't yet looked at.

Separately, Chen seems to identify the "Strong Past Hypothesis" as a fundamental law of physics – but it isn't a law. It is a hypothesis, something you can use as a starting point for "what if" speculation but that carries no predictive weight.

One might point to other "fuzzy" areas of modern physics, such as the inflation hypothesis: we are pretty sure there was inflation, but we have no idea what might have caused it and it has no predictive power. The universe will do what it will do. Current models, patterns and theories have massive holes.

It may be a surprise to a non-physicist that we can't completely define the universe with mathematics. Physicists, however, are used to the idea that some things may "just be". A bit of fuzzy uncertainty doesn't fundamentally undercut the enterprise – it simply reveals areas needing more work.

No time to waste, let's get on with restoring the sky

22 August, p 24

From John Crook, Napier, New Zealand

I was inspired by Graham Lawton's description of Rob Jackson's plea to restore the atmosphere to its pre-industrial state. We absolutely must do this. Any plan or course of action that falls short of full reinstatement to pre-industrial conditions, with the associated thermal equilibrium of the planet that is so vital, will inevitably consign our descendants to a planet that just gets hotter and hotter. This will be a vastly bigger task than merely hitting the target of no more than 1.5°C of warming by the end of the century.

Granted, the temperature is rising gradually, but we need to have the breadth of vision to see that the heating is relentless and made faster and faster by every puff of CO_2 put into the atmosphere. The time for action is now. The longer we leave the task, the harder and costlier it will become, but the price of not doing this is incalculable. Let us set out the plan and get on with it.

Many ways to look at the impact of social contact

15 August, p 32

From Terry Cannon, Lewes, East Sussex, UK

In his look at the benefits of "social capital", inspired by the pandemic lockdown, David Robson argues that "in recent decades, a raft of research has shown that individuals with richer social worlds tend to have better mental well-being and lower stress, and to perform better at work".

Does this research demonstrate clearly that the direction of causation is from good "social worlds" to better mental health? Surely it is entirely plausible to argue for the reverse of this causation, or even a mutually reinforcing circularity.

I also think that the notion of social capital used in the article is idealised and desocialised. All social networks are embedded within systems of power, including class and gender, that are significant determinants of who can (or can't) connect with who. Some networks are constructed by troubled people as survival mechanisms when options they would prefer are closed to them. These might assist with their mental health, but they aren't their first choice.

On the search for ways to end the pandemic

5 September, p 7

From Jonathan Watson, London, UK

Could there be an alternative to a coronavirus vaccine to achieve herd immunity if we could come up with a test to predict who would be asymptomatic? Many people would probably fall into this category. They might have something in common other than their underlying good health that could be the basis of such a test.

If this were possible, then herd immunity might be achievable with deliberate asymptomatic infection rather than vaccination.

Partial postal voting could yet upset the US election

5 September, p 20

From Ed Prior, Poquoson, Virginia, US

You report on an analysis that found voting by mail would have little effect on US election results. It seems to assume that Democrats and Republicans would vote by post in similar numbers. In fact, a recent poll indicates that a significantly higher proportion of those who support the Democrats would choose to vote this way compared with Republicans, who would rather turn out in person.

In a recent New Jersey primary, thousands of postal votes were rejected, in part because officials decided voter signatures didn't look enough like those held on file. Other reasons include ballots arriving late or without the required certification.

If, say, 10 per cent of Democrat vote-by-mail ballots are rejected while 100 per cent of Republican in-person ballots are accepted, Donald Trump may have a significant advantage.

Here is how to turn the tide against junk science

22 August, p 36

From Tim Stevenson, Great Missenden, Buckinghamshire, UK

All strength to Stuart Richie in his crusade against the perverse motivations that lead to the publication of junk science, but an article or a book won't rid us of this problem. It will take money.

What might work would be for some considerably rich business leader to set up a strikingly large prize for the best paper that showed up a slovenly piece of research that had made headlines, then give this paper publicity.

Motion sickness? Choose your meal carefully

22 August, p 47

From Alexander Pettigrew, Newquay, Cornwall, UK

As a long-time yachtsman, I found your article on motion sickness very interesting. It reminded me of an age-old question among sailors: if you think you might become seasick, what is the best thing to eat? The answer is peaches and cream, because they taste just as good on the way up as they did on the way down.

From David Eadsforth, Alresford, Hampshire, UK

When contemplating a rough boat ride or some aerobatics, many people will instinctively opt to eat nothing beforehand, fearing motion sickness. Instead, they could try a remedy adopted by me and a number of friends decades ago: scoff a couple of large, sugary doughnuts about an hour before the activity. It works wonders. ▮

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Signal Boost

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

Humanity First
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Humanity First is a multi-sector NGO, responding when disasters strike as well as working on development projects. From installing water wells, providing agricultural support and running medical camps to building schools and hospitals, we strive to bring sustainable provision, access to healthcare and opportunity for a better future to all people, regardless of race, religion or creed.

We have been at the forefront of fighting covid 19 globally with trained volunteers including medical professionals and disaster responders.

GLOBAL COVID RESPONSE

So far in the fight against covid 19 our 3487 unpaid volunteers across the world have:

- Distributed 185,140 PPE items
- Supported 148 hospitals
- Donated 2190 units of blood
- Provided over 10 million meals
- Worked 726,700 volunteer hours
- Served 650,492 beneficiaries

UK RESPONSE

- In the UK, we support communities up and down the country, including our new Foodbank in Mirfield, Yorkshire.
- We partner with International Health Partners (IHP) to donate and deliver essential PPE to our brave frontline NHS workers in the UK.
- Our national support line helps to signpost people to services relating to the Coronavirus (Covid-19) pandemic

THOUGHT LEADERSHIP

At the same time, we have pushed on Thought Leadership with our Webinars including on:

- *Humanitarian Ethics in Covid* by Dr Hugo Slim formerly of ICRC and now at Oxford.
- *Mental Well Being & the Covid Crisis* by Professor Jeremy Howick, Director of the Oxford Empathy Programme, University of Oxford
- *The Global Economy & Covid* by Professor Atif Mian, Princeton University
- *Cancer Care in the Covid era* by Royal Marsden Cancer experts.

WHAT NOW?

The covid-19 crisis has hit many charities financially with a massive dip in donations. More than 53% of charities have reported a drop in donations, however most have reported a spike in demand for their services. Despite the different streams of funding made available by the UK government, many charities are still struggling.

Humanity First's huge volunteer base ensures great efficiency and our pound or dollar goes much further. All our management team here do not take a salary for their services.

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We need the support of our donors to continue to carry out the work we do. Help us reach out to many more people here in the UK and abroad by donating to our Coronavirus Emergency Appeal. **For more information visit: hfuk.org**

How our brains make us

Livewired reveals the intriguing reasons why a 6-year-old can thrive with half a brain and why some people who are blind can echolocate, finds **Clare Wilson**

Book

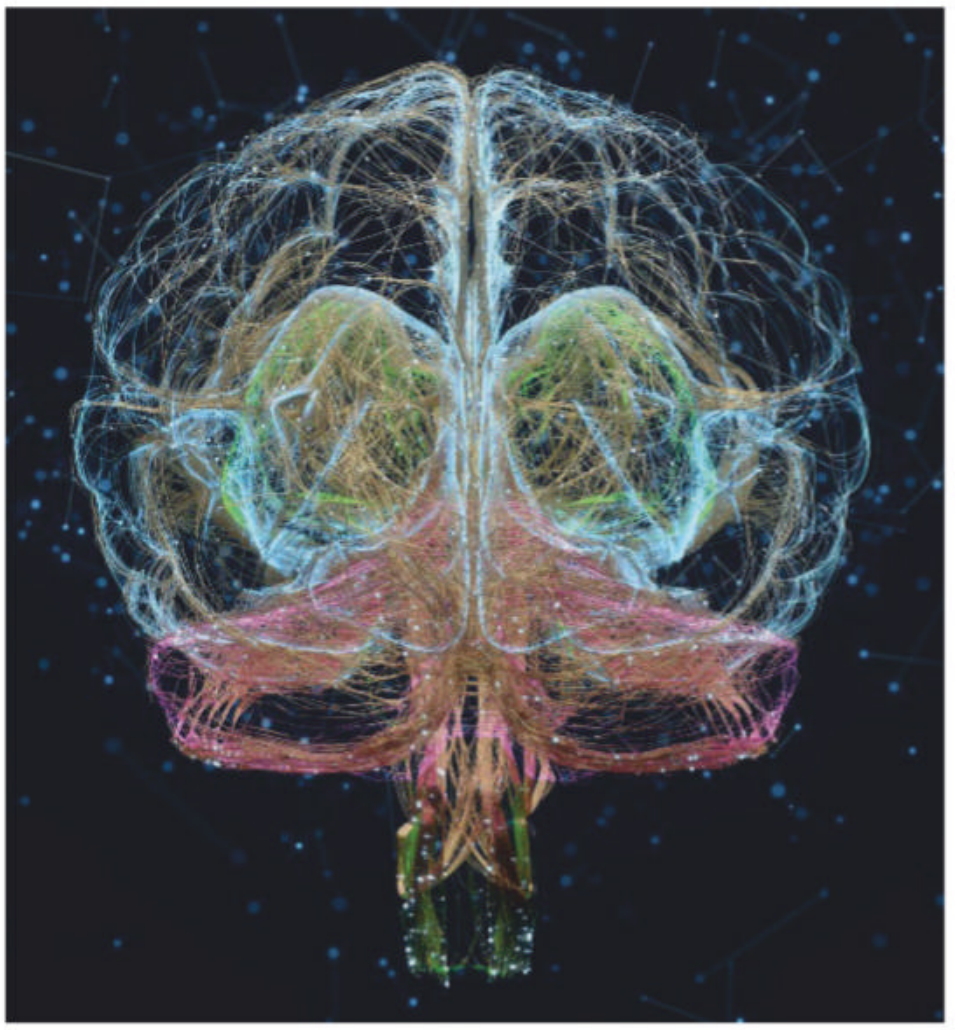
Livewired: The inside story of the ever-changing brain
David Eagleman
Canongate Books

IMAGINE if your 6-year-old son needed surgery to remove a staggering half of his brain. That was what faced Matthew, a boy with a rare condition triggering many epileptic seizures a day and that could only be treated with this drastic surgery. When he woke up afterwards, he was incontinent and couldn't walk or speak.

Yet with daily physical and language therapy, Matthew regained these abilities. In three months, he was almost back to normal, minus the seizures. Now an adult, brain scans show half of Matthew's skull as a black void, yet the only visible effects are his slight limp and a little clumsiness in his right hand.

How could someone lose half of their brain and recover almost all of their functioning in three months? For neuroscientist David Eagleman at Stanford University in California, this demonstrates one of the brain's most remarkable qualities: neuroplasticity, or the ability to remake itself in response to changing circumstances.

In *Livewired*, Eagleman explains why this ability is so fundamental to who we are that James Watson and Francis Crick's claim to have discovered the "secret of life" with their work on DNA is only half of the story. The rest of what makes you who you are is "every bit of experience you have with the world: the textures and tastes, the caresses and car accidents, the languages and love stories... all of which sculpt the vast, microscopic tapestry of your brain cells and their connections," he writes.



ANDRIY ONUFRIYENKO/GETTY IAMGES

Our brains can remake themselves to adapt to changing circumstances

In extreme cases, this brain resculpting is visible at the anatomical level through post-mortems or scans. Professional musicians develop a small bulge on a ridge of their motor cortex – a part of the brain that controls movement – revealing the effects of thousands of hours moving their fingers in complex choreographies. It is reminiscent of the way a large bicep may reflect the hours spent at the gym.

Research on animals shows that such a cortical bulge arises from rewiring at multiple levels. Not only is there the growth of new synapses (connections between brain cells) but there are also changes to the molecular machinery of those synapses. Neurons can sprout more branches, and sometimes whole new neurons can form.

"DNA is only half of what makes you who you are – the rest is all the experience you have with the world"

Obviously, since we can't dissect the brains of living people, it is very hard to observe those transformations at the molecular and cellular level. Yet we can clearly see their effects on behaviour and abilities. It is why we are able to learn new skills, even in later life, and why some people who are blind can learn to echolocate in a similar way to bats.

Brain scans show that in people who lose their sight, the part of the brain that usually receives signals from the eyes instead starts processing input from their ears and their sense of touch. This starts to happen even in people who are blindfolded for a few days.

Eagleman and his team are exploiting this flexibility by making devices that let people receive sensory information in new ways. They have built special vests and wristbands for people who are deaf. These capture sounds and translate them into vibrations through pads next to the skin. Eagleman envisages that, one day, such devices may not only replace lost senses, but also create new ones. For instance, a politician giving a speech could use a vest to monitor its reception on Twitter and dial it up or down accordingly.

The nervous system seems to accept such tinkering surprisingly quickly. Eagleman has a good example: can you guess how long it takes people to get used to manipulating three arms in virtual reality, with the third sprouting from the middle of their chest? Just 3 minutes.

Yet neuroplasticity has its limits. As we get older, our brains become less flexible and more stable. Older people can still learn a language or musical instrument, but the operation experienced by Matthew would be disastrous – it isn't generally recommended for children aged 8 or older.

A less-plastic brain might sound bad, but as Eagleman writes: "If plasticity didn't decline, you would not lock down the conventions of the world. Preserving total flexibility would retain the helplessness of an infant."

Prematurely locking down those conventions may explain the phenomenon of synaesthesia, in which people have fixed associations between unrelated stimuli – for instance, the letter "A" may always seem blue to some. Eagleman believes synaesthesia stems from the early formation of memories that are too stable. For instance, he thinks alphabet-colour associations, a common form of the condition, may sometimes occur because someone can't forget the colours of the first letters they learned as a child.

In a study of more than 6500 synaesthetes, Eagleman and his team found that the letter-colour pairings are usually random, but for 15 per cent of people who were young children in the 1970s and 1980s, they follow a telltale pattern: A is red, B is orange, C is yellow, D is green, E is blue, F is purple and then the cycle repeats through the alphabet. This just happens to be the pattern of a Fisher Price alphabet magnet set that was popular in that period.

It is unclear how he extends his idea to explain less common forms of synaesthesia, like the association of sounds with colours, but the idea seems plausible for letter-colour pairings.

However, most of the book isn't about Eagleman's research, but is a broader overview of this important field of neuroscience. I finished *Livewired* feeling that I had learned a lot about the brain, without it ever being too dry or academic. Eagleman brings the subject to life in a way I haven't seen other writers achieve before. ▮

Utopian nightmare

A thrilling TV series resonates with the threats of our pandemic times, finds **Gege Li**

TV

Utopia

Adapted by Gillian Flynn
Amazon Prime Video
(from 25 September)

"WHAT have you done today to earn your place in this crowded world?" This ominous question – frequently posed in the US TV series *Utopia* – hangs over the world envisaged by the show.

The series has been adapted by Gillian Flynn (screenwriter for hit film *Gone Girl*) from the 2013 British TV series of the same name, created by Dennis Kelly. It follows five strangers who connect online over their obsession with an elusive comic called *Utopia*. But these aren't your typical comic book enthusiasts and this may be no real Utopia.

For complex and plot-spoiling reasons, the group is convinced the comic contains hints about future disasters and that finding it will shed light on what or who will be responsible.

The series begins when a young couple discover the original *Utopia* manuscript. Oblivious to its true value, they know enough to try to sell it at an upcoming comic convention in Chicago. This is the news the group has been waiting for.

At first, the group's members seem like the conspiracy theorists other *Utopia* fans take them for. But when the comic is successfully auctioned, things take a sinister turn, with the arrival of the emotionally detached Arby (played by Christopher Denham) and his partner Rod (Michael B. Woods).

They are also hunting *Utopia*, and one of its not-so fictional characters, Jessica Hyde (Sasha Lane). So they are tracking down everyone at the auction who set eyes on the comic, including the group.

Meanwhile, a mysterious flu virus is killing schoolchildren in isolated pockets across the US. At the centre of this storyline is a doctor, Kevin Christie (John Cusack) of Christie Labs, a pharmaceuticals-turned-food company now rolling out its own version of lab-grown meat.

As the show develops, with images of disasters like fires and melting ice caps in the title sequence that may foreshadow what is to come, the group's original suspicions about *Utopia* seem less and less fantastical.

Packed with thrills and some violence, *Utopia* lives up to what Flynn envisioned: "Gnarly, nasty, raw and unnerving". Perhaps what conveys this best is that it draws convincing parallels with real and tangible threats, including the coronavirus pandemic and runaway fires. That is what makes the idea of needing to earn your place – left hanging for future episodes – all the more disturbing. ▮

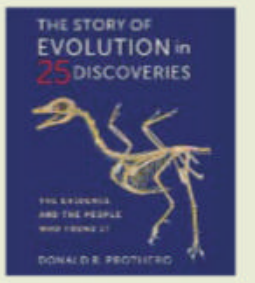
ELIZABETH MORRIS/AMAZON STUDIOS

From left: Becky (Ashleigh LaThrop) and Jessica Hyde (Sasha Lane) in *Utopia*

Don't miss

Visit

Paradise Lost brings artist Jan Hendrix to London's Kew Gardens from 3 October with an exhibition mourning Kamay Botany Bay in Australia. Kew founder Joseph Banks collected plants from it in 1770, when it was pristine.



Read

The Story of Evolution in 25 Discoveries is palaeontologist and geologist Donald Prothero's entertaining guide to the past, present and future of living things – with nature's more bizarre aspects to the fore.

Listen/watch

Objects of Crisis is a hybrid series of Zoom podcasts in which British Museum director Hartwig Fischer reveals objects – from a tiny oil lamp to a Buddhist prayer manuscript – that helped us ride out past crises.

E J SCHEMPH; THE TRUSTEES OF THE BRITISH MUSEUM

The film column

Deathlessness isn't the same as life

Hope Frozen is a painful documentary that asks deep questions about life and death technologies through the story of Einz, a terminally ill baby girl, and her family, says **Simon Ings**

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

NETFLIX

Einz's mother remembering her 2-year-old daughter

THE world – including this magazine – hasn't shied away from expressing opinions about the Alcor Life Extension Foundation, the US non-profit founded by Fred and Linda Chamberlain in 1972 to freeze corpses and body parts in the hope of one day resurrecting the dead.

Most observers are content with interrogating Alcor's bizarre mission by asking if technologies for resurrection will ever be viable. This, of course, is a non-question: who knows what is around the corner? The successful freezing and thawing of a whole rabbit brain in 2016 shows how careful we must be in dismissing such ideas.

Mark O'Connell's approach in *To Be a Machine* was more fruitful: he asked why people would want to freeze themselves or their loved ones at all. *Hope Frozen*, filmed in Thailand at around the time O'Connell was writing his book, goes some way towards an answer.

Matheryn, nicknamed Einz, was born in 2013 to parents Nareerat and Sahatorn Naovaratpon. For more than two years, they and their besotted son, Matrix, filmed hour after hour of the little girl's life. She was – and is still, in Pailin Wendel's ravishing, painful documentary – captivating.

Just before her third birthday, Einz died of ependymoblastoma. After 10 surgical operations, 12 bouts of chemotherapy and 20 rounds of radiation therapy, her family and the doctors knew it was coming: this highly aggressive brain cancer is a killer.

> **"Some critics in Thailand, a mostly Buddhist country, felt the family had thwarted Einz's reincarnation"**

At the eleventh hour, Sahatorn persuaded his family that on her death, her brain and some of her tissue should be frozen and transferred to Alcor's Arizona facility. Einz became the youngest person to be cryonically preserved. The story created a media storm in Thailand. In the film, some critics in this mostly Buddhist country complained that her family had prevented Einz's reincarnation and consigned her to limbo.

Sahatorn and Nareerat, meanwhile, are both working engineers, and Sahatorn says they have put their faith in science. Matrix, caught in the middle as a novice monk and a gifted student of science, carries the weight of this dilemma with admirable fortitude. At the end of the film, my strongest wish was that he would one day escape these competing pressures and live his own life.

Yet anyone hoping for a uniquely Buddhist take on the transhumanist promise will be disappointed. There is very little to distinguish Buddhist objections from wider unease about not leaving the dead to rest in peace.

Wedel lets the family speak for themselves. Inevitably, they come close to revealing the faultlines in their choices, especially Sahatorn. "I don't care that people say I can't move on," he says. "I don't care because it's true." When the family visits Alcor, Sahatorn loses himself in the technical details while Nareerat weeps quietly.

Hope Frozen leaves me worrying that by denying themselves some form of spiritual afterlife for Einz, her relatives have lost her twice over. They have lost her physical form and now they can't even animate her spirit in their imaginations. "For sure, we are headed towards deathlessness," says Sahatorn, proselyting for the strange scientistic faith that is his defence against grief.

He isn't wrong: from cryonics to CRISPR gene editing, there is no shortage of effort going into avoiding death. As Wedel's upsetting film reveals, however, deathlessness isn't life. ▮

Film

Hope Frozen: A quest to live twice
Pailin Wedel
Netflix

Simon also recommends...

TV

Be Right Back
Owen Harris
Bereaved and pregnant, Martha (Hayley Atwell) receives a robot replacement for her late boyfriend in a devastating episode of Black Mirror, *Charlie Brooker's sci-fi anthology.*

Film

Marjorie Prime
Michael Almereyda
Jon Hamm plays an AI bringing comfort to Marjorie (Lois Smith), a woman with Alzheimer's. The film, based on Jordan Harrison's play, manages to be both mind-bending and touching.

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The ultimate battery

A forgotten kind of nuclear power could create incredibly long-lasting batteries, says **David Hambling**

THE VOYAGER probes blasted off in 1977, beginning what would prove to be the longest journeys ever taken by objects from Earth. The two spacecraft have now left the solar system and Voyager 2 is sending back measurements of interstellar space. As achievements go, it ranks among humanity's most profound. But a crucial aspect of that success is seldom celebrated: those probes sure do have good batteries.

In the day-to-day grind of life, batteries never seem to last long enough. We must juice up our phones every day, laptops seem to constantly thirst for their power cables, electric cars only go so far before they fizzle out. It is enough to make you want a new type of power supply.

We may be edging closer to exactly that. The Voyager probes employ a weak nuclear power source that, being radioactive, is considered dangerous to use on Earth. But there is a closely related form of energy that packs even more of a punch and could work safely in your average car. It is a long shot. The last time this outlandish technology was seriously considered, 20 years ago, it ended in a broiling controversy. However, now the US Army has it firmly in its sights and has conducted an experiment that might just give it a new lease of life.

Most of the ways we store energy involve chemistry. When we burn petrol in a car engine, we are releasing energy stored in chemical bonds. Similarly, lithium-based batteries in devices like mobile phones work by allowing charged ions to flow. But there is greater power to be had if we look beyond chemistry, inside the atom itself.

Each atom consists of a nucleus made of particles called protons and neutrons orbited by a cloud of electrons. These protons and neutrons are usually melded together in the extreme temperature and pressure inside a star, and if you delve into an atom's nucleus in the right way, you can extract some of that awesome power. The main way we do that is nuclear fission, in which a nucleus releases neutrons that can then split more atoms, causing a chain reaction that releases huge amounts of energy. That is the way the world's 440-odd nuclear energy plants work. There is also nuclear fusion, which is potentially much more powerful, but relies on smooshing together nuclei in a controlled fashion that we haven't yet mastered.

The Voyager probes get their power in a different way: they make use of natural radioactivity. Some atoms are unstable and spit out a chunk of matter and energy now and again. It could be a cluster of two protons and two neutrons (alpha radiation), an electron (beta radiation) or raw energy in the form of gamma rays.

We can't predict when a specific atom will decay in these ways, but we can say how long it will take for half of the atoms in a lump of radioactive material to do so. This is its half-life and the number can vary widely. Some radioactive materials vanish in seconds. Plutonium-238 has a half-life ›

SEÑOR SALME

of 87.7 years, which is why it was chosen as the power source for Voyager 2. The plutonium dribbles out a stream of alpha particles, generating heat that is turned into electricity by the probe's three roughly suitcase-sized radioisotope thermoelectric generators.

Radioactivity has a bad reputation, but not all types are equal. Gamma radiation penetrates human tissue most deeply and is dangerous. Beta radiation isn't so bad. Alpha radiation doesn't get through the skin, so it is only damaging if it gets loose inside you. In fact, pacemakers were powered with well-contained radionuclide thermoelectric generators until the early 1970s.

The concept that the US Army is eyeing up is a kind of nuclear power that blends some of the best bits of the other types – it could be powerful, safe and long-lasting. It depends on the fact that the protons and neutrons of a particular element can be clustered together in different arrangements in an atomic nucleus. These are called isomers and each has a different energy. Atoms usually reside in what is normally their most stable isomer, the ground state. Higher energy isomers tend to quickly rearrange themselves back to this state. But there are a few high-energy isomers that hang around for a long time.

NASA/JPL-CALTECH

Voyager 2 was launched more than 40 years ago, yet its battery is still going

Pent-up energy

In 1998, Carl Collins at the University of Texas used a particle accelerator to prepare one of these stable high-energy isomers, called hafnium-178m2 (the m2 notation means this is the second isomer of hafnium-178). He then fired X-rays at its nucleus and claimed that this shifted the nucleus to its ground state, releasing a burst of gamma rays. These would be hard to tap as an energy source because they are so dangerous, but Collins saw it as proof of principle that nuclear isomers could be useful power sources. He thought they could even be used as a new type of nuclear bomb.

Many scientists ridiculed Collins's claims, arguing that he had to put in more energy to trigger the isomer shift than he got out. Plus, the fact that you need a particle accelerator to make the hafnium isomer meant it could only be produced in small quantities at great expense. The episode became known as the "hafnium controversy".

Other high-energy isomers might get around the problems. For example, tantalum-180m occurs naturally, if rarely, in mineable tantalum deposits. Silver-108m produces beta radiation, which is less dangerous and easier to tap. None of this makes isomer power a safe bet, but the pay-off from creating an effectively unlimited energy source may make it worthwhile. A similar rationale applies to the £11.6 billion being spent on the ITER fusion reactor in France, even though it is intended merely as a technology demonstration and won't generate power.

Collins's approach was to get all the pent-up power of an isomer out in one go. But there is, in principle, a different and arguably more useful method. We have known about it for decades, it just hasn't been properly pursued.

Imagine you have a lump of radioactive isomer that, like hafnium-178m2, is high energy but stable. You could have this sitting safely in a container for a long time because it emits barely any radiation. When you need some power, you convert a small amount of it into its ground state, which is less stable and begins to radioactively decay quickly. This gives you a generator akin to the one in Voyager 2, but which can be cranked up in power at will.

James Carroll at the US Army Research Laboratory in Adelphi, Maryland, has been investigating whether interconverting isomers in this way is possible. One potential way to do it, first proposed in 1976, involves firing an electron at an isomer and it being absorbed into an orbit around the nucleus. This prompts the protons and neutrons to rearrange. It is called nuclear excitation by electron capture (NEEC).

Carroll and his team used a particle accelerator at Argonne National Laboratory near Chicago to create a beam of molybdenum-93m atoms, with a half-life of about 7 hours. This beam was travelling at about 10 per cent of the speed of light, fast enough to strip away some of the

"Isomers blend the best bits of other types of nuclear energy. They could be safe, powerful and long-lasting"

atoms' electrons. It was then smashed into a target, which injected electrons back into the nuclei, while nudging them into a less stable isomer. This isomer decayed so quickly that the researchers couldn't observe it. But they inferred it was created by the gamma rays it produced. The work, published in 2018, is the first time NEEC had been demonstrated.

"The experiment has been a significant step forward, but the jury is out regarding whether or not it is a breakthrough for NEEC," says Philip Walker, who studies nuclear isomer physics at the University of Surrey, UK. This is largely because there is dispute over how much energy can be wrung out of isomers. Carroll's figures suggest that the process could produce 5 joules of energy for every joule put in, assuming 1 per cent of atoms undergo NEEC.

Adriana Pálffy at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany, isn't so sure. Her calculations suggest that a billion times fewer atoms should be depleted through radioactive decay. If true, that raises questions about where the energy that Carroll saw is coming from. "The experimental results may be valid, but their interpretation of what happened in the process cannot be correct," says Pálffy.

Carroll admits that isomers are far from being of practical use as batteries. But the arguments that applied after Collins's work still apply: there are other isomers that could be more accessible and easier to harness. The trouble is that the exact properties of isomers are tough to calculate, and we won't know how suitable they are until we try them.

That is exactly what the US Army now wants to do. The Army Research Laboratory is sponsoring Poland's Department of Nuclear Techniques and Equipment at Swierk to explore the science of isomer depletion. The team is led by Jacek Rzadkiewicz and has access to the Polish MARIA experimental nuclear reactor, which can produce a variety of different isomers. "The goal of the project is to learn the nature of the process of charging isomers and their discharge on demand," says Rzadkiewicz. In other words, find out which isomers would make a good battery. The Polish team is looking at rhenium-186m and americium-242m among other isomers.

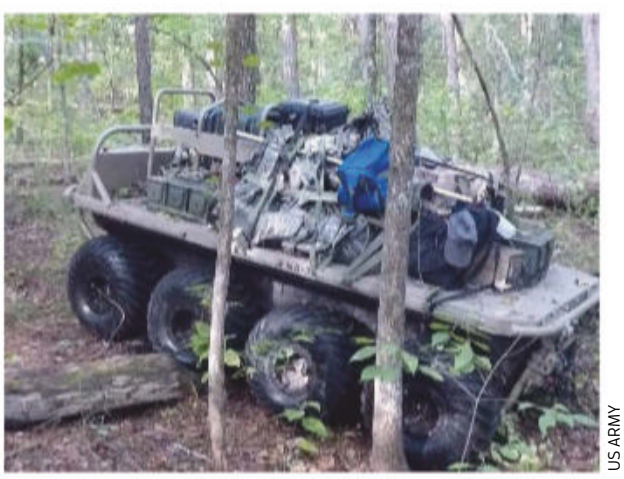
At the moment, there is no sense of how isomer shifting could be done at a smaller scale than in a particle accelerator. Still, there is ample drive to get isomer batteries to work because they would pack gigantic amounts of energy into a small volume. "Isomers can store energy with a capacity of up to over gigajoules per gram," says Rzadkiewicz. That's a million times more than lithium-ion batteries, and tens of thousands of times more than petrol.

Risk and reward

Carroll says an uncrewed army vehicle known as a SMET, used to carry soldiers' equipment, could run for 163 days on 1 kilogram of americium-242m. The current version runs for three days on 20 litres of petrol. Drones or robot submarines could also be given isomer energy sources. It is easy to see why the US Army is interested.

Safety is going to be a concern for anything with "nuclear" in its name. And if isomer power produces gamma rays, that will preclude its use. But if isomers can be found that emit beta or alpha particles, it could be feasible. Plenty of people work close to stores of materials used for radiotherapy and diagnostics. "The amounts of radioactive material needed for a battery are probably less than the material routinely shipped around hospitals," says Patrick Regan at the University of Surrey.

Isomer power is the longest of long shots. But then many of our greatest achievements seemed that way at the beginning. When the space race began, who would have thought that, just decades later, we would have sent a probe beyond the edge of the solar system? ▮



US ARMY

Army vehicles like the SMET might one day be able to run for months on an isomer battery

David Hambling is a technology journalist based in London

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Evolving evolution

Our modern conception of evolution started with Charles Darwin and his idea of natural selection – "survival of the fittest" – to explain why certain individuals thrive while others fail to leave a legacy. Then came genetics to explain the underlying mechanism: changes in organisms caused by random mutations of genes.

Now this powerful picture is changing once more, as discoveries in genetics, epigenetics, developmental biology and other fields lend a new complexity and richness to our greatest theory of nature. Find out more in this 12-page feature special.

TIM MCDONAGH

1

GENES AREN'T DESTINY

The principle of genetic plasticity

IN 1990, an international group of scientists embarked on one of the most ambitious research projects ever undertaken. They would sequence the entire human genome, determining the order of the 3.3 billion base pairs that code for the genes that make the proteins that each of us are built from. There was huge excitement at the prospect of decoding the "blueprint" of humanity. Given the complexity of our species, our genome was expected to contain at least 100,000 genes. What makes us human would finally be laid bare.

It didn't quite work out like that. The Human Genome Project was a resounding success, publishing its results in 2003, two years ahead of target. However, it revealed that humans only have around 22,000 genes, which is about the same number as other mammals. Meanwhile, the blueprint itself turned out to be encrypted in ways we are still trying to crack.

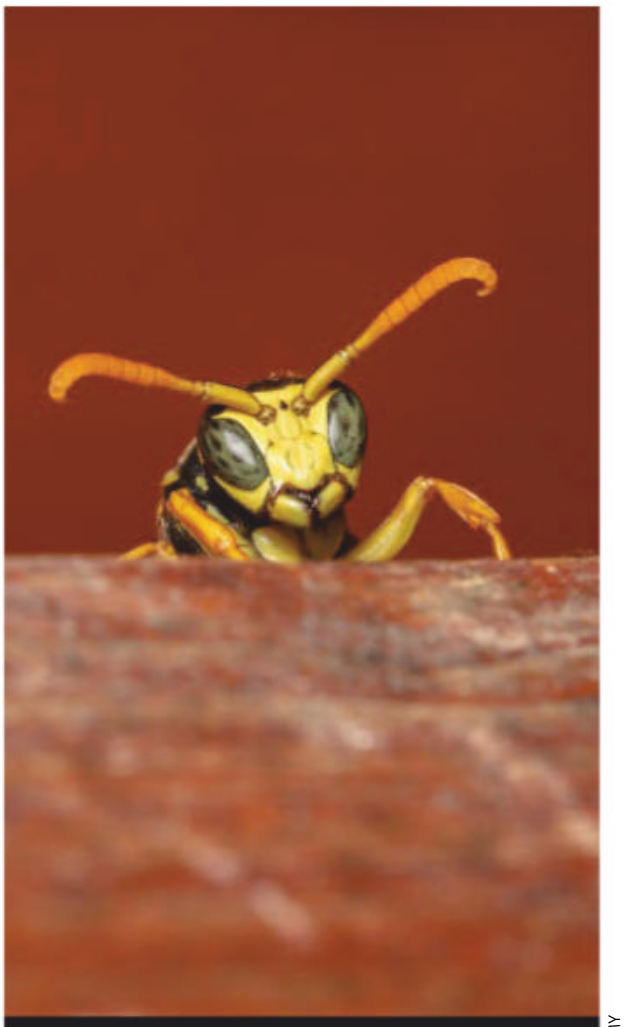
The same thing is true of us that is true of every species: our DNA can be expressed in myriad different ways depending on which combination of sequences is activated. It is this, not the ›

number of genes in the genome, that creates the complexity of life.

The more we learn about genetics, the clearer it becomes that "genetic determinism" – the idea that genes and genes alone fix our destiny – is a myth. A given set of genes has the potential to produce a variety of observable characteristics, known as phenotypes, depending on the environment. An Arctic fox changes its coat colour with the seasons. The presence of predators causes water flea *Daphnia longicephala* to grow a protective helmet and spines.

The power of flexibility

Even a change in social environment can prompt a shift. In the European paper wasp (*Polistes dominula*), for example, when the queen dies, the oldest worker transforms herself into a new queen. But she isn't the only one to respond. Seirian Sumner at University College London and her colleagues found that the death of a colony's queen results in temporary changes in the expression of genes in all workers, as though they are jostling genetically for succession. This flexibility is key to the survival of the colony and the species, says Sumner.



Genetic flexibility allows any paper wasp to become queen

UWE GRUN/ALAMY

"EVOLUTION'S SIMPLE PROCESSES MIGHT FORM A LEARNING MACHINE"

The power of genetic plasticity can be seen in the humble house finch. In the past 50 years, it has colonised the eastern half of North America, moving into habitats ranging from pine forests near the Canadian border to swampland in the Gulf of Mexico. The finch's underlying developmental plasticity provided the raw material from which novel features evolved, including a range of new colourings and other physical and behavioural traits, says David Pfennig at the University of North Carolina at Chapel Hill. "Stop thinking about this as being like genes or environment, because it's a combination of the two," he says. **Carrie Arnold**

2

EVOLUTION SHOWS INTELLIGENCE

Natural induction

HOW has life on Earth evolved such a dazzling array of beauty and complexity in the 3.8 billion years since it emerged? The standard answer is that the sheer abundance of life forms means a huge number of random genetic mutations are happening all the time, allowing natural selection to test many prototypes at once (see "The standard model of evolution", page 45). But some researchers suggest a radical twist to that explanation. They argue that evolution can learn.

Their inspiration comes from computer science. Computers can mimic intelligence using algorithms: iterative rules that combine existing knowledge with fresh information to generate novel outputs. A simple algorithm called Bayesian updating, for example, starts with many hypotheses and homes in on the best ones as new information becomes available.

Likewise, natural selection incorporates new information from the environment to favour the best-adapted organisms. Richard Watson at the University of Southampton, UK, decided to look at the mechanisms involved to try to work out what is going on. In evolutionary terms, information about the past is carried in genes inherited by the offspring of fit individuals. But a relatively recent insight is that genes don't code "for" particular traits. They are team players, and their activity is regulated by other genes to create a network of connections. Natural selection favours those connections that work best. This, Watson realised, is just like how a brain learns. Brains consist of networks of neurons whose structure is shaped by learning because the more a connection is

used, the stronger it becomes. Sure enough, when Watson and his colleagues built a computer model that took account of the networked nature of genes, they found it could evolve to learn and remember solutions to problems with just a simulacrum of natural selection to reinforce the best attempts.

Brains don't just learn specific solutions to particular problems: they also generalise to solve problems they have never encountered. They do this by recognising similarities between new challenges and past ones, and then combining the building blocks of previous solutions to come up with novel ones. This is called inductive learning. Can gene networks do induction too?

Watson and his colleagues argue that they can. The key, they say, is that energy is required to connect genes, because proteins must be produced to achieve this. So, for efficiency, evolution favours networks with fewer connections, which are loosely linked with other subnetworks. These building blocks can be recombined in different ways to generate novel solutions to the problems that challenge life. Thus, evolution's simple processes form an inductive-learning machine that draws lessons from past successes to improve future performance.

This conception of evolution has far-reaching implications. For a start, it can explain how entire ecosystems evolve to be well-adapted despite natural selection favouring fit individuals, not fit communities. Think of the connections between organisms within an ecosystem as a network, and they too can learn by induction, as Watson and his Southampton colleague Daniel Power have demonstrated using computer modelling. "An ecosystem can't be adapted by natural selection, but it can be adapted by natural induction," says Watson.

This raises an intriguing question. If natural induction isn't about survival of the fittest, what is it about? "Maybe, evolution is less about outcompeting others and more to do with co-creating knowledge," says Watson. That really is a radical idea. **Kate Douglas**

Kenya's Samburu people show how cooperation evolves

TON KOENE/VWPICS/SCIENCE PHOTO LIBRARY

3

MOVE OVER, SELFISH GENE

Cultural group selection

EVOLUTION traditionally has a problem with Good Samaritans. If only the fittest individuals survive, then those who are nice to others at their own expense will surely be weeded out. Yet cooperation is widespread in nature, from plants that alert each other to danger and colonial insects that work as one to dolphins cooperating to round up fish.

A decades-old idea called kin selection can explain some of this: if organisms have enough DNA in common, then they can further their own selfish genes by helping one another. Bees, ants and wasps have a system of reproduction called haplodiploidy, which leaves colony members so closely related that they act almost as a single superorganism. And among any sexually reproducing species, parental care helps individuals propagate their genes.

But kin selection cannot explain why humans are so nice to strangers. One idea is that we have evolved to be super-cooperative because, over time, more cooperative groups have outcompeted less cooperative ones. But there generally isn't enough genetic variation between groups to allow natural selection to favour more cooperative ones.

Some researchers think the solution lies in an idea called cultural group selection. Forget shared genes, they argue: selection can favour cooperative groups if the people within them share enough culture. The idea is controversial because to work it requires that groups remain culturally distinct. As critics point out, people tend to migrate between groups, which should homogenise ideas and customs. Those who back the concept counter that groups have ways to retain their distinct culture, including a process called norm enforcement. Put simply, if someone migrates into a new cultural group, they are pressured into following the local rules because failing to do so leads to punishment.

Earlier this year, Sarah Mathew and Carla Handley at Arizona State University published a pioneering field study testing the idea. They sampled 759 people from four pastoral ethnic groups in Kenya – the ›

Turkana, Samburu, Rendille and Borana – who compete intensively for land, water and livestock. The pair estimate that genetic differences between individuals from different groups was generally less than 1 per cent. Cultural practices and beliefs varied much more, by 10 to 20 per cent. People cooperated most with members of their own group, as cultural group selection predicts, and to a lesser extent with members of other groups whose norms most closely matched their own. That makes sense if culture rather than genetics is what matters. "I think this is one of the most explicit tests of cultural group selection theory so far," says Mathew.

Not everyone is persuaded. Max Krasnow at Harvard University sees no theoretical flaw with the idea, but says that some of his research undermines it. He has found that people don't just enforce the rules within their group, but also punish people from other groups who fail to follow their own group's norms. Mathew counters that it is reasonable to enforce the norms of outsiders as a step towards incorporating them into your cultural group. "This is often how empires expand," she says. **Colin Barras**

4

THERE IS MORE TO INHERITANCE THAN JUST GENES

Epigenetic marks

IF GENES form the words in the book of life, then epigenetic marks are the punctuation. These chemical tags affect which genes are turned on and off in an organism. They are created in response to changes in conditions within cells or the external environment, such as temperature, stress or diet. Since their discovery in the 1950s, scientists had thought that all epigenetic marks were erased before genes are passed from parents to offspring. A dark episode in human history provided an early hint that this might not be so.

In late 1944, as retaliation for a Dutch rebellion against German occupiers, the Nazis cut off food and fuel supplies to the Netherlands. By the time the country was liberated, adults were subsisting on an average of 580 calories per day. Children born to women who were pregnant during this time were small and had low birth weights. Surprisingly, though, later in life they had unusually high levels of obesity, diabetes and schizophrenia. So, too, did their children.

It makes sense if epigenetic marks are being passed down the generations. Marks created when food was scarce became associated with a high incidence of metabolic diseases in times of plenty.

Subsequent studies in plants and animals suggest that epigenetic inheritance is more common than anyone had expected. What's more, compared with genetic inheritance, it has some big advantages. Environments can change rapidly and dramatically, but genetic mutations are random, so often require generations to take hold. Epigenetic marks, by contrast, are created in minutes or hours. And because they result from environmental change, they are often adaptive, boosting the survival of subsequent generations.

Take the pea aphid. It is capable of both sexual and asexual reproduction, and comes in two varieties: winged and wingless. When scientists exposed a group of genetically identical pea aphids to ladybirds, the proportion of winged aphids increased from a quarter to a half. This adaptation, which helped them escape the predatory ladybirds, persisted for 25 generations. The aphid DNA didn't mutate, the only change was epigenetic.

Epigenetic bequests aren't always beneficial. Experimenting with nematode worms, Martin Lind at Uppsala University in Sweden and his colleagues have discovered that the key factor is whether environmental conditions remain stable. If they change, then adaptations may be detrimental to subsequent generations – as happened with descendants of the Dutch Hunger Winter.

The extent of epigenetic inheritance is contested. Some sceptics point out that, during mammalian reproduction, the creation of sperm and egg cells involves erasing epigenetic markers. Others argue that epigenetic transmission across generations is extremely widespread and useful. In plants, for example, it can account for differences in fruit size, flowering time and many other survival-boosting traits. **Carrie Arnold**

BLICKWINKEL/ALAMY

Plants can vary their fruit size because of epigenetic marks

"COMPARED WITH GENETIC INHERITANCE, EPIGENETICS HAS BIG ADVANTAGES"

The African elephant is now seen as two species not one

WIM VAN DEN HEEVER/NATUREPL.COM

5

SPECIES DON'T REALLY EXIST

Taxonomic anarchy

FOR most of history, we have had little trouble defining species. There was a general assumption that a finite number of distinct forms of life had existed unchanged since creation, each sitting in a clearly defined pigeonhole: human, housefly, hawthorn and so on. Within the past few centuries, and particularly after Darwin, evolutionary theory has emerged as a more satisfactory way to explain how species came into existence. Yet in doing so, it has made species far harder to define.

There are several aspects to the problem. One is that if we accept the idea of species evolving from other species, then we must allow that an ancestral species can gradually morph into one or more descendants. We would still like to place organisms in discrete categories, but doing so is difficult if species blur into one another through time. "As we have come to terms with evolution, it has highlighted a problem with the machinery in our heads we use for classifying," says Frank Zachos at the Natural History Museum of Vienna in Austria.

For Jody Hey at Temple University in Philadelphia, the more important problem is that biologists often have two objectives in mind when they define species: one is the traditional desire to divide nature into easily recognisable packages; the second is to explain, in evolutionary terms, how those species came into existence. "Humans have conflicting motivations towards species," he says.

Some researchers argue that these two objectives can never be achieved simultaneously. Down the decades, biologists have come up with a few dozen clever ways to define species. Some make it easy to classify the organisms we encounter – by their physical appearance, for example – but tell us little about the evolutionary process itself (see "Sadistic cladistics", page 49). Other definitions get to the heart of how species come to exist, but can be difficult to use in the real world.

Hybrid bonanza

In principle, advances in genetic sequencing could have helped by indicating how genetically distinct different groups of organisms are and how long ago lineages diverged. But sequencing has arguably made the problem worse by revealing that interbreeding – more technically, introgression – between closely related "species" is common across the tree of life. "It does seem to be the rule, not the exception," says Michael Arnold at the University of Georgia in Athens. Indeed, evidence of introgression stretches right to our front door: our ancestors interbred with various ancient hominins that might, in the eyes of some, count as distinct species.

Another problem is that looking at genes rather than observable features makes it easier to find new species, leading to what some researchers have called taxonomic anarchy. For instance, a biologist can argue that a previously recognised species should really be split into two or more "new" species, as happened when genetic analysis of the African elephant led to its being separated into savannah and forest-dwelling species.

To help add more rigour to the business of defining new species, earlier this year Zachos and other biologists proposed establishing the first single authoritative list of the world's species. "Species" itself will remain a slippery concept, but at least we could all agree on where to draw the lines. **Colin Barras**

6

ADAPT FIRST, MUTATE LATER

Neo-Lamarckian adaptation

IN THE 1880s, August Weismann began cutting the tails of mice. He wasn't sadistic, he just wanted to find out whether animals can inherit traits their parents have acquired during their lifetime. In 1807, French biologist Jean-Baptiste Lamarck had argued that this is how novel traits evolve – the giraffe's long neck, for instance, arising as the result of successive generations of animals reaching to higher branches for food. But according to Darwinian evolution, organisms must acquire a genetic mutation before they can adapt to a new environment. To survive on land, for example, fish first had to evolve the ability to get oxygen from the air.

Unsurprisingly, Weismann's experiment failed: the offspring of his mutilated mice all had normal tails. But perhaps he was just ahead of his time. Today, there is evidence of Lamarckian evolution – of a sort. Take the Mexican spadefoot toad (*Spea multiplicata*). It breeds in ponds that appear after summer monsoons and the newly hatched tadpoles typically survive on a diet of algae and bacteria. However, should tadpoles find themselves in a pond where fairy shrimps are available, they adapt to take advantage of the more nutritious fare, developing larger jaws and shorter guts. To Nicholas Levis at the University of North Carolina at Chapel Hill, spadefoot toads provide a perfect example of plasticity-led evolution. "It reorients how we think about the adaptive process," he says.

Such plastic changes occur because an environmental trigger affects an organism's development in some way. Levis has found that in the spadefoot toads this happens via 14 genes that underpin their ability to switch between the two different body types. Other organisms may achieve a similar result via epigenetic tags that turn genes on and off (see page 42). Research by Morgan Kelly at Louisiana State University suggests that eastern oysters in the Gulf of Mexico have populations that can survive in low salinity waters because of epigenetic tags.

If the environment remains unchanged – abundant shrimps in the case of the tadpoles and low salinity for the oysters – then subsequent generations will continue to exhibit the traits that help them survive. But these traits are induced anew each time by the environment, not directly inherited from a parent, so how can they affect evolution?

"You can't evolve if you're dead," says Kelly. Plasticity may buy organisms valuable time to adapt genetically. Here's how it might work. In an environment where survival depends on a particular response, only mutations that reinforce that response, or at least don't undermine it, will spread so that eventually a plastic change becomes "fixed".

We don't know how prevalent this sort of evolution is. However, one study found that if you put fish on land they learn to "walk". Admittedly, the fish in question were bichir fish, which can breathe air and haul themselves along out of water if necessary. Nevertheless, simply being on land improved their walking abilities, hinting that plasticity-led evolution might underpin some key transitions in the development of life on Earth, such as the evolution of terrestrial animals. **Carrie Arnold**

The tadpoles of spadefoot toads can switch body type

ROLF NUSSBAUMER/NATUREPL.COM

A beaver's dam is both a product and cause of evolution

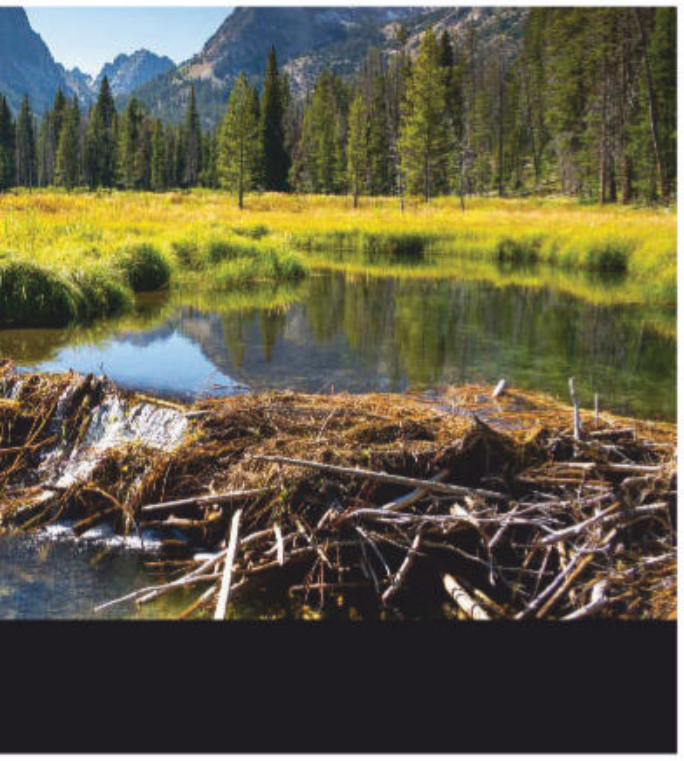
7

WE CAN SHAPE OUR OWN EVOLUTION

Niche construction

EVOLUTION may be a game of chance, but some species load the dice. They modify their environment and so may improve their chances of survival. In doing so, they can change the course of their own evolution. This process is called niche construction.

Birds build nests, termites make mounds, beavers create dams and countless other organisms engineer their environments. Traditionally, biologists thought of niche construction purely as a consequence of natural selection. However, that argument doesn't always work. "It's not the case that genes for building concrete have spread through human populations and that's what led us to build our urban environments," says



JOHN WEBSTER/GETTY IMAGES

Kevin Laland at the University of St Andrews, UK. While niche construction isn't always an outcome of evolution, it is often a cause.

Our own species provides a classic example. By inventing farming, humans not only modified the landscape dramatically, they also changed their diets. As time passed, human genetics began to change in response. "There was selection on our digestive enzymes that allowed us to process carbohydrates and milk protein," says Laland.

Niche construction isn't a niche activity, says Laland. It happens across the tree of life – in animals, plants and even bacteria – and can have big impacts. With niche construction, organisms can ensure that the selective pressures acting on them are more consistent through time and space. By creating the conditions of their existence, they are active players in their own evolution.

Some believe this is overstating it. "Niche construction plays little, if any, role in most kinds of adaptation," says Gregory Wray at Duke University in North Carolina. But there could be a way to settle the debate. If niche construction is widespread and many species manipulate the selective pressures they experience, then evolution should lead to broadly predictable changes. "A traditional biologist will say you won't be able to predict general patterns in evolution – some of us think we might be able to," says Laland. They plan to test the idea. "We'll find out who's right," he says. **Colin Barras**

8

CHANGE CAN BE QUICK

Contemporary evolution

MANY people think evolution is something that takes millions of years, making it imperceptible on human timescales. They have it upside down, says Michael Kinnison at the University of Maine. He and others have shown that organisms can evolve extremely rapidly in response to changes in their environment. However, evolution often reverses direction, making it appear slow over long stretches of time.

The famous finches of the Galapagos islands, which inspired Charles Darwin's thinking about evolution, provide a prime example of this. A single founder species reached the islands around 2 million years ago and gave rise to at least 14 different species, some with large beaks for feeding on big seeds, and some with much smaller beaks for other foods. That was considered fast for evolution, but newer findings suggest that these finches have been evolving far more rapidly than Darwin suspected.

In 1977, a drought on one of the islands, Daphne Major, wiped out ground finches. Only relatively large seeds were available to eat, so birds with larger beaks did better, and within a few generations, beak size had increased by around 4 per cent. Then the wet year of 1983 saw small seeds become abundant again and, over a few years, beak size shrunk back. The finches had evolved quickly but ended where they started.

Likewise, new species of finches may have come and gone. In the 1980s, a male cactus finch arrived on Daphne Major from an island 100 kilometres away and bred with two female ground finches. The offspring were fertile and bred only with each other in subsequent generations. Such genetic ›

The standard model of evolution

Twentieth century ideas about evolution rest on three pillars: variation, inheritance and selection. In this "modern synthesis", which combines Darwinian theory with genetics, variation arises in the form of genetic mutations. DNA sequences change at random as the result of external forces, such as radiation, and internal ones, such as damage to DNA or RNA caused by highly reactive molecules called free radicals. Most of these changes are either neutral or detrimental to life, but a few lead to the adaptations on which evolution is built.

Mutations may occur in any cell, but only those in germ cells, such as eggs and sperm, are passed down the generations to produce genetically distinct individuals: this is the basis of inheritance. One of Charles Darwin's greatest insights was the realisation that organisms tend to produce a variety of offspring, not all of which survive to reproduce. Natural selection weeds out those less well suited to their environment, he said, while fitter individuals survive and pass their traits on to their offspring. In this way, variation, inheritance and selection result in evolution, allowing life to adapt and new species to form as conditions change.

Today, evolution remains one of the most powerful ideas in science but, as with all good ideas, it is evolving. Many of the new conceptions arise from a better understanding of the mechanisms involved and a realisation that organisms take active roles in their own evolution. While accepting the underlying biological principles, many people see this model of evolution – the so-called "extended synthesis" – as a ragtag list of special examples. "The movement has identified the problem, but not the synthesis," says Richard Watson at the University of Southampton, UK.

But last year, Watson and his colleague Christoph Thies published a paper in which they argue that the progress of evolution on Earth – from the first single-celled organisms to the complexity of biological organisation we see today – couldn't have happened without the extra mechanisms in the extended synthesis. "In short, the extensions are the 'glue' that make the whole more than the sum of the parts," they conclude. Kate Douglas

isolation, which is the key to creating new species, was once believed to occur over hundreds of generations, but here it happened in just three. Species formation can go rapidly backwards too. On the nearby island of Santa Cruz, finches had split into large and small-beaked birds. But the distinction between these species is starting to erode. Now, most have medium-sized beaks, probably because people feed them rice so they don't need a specialised beak.

Thousands of examples of rapid evolution have been documented. For instance, in just half a century, killifish in the US evolved to cope with pollution many times higher than the usual lethal dose. In fact, Kinnison avoids the term rapid evolution because he thinks this is the norm. Instead, he talks of "contemporary" evolution. **Michael Le Page**

9

SURVIVAL OF THE... LUCKIEST

Genetic drift

THE Great Ziggurat of Ur – a massive step pyramid – is one of the finest examples of 21st-century urban architecture. The 21st century BC, that is. Large cities were still quite a recent invention when it was built. Urban landscapes are very new in the context of life on Earth. Yet many species now call them home – and their evolution may have had more to do with luck than adaptation.

Natural selection favours certain genes – those that make an organism best adapted to a particular environment. But evolution can also occur through a non-adaptive process called genetic drift, whereby a gene may become dominant in a population purely by chance. Genetic drift is often explained in terms of a bag of tokens with equal numbers of two colours – 20 green and 20 yellow, say. A person draws a token, notes its colour and returns it to the bag, before repeating the process a further 39 times. These picks give a second "generation" of tokens – and chances are it contains more of one colour than the other: 17 green and 23 yellow, for instance. Repeating the process with this new population as a starting point will give a third "generation", which may be even more skewed in favour of yellow tokens. Eventually, the experimenter might randomly pick a generation containing all yellow tokens.

This monochromatic outcome is more likely in smaller populations: it would take countless generations for 1000 green and 1000 yellow tokens to "drift" into a population of 2000 green tokens, for example, but perhaps just a few generations for 10 green and 10 yellow tokens to become a population of 20 green tokens. Such outcomes can and do occur in nature, which shows how a population can lose genetic variability simply through chance.

Biologists have known about genetic drift for a century, but in recent years they realised that it could be especially common in urban settings where roads and buildings tend to isolate organisms into small populations. A 2016 study of the white-footed mouse, *Peromyscus leucopus*, in New York supported the idea. Jason Munshi-South at Fordham University, New York, and his colleagues discovered that urban populations have lost as much as half of their genetic diversity compared with rural populations.

Last year, Lindsay Miles at the University of Toronto Mississauga, Canada, and her colleagues published a review of evidence from about 160 studies of evolution in urban environments, in organisms ranging from mammals and birds to insects and plants. Almost two-thirds of the studies reported reduced genetic diversity compared with rural counterparts, leading the researchers to conclude that genetic drift must have played a role. "Genetic drift can definitely be a significant driver of evolution," says Miles.

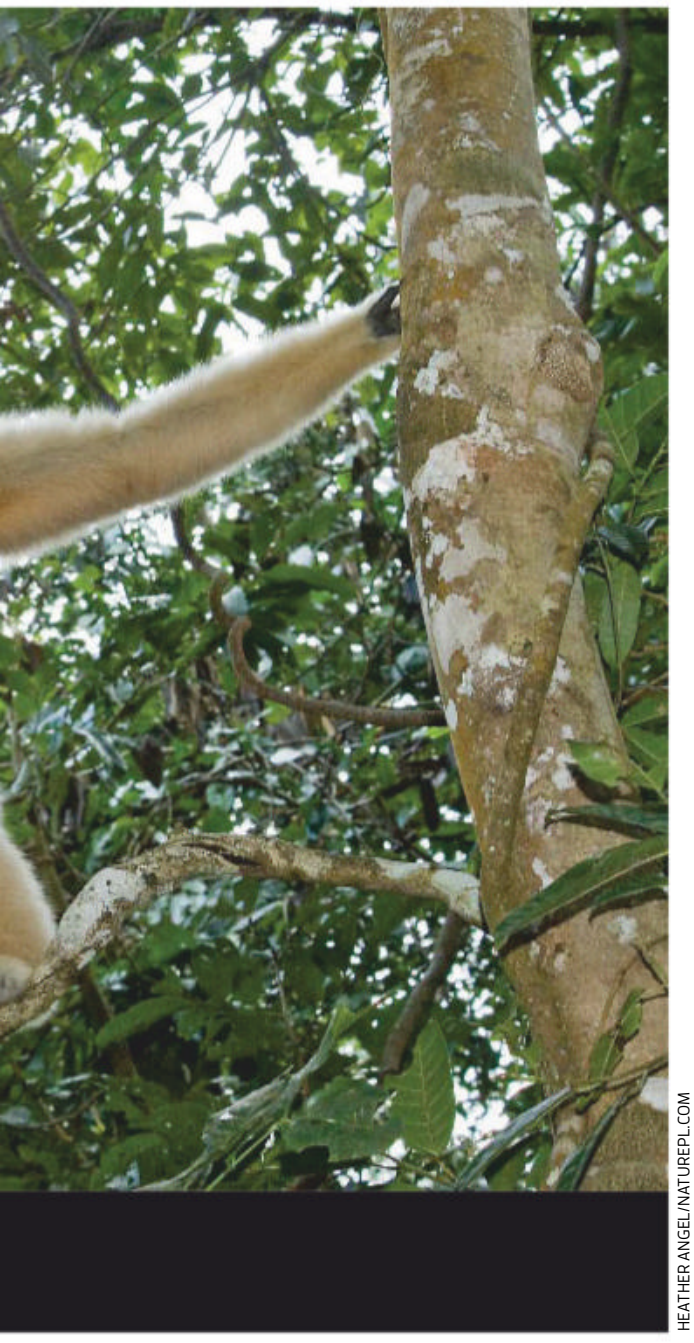
These findings have big implications, because populations lose their ability to adapt and thrive if they lack genetic diversity for natural selection to work on. Of course, genetic drift isn't confined to urban settings, but given how much urbanisation is expected to grow, the extra threat it poses to wildlife is concerning. It highlights the need to create green corridors so that animals and plants don't become isolated into ever-smaller populations. **Colin Barras**

Gibbons' long arms are a sign of how evolvable apes are

10

GENES DON'T JUST COME FROM PARENTS

Horizontal gene transfer



HEATHER ANGEL/NATUREPL.COM

CHRIS HITTINGER studies budding yeasts, the group that includes *Saccharomyces cerevisiae*, the yeast beloved of beer brewers and bread makers. It is one of the most diverse groups of organisms with a nucleus (aka eukaryotes), so Hittinger is used to seeing bizarre things in his lab. A few years ago, however, he saw something that really surprised him. "There were a bunch of genes in some of these yeasts that simply should not have been there," says Hittinger at the University of Wisconsin-Madison. The genes were used by bacteria to make iron-grabbing enzymes, and it looked like an ancestor of the yeast had stolen them – as indeed it turned out they had.

For nearly a century, microbiologists have known that bacteria can swap genes with each other, acquire viral genes when infected by viruses and even snatch free-floating DNA from the environment. This process is called horizontal gene transfer. As increasing numbers of microbial genomes have been sequenced, scientists have come to realise that it is remarkably common. Microbes aren't passively waiting around to accumulate mutations to adapt to changing environments. Instead, they can pick up genes they encounter, giving natural selection far more variety to work on. "They're all sharing genes with each other, and it's really a massive network of gene transfer events," says Gregory Fournier at the Massachusetts Institute of Technology.

Horizontal gene transfer has been most frequently documented in prokaryotes, single-celled microbes that lack a nucleus and so have few physical barriers to stop DNA from elsewhere being incorporated into their genome. But Hittinger's work shows that even some eukaryotes can borrow from distantly related bacteria. "Yeast and bacteria have fundamentally different ways of turning DNA into protein, and this seemed like a really, really strange phenomenon," he says.

DNA jumble sale

Melanie Blokesch at the Swiss Federal Institute of Technology in Lausanne has shown that physical closeness and the amount of time two organisms spend next to each other is key to their chances of acquiring DNA. Other studies indicate that metabolic and functional genes, such as those that help an organism utilise a novel food source or detoxify a harmful chemical, are the most likely to end up at the ersatz DNA jumble sale. The spread of antibiotic resistance genes in bacteria shows just how important this phenomenon is to the survival of microbes.

What about the wider role of horizontal gene transfer in evolution? "The question is how much [horizontally transferred DNA] persists over long periods of time, and ends up being material that is inherited and passed down to future species," says Fournier. There are hints that it could be quite a lot. Hittinger isn't alone in finding out-of-place clumps of DNA. Others have discovered them in mammals, and analysis of the entire human genome revealed that at least 8 per cent of our DNA derives from viruses. Indeed, by one estimate up to half of all human DNA derives originally from horizontal gene transfer. **Carrie Arnold**

11

SOME THINGS ARE BETTER AT EVOLVING

Evolvability

MONKEYS didn't stand a chance. When it came to walking on two legs, apes were always going to win out. Our branch of the primate family tree had what it took to evolve long legs, freeing up hands for other functions such as making complex tools – a significant adaptation on the road to becoming human. In this respect, monkeys just aren't as evolvable as apes.

Evolvability is a simple concept. "It's the capacity of a population to evolve adaptively and to generate phenotypic [observable] variation that's heritable," says Tobias Uller at Lund University in Sweden. Some organisms are better at this than others, as the evolution of bipedal locomotion in primates illustrates. Early primates – in common with many animals – had four limbs that were approximately the same length and performed a similar function. All monkeys retain this anatomy. But at some point, apes broke free of this constraint and became more likely to generate front and rear limbs of different lengths. The result is clear to see in the range of ape body shapes today – from long-armed gibbons to long-legged humans.

What isn't so clear is exactly what it means for a group to be evolvable. Biologists have been discussing evolvability for two decades, but there is still no agreement on exactly how to use the term. Rachael Brown at the Australian National University, Canberra, has identified five distinct definitions. She points out that a population might be considered highly evolvable according to one, but not particularly evolvable according to another.

As the climate becomes drier, for instance, some plants grow smaller leaves that lose less water through evaporation. In doing so, ›

they arguably demonstrate a form of evolvability, says Uller. The plants haven't changed genetically, but they have found a way to survive in the short term, buying some time during which they might accumulate genetic mutations and so evolve for a more arid life.

Other biologists argue that this isn't evolvability at all. Rachel Wright at Smith College, Massachusetts, is one of them. She and her colleagues recently published research on the evolvability of reef-building corals in the face of three environmental challenges: rising sea temperature, ocean acidification and increase in infectious diseases. They found that the corals with a tolerance for one of these stressors were also able to cope well with the others. This, they say, shows that these corals have the potential for rapid adaptation under climate change. "If the responses we observed were due to completely non-genetic effects, I would not consider this evolvability," says Wright.

The concept of evolvability is flawed but Brown says biologists need to agree a proper definition if they are to use it effectively. That is important because evolvability goes to the heart of some big evolutionary questions, from the potential effects of global warming to the evolution of bipedalism. **Colin Barras**

CARLOS VILLOCH, MAGICSEA.COM/ALAMY

Some corals can rapidly adapt to stressful conditions

12

EVOLUTION FAVOURS CERTAIN OUTCOMES

Developmental bias

AT THE heart of evolution is a random process: mutations to DNA that result in genetic variation. Yet, observe what evolves and you find that some outcomes are more likely than others. Instead of appearing directionless, as you might expect with a truly random process, evolution is full of repeating patterns. Now we know why. "You find some solutions evolving over and over again, not because they're the best, but because the developmental system [of organisms] has the tendency to throw up certain variations," says Tobias Uller at Lund University in Sweden.

This is called developmental bias, and it can be seen clearly in domestic animals. Many of them have floppy ears and curly tails along with shorter snouts and different coat colours compared with their wild ancestors. Yet, these characteristics have no obvious links to the qualities for which these creatures have been bred, such as tameness, milk production and meat yield. The mystery of so-called domestication syndrome was cracked when scientists homed in on a tiny cluster of stem cells in the developing embryo. These "neural crest cells" are involved in the development of a variety of tissues influencing things like face and ear shape and coat colour. They also give rise to the adrenal glands, which play a key role generating the fight-or-flight response that underpins tameness. Increase tameness by breeding for it, and the shorter snout and curly tail are dragged along for the ride.

If certain characteristics can develop more easily than others, than we should expect to see recurring patterns in nature. Developmental bias could be behind a fascinating quirk of evolution called parallel radiation: the phenomenon in which a species in one location diversifies into several distinct forms and, independently, the same diversification occurs in a different location. A famous example is cichlid fishes living in Lake Malawi and Lake Tanganyika in Africa. Each lake contains many different species that show striking similarities in the variety of body shapes to species in the other lake, despite being more closely related to those living in their own lake. These body shapes adapt species to particular niches or diets, so must have evolved by natural selection. But the forms the fish take aren't necessarily the only possible adaptive solutions. This suggests there are features of cichlid development that make some body types more likely to arise.

Despite directing evolution down certain tracks, developmental bias isn't inherently limiting, says Uller, because it can promote variation that is more likely to be beneficial and therefore more likely to survive. It could help explain why cichlids are so diverse and similar bursts of evolution among all sorts of organisms, from the Galapagos finches studied by Charles Darwin to Australian marsupials. **Carrie Arnold**

13

WE CAN STOP EVOLUTION

Anti-evolution

EVOLUTION didn't just happen in the past. It is happening right now, and it is often seriously bad for us. That is why researchers are exploring ways to slow, stop or even reverse unwanted evolution, or out-evolve it.

Perhaps the biggest threat posed to us by evolution is the rise of antibiotic-resistant superbugs, which already kill 35,000 people each year in the US alone. Evolution also

enables the growth of cancers that many of us will eventually succumb to. It is also to blame for pesticide-resistant insects that spread diseases such as malaria, "super rats" immune to poison and weeds that shrug off herbicides.

Some solutions are low tech. For instance, companies selling seeds for crops that are genetically modified to produce an insecticide called Bt often mix these seeds with non-Bt versions. If farmers grow only Bt-producing crops then only Bt-resistant pests will survive. Using a mixture allows some Bt-susceptible pests to survive too and mate with others, slowing the evolution of resistant strains.

Winning the arms race

The opposite strategy is to attack organisms on so many fronts that they have no chance of evolving resistance. This has saved the lives of millions of people who are HIV-positive. While the virus rapidly evolves resistance in the bodies of people taking just one antiviral drug, it is overwhelmed by combination therapies. Lee Cronin at the University of Edinburgh, UK, believes combination therapies can tackle antibiotic resistance too. His team is creating a robotic system for generating and testing the new drugs needed to do this. Part of the approach is to predict how superbugs will evolve, to stay ahead in the arms race.

Others are creating "anti-evolution" super-weapons. To reverse antibiotic resistance, they take viruses that attack bacteria and equip them with the CRISPR gene-editing system. The CRISPR system can be programmed to delete genes that confer antibiotic resistance, rendering bacteria vulnerable to antibiotics once more. Groups working on this approach include an Israeli-based company called Trobix Bio. It is developing a pill, codenamed TBX101, intended to target gut bacteria that are resistant to a group of antibiotics called carbapenems. These bacteria can cause deadly hospital-acquired infections.

Meanwhile, Jeffrey Barrick at the University of Texas at Austin is trying to undermine the genetic mutation process itself. He tweaks the proteins that replicate DNA in *E. coli* bacteria so that they make fewer mistakes when copying the genetic code. That means fewer mutations and slower evolution. Ironically, Barrick achieved this using a method for engineering desirable protein variants called directed evolution. Evolution is evolving – and not just through its own devices. **Michael Le Page** ▮

Sadistic cladistics

Classifying nature was once so simple. Learned, often bearded, men travelled the world collecting specimens and ordered them on the basis of shared behaviour and traits into their rightful groupings to give a branching hierarchy of kingdom, phylum, class, order, family, genus and species.

All that began to change in the 1950s – and that is in turn changing how we view the products of evolution. Devised by German entomologist Willi Hennig, cladistics is a more systematic way of analysing the relationship between organisms based on traits that aren't just shared, but also genetically derived from one another. As our tools for doing "phylogenetic" analyses have become more powerful, cladistics has run a coach and horses through many familiar and much-loved taxonomic groupings.

In cladistics, the gold standard for a group, or "clade", is to be monophyletic, meaning all species in the clade share one common ancestor. Slightly sniffed at are groupings that turn out to be paraphyletic, meaning that all species in them share a common ancestor, but there are species outside them that also share that common ancestor. Doubleplusungood is for a group to be polyphyletic, with its members having more than one common ancestor.

A prominent casualty of cladistics analysis is the class Reptilia. The common ancestor of all scaly, cold-blooded reptiles – crocodiles, lizards, snakes, tortoises, dinosaurs and the like – also gave rise to the warm-blooded, fur-and-feathered mammals and birds, but at different points. So reptiles are cladistically paraphyletic. To be taxonomically correct, you should refer to birds, mammals and reptiles together as "amniotes". Alternatively, accept that birds are reptiles, since all members of both groups share a common ancestor, and you will be doing just fine. Confusingly, though, both birds (Aves) and mammals (Mammalia) are true, monophyletic clades each with a separate, common ancestor.

Cladistics also causes trouble for the largest group of vertebrates on the planet, the bony fish. Traditionally, they were put in the class Osteichthyes. But given that tetrapods – land vertebrates – evolved from a fish that learned to walk, cladistics would classify all mammals, birds, amphibians and reptiles, including dinosaurs, as fish. (Yes, that makes you a fish, too.) The problem is solved in modern taxonomy by redefining the Osteichthyes as a "superclass" consisting of the tetrapods and lobe-finned fish, which share a common ancestor. Ray-finned fish, which are most of what we consider fish, are hived off into their own satisfyingly monophyletic class, the Actinopterygii.

TANGLED CLADES

But marine taxonomists take note: corals, crustaceans, jellyfish and sponges all officially don't exist either, because they are all paraphyletic. In fact, invertebrates generally aren't a thing, phylogenetically speaking: if they were, they would have to include all vertebrates too. More specifically, you may be pleased to learn that there is also no such thing as a wasp. They are paraphyletic, sharing a common ancestor with ants, of which there are more than 10,000 species. Moths are out too, for the same reason. But butterflies all share a common ancestor, so they can stay. Worms, meanwhile, once misidentified as reptiles, are a complete tangle of long, thin things belonging to a whole host of different clades. Richard Webb

Fellowships for Postdoctoral Scholars

WOODS HOLE **OCEANOGRAPHIC** INSTITUTION

Scholarships are available to new or recent doctoral graduates in diverse areas of research
Applications will be accepted from doctoral recipients with research interests associated with the following:

Departments - Applicants who wish to conduct research on topics of general interest to one or more of the departments are encouraged to apply. Interdepartmental research, including with the Marine Policy Center, is also encouraged. The Departments are:

- **Applied Ocean Physics & Engineering**
- **Biology**
- **Geology & Geophysics**
- **Marine Chemistry & Geochemistry**
- **Physical Oceanography**

A joint USGS/WHOI award will be given to a postdoc whose research is in an area of common interest between USGS and WHOI Scientific Staff. The individual will interact with both USGS and WHOI based advisors on their research.

The Center for Marine and Environmental Radioactivity (CMER) will award a fellowship for research on natural and human-made radioactive substances in the environment including the study of their sources and fate or use as tracers of ocean processes.

The National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS) will award a fellowship in the development and implementation of new techniques in marine science radiocarbon studies.

The Ocean Bottom Seismic Instrument Center (OBSIC) will award a postdoctoral fellowship for research on the earth's internal structure and earthquake processes using seafloor seismic measurements.

The Ocean Twilight Zone (OTZ) project will award a fellowship for research on twilight zone (100-1000 m) ecosystems and processes, including biomass, biodiversity, life histories and behavior, trophic interactions, links to the global carbon cycle, and ways to engage scientists with stakeholders.

Recipients of awards are selected competitively, with primary emphasis placed on research promise. Scholarships are awarded for 18-month appointments with a stipend of $62,250 per year, a health and welfare allowance and a modest research budget. Recipients are encouraged to pursue their own research interest in association with resident Scientific and Senior Technical Staff. Communication with potential WHOI advisors prior to submitting an application is encouraged. Completed applications must be received by October 15, 2020 for the 2021/2022 appointments. Awards will be announced in December. Recipients of awards can initiate their study and research period at the Institution any time after January 1, 2021 and before December 1, 2021.

Further information about the Scholarships and application forms as well as links to the individual Departments and their research themes may be obtained through the Academic Programs section of the WHOI web pages at:

www.whoi.edu/postdoctoral

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Maker Science of gardening

Green your walls

Growing ivy is a great way to cover ugly walls and support local wildlife. Just don't let it get the better of you, says **Clare Wilson**

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

What you need

An ivy plant
A wall
A pot (optional, but recommended)

Science of gardening will appear every four weeks

Next week

Citizen science

THE latest thing in architecture is green buildings – covering walls and roofs with a carpet of plants to insulate, soak up rain and provide a home for wildlife. Many such buildings need complex systems for holding and irrigating the soil, but there is a much easier approach: growing some ivy.

Ivy is a group of about a dozen species of evergreen climbing plants in the genus *Hedera* that are happy in shade or full sun and with most kinds of soil. They don't need supports as they grow aerial roots that latch on to most things. Many people use ivy to quickly cover an ugly wall or fence. It also provides nectar for pollinators and its berries are a valuable food source for birds in winter.

In a temperate climate such as the UK's, an ivy covered wall will slightly warm a room in winter. As well as insulating, ivy cools a room in summer through shading and by water evaporation from its leaves. "It cools the surrounding air. It's like sweating," says Tijana Blanuša at the University of Reading, UK, who has examined the insulating effects of climbers. She and her colleagues found that *Hedera helix* ivy created a larger cooling effect than two other climbers, Boston ivy (*Parthenocissus tricuspidata*) and climbing hydrangea (*Pileostegia viburnoides*).

This is probably because its leaf cover is so dense, says Blanuša. *Hedera helix*'s exact cooling effect is hard to quantify as it depends on so many factors, but it could be by a few degrees, she says.

CERI BREEZE/ALAMY

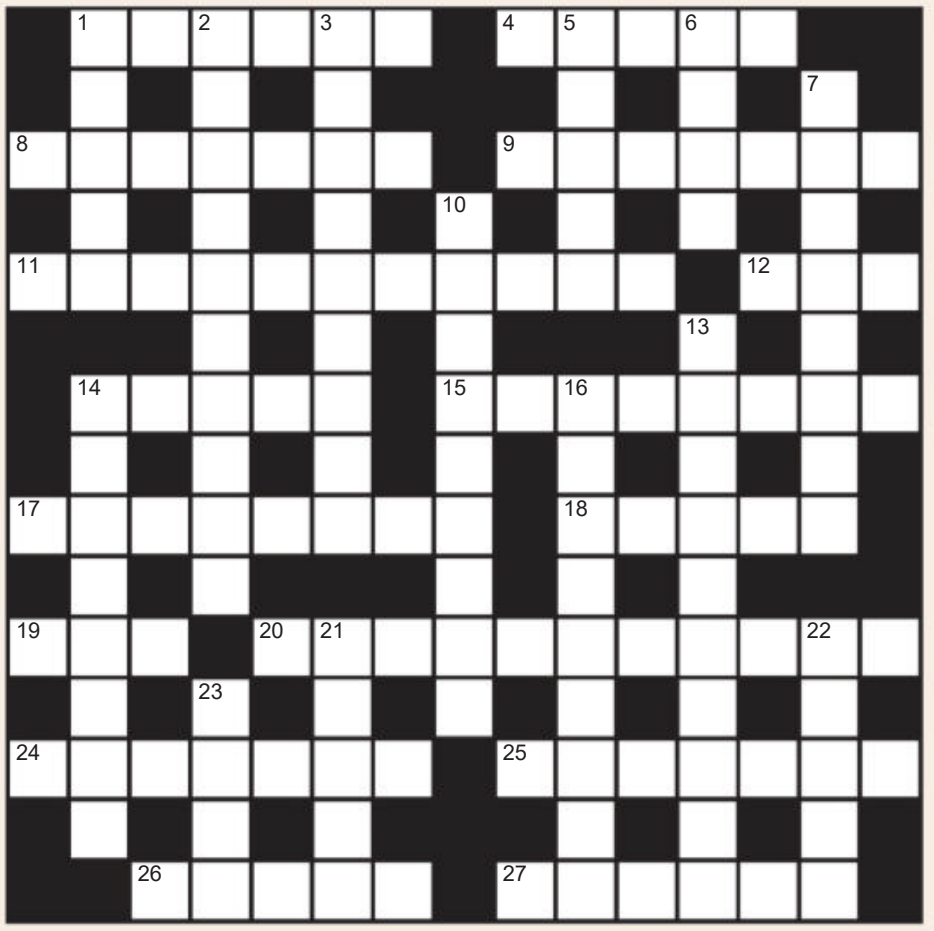
Ivy has a reputation for damaging buildings, but according to the UK's Royal Horticultural Society, this doesn't usually happen unless they already have cracks – the aerial roots can't penetrate sound masonry. The other fear is that it can make walls damp, but Blanuša's study found that ivy raised humidity next to the wall by only a small amount. You do need to be careful, though, as once ivy has been in the ground for a few years, it can grow like billy-o. In some parts of the US and Australia, certain kinds of ivy are classed as invasive weeds.

I can empathise, having had a few battles with ivy plants that I let get out of control. If it reaches the roof, it can get under tiles and block gutters. So don't plan on covering a wall with ivy unless you are willing to get up a ladder twice a year to cut off any shoots that are approaching danger zones. One option is to paint vulnerable structures with anti-graffiti paint that contains a chemical called silane. This reduces attachment of the plant's aerial roots.

Because of ivy's vigorous nature, I also wouldn't recommend planting it in a flower bed with the intention of covering a fence or shed, as you will be forever pulling out shoots trying to take over the patch. Instead, you could use a large pot or confine it to a small patch with a few bricks – I took some from my patio. You just have to keep the upper hand. ▮

Maker projects are posted each week at newscientist.com/maker

Quick crossword #67 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1/4 2006 BBC wildlife documentary series (6,5)
8 Flower – of cherry or apple, perhaps (7)
9 Waxy, strong-smelling substance, $C_{10}H_{16}O$ (7)
11 Fear of water; rabies (11)
12 See 14 Down
14 Part; segment (5)
15 Circling a planet or star, for example (8)
17 Safety signal; medical diagnosis (3-5)
18 See 10 Down
19 Fall of a tide (3)
20 Domestic messaging machine (11)
24 Largest continental land mass on 1 across/4 Across (7)
25 Organic compound with a –C≡N functional group (7)
26 Emulsion produced by some trees, used to make rubber (5)
27 Thomas ___, "The Wizard of Menlo Park" (6)

DOWN

1 William ___, 18th-century philosopher noted for the watchmaker analogy (5)
2 Ability to soak up (10)
3 Global sum of ecological systems (9)
5 Video game developer founded in the US in 1972 (5)
6 Magnetic recording medium (4)
7 Contained in a chrysalis, perhaps (8)
10/18 *Tomorrow's* ___, long-running BBC science programme (9,5)
13 Maps of the night sky (4,6)
14/12 Carl Sagan's famous description of 1 Across/4 Across (4,4,3)
16 Member of the family Ptilonorhynchidae, noted for elaborate courtship displays (9)
21 Unwanted sounds or signals (5)
22 Synthetic polymer first used commercially in 1938 (5)
23 Hypothesis of 1 Across/4 Across devised by James Lovelock (4)

Quick quiz #70

1 The first test of a UK atomic bomb took place in which country?

2 What is made using the Haber-Bosch process?

3 How many qubits did Google's Sycamore computer use to achieve quantum supremacy in 2019?

4 Latvian mathematician Daina Taimina is best known for using crochet models to visualise what concept?

5 Ménière's disease affects which part of the body?

Answers on page 55

Puzzle
set by Chris Maslanka

#78 Farewell My Blubbery

"The most interesting thing about Milly Farlowe's latest 'effort' in the detective fiction genre is the page numbering: it starts at 1 and goes up to some highest number, a number of itself quite modest, but far too high for a plot of such flimsy construction." Thus spake Zara Thrusta, the literary critic of the *Daily Grind*, dismissing her best friend's new crime novel, *Farewell My Blubbery*.

Well, I had a look at the numbering and it was just as Thrusta had said. But I noticed something else. If you reverse the order of the digits of the three-digit number at the bottom of the last page of this book, you get exactly the same number as the total number of digits used in numbering its pages. "Is it a long book?" I hear you ask. Well, you tell me: how many pages are there in *Farewell My Blubbery*?

Answer next week

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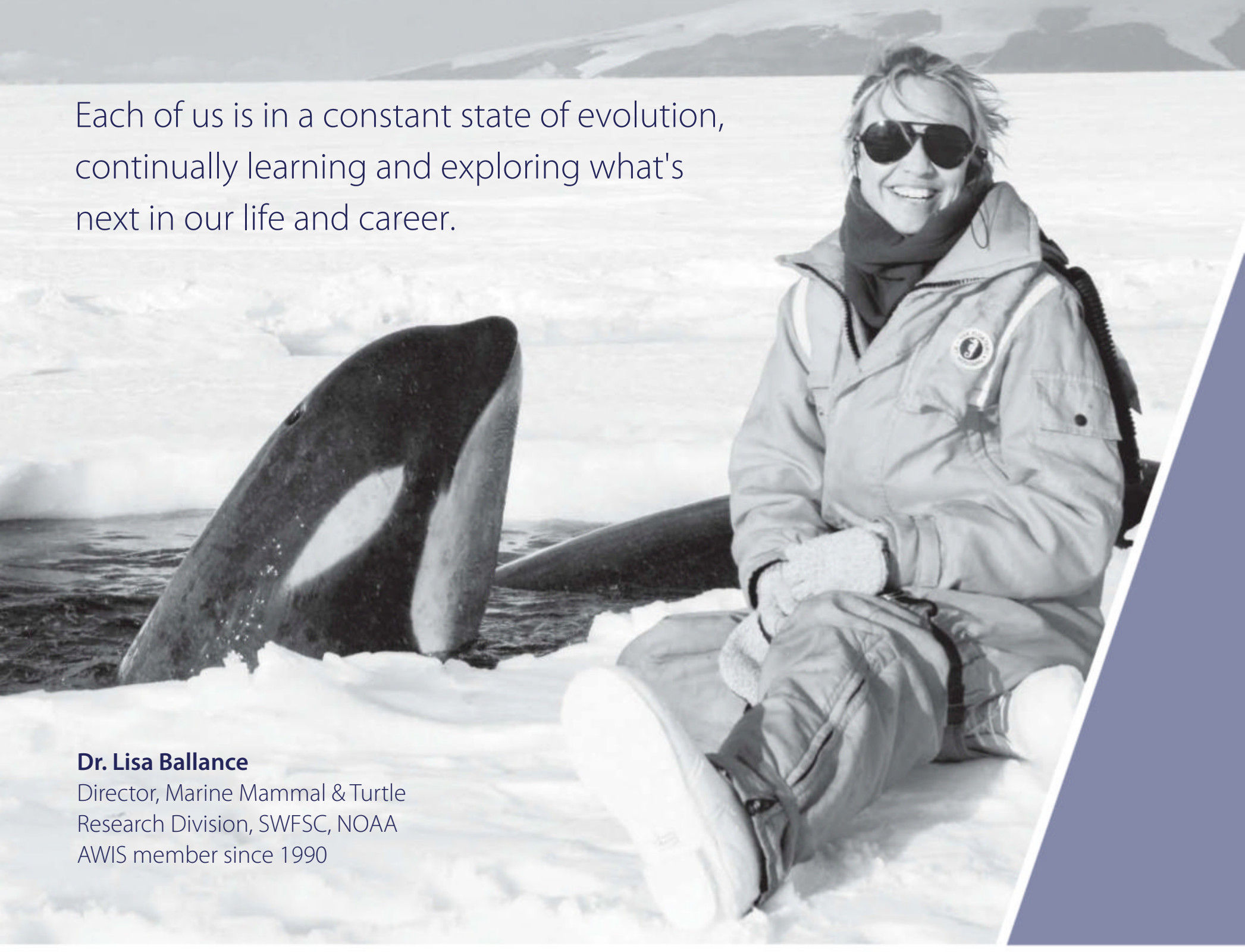

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Sundown

How did people in the Arctic in the distant past deal with no sun in winter and weak sun the rest of the year? Did food provide vitamin D?

Roger Williams
Lucerne, Switzerland
According to the US National Institutes of Health, 100 grams of salmon or trout provides enough daily vitamin D for adults of most ages. This wouldn't have been hard for a hunter-gatherer to find in Arctic Scandinavia, North America or Russia.

Guy Cox
School of medical sciences, University of Sydney, Australia
The major dietary source of vitamin D is oily fish, which was, and is, a staple food in northern latitudes (just try to separate a Swede from pickled herrings). So vitamin D deficiency wasn't a problem. In English slums, rickets caused by vitamin D deficiency was a major problem in the 19th and early 20th century. During

"Raw meat comes to the rescue: seal brain, uncooked caribou liver and muktuk, made from whale skin and blubber"

and after the second world war, the UK government issued cod liver oil to all children. Because of this, rickets didn't really exist at the time. But the oil tasted awful.

Mike Follows
Sutton Coldfield, West Midlands, UK
Most people get the bulk of the vitamin D they need from the action of sunlight on their skin. Ultraviolet light turns cholesterol in the skin into vitamin D.

However, many indigenous Arctic people have a dark complexion that acts as a natural sunscreen and makes getting vitamin D this way more difficult. While it is widely believed that they derive the vitamin D they need from their diet, which includes oily fish, the reality is that their vitamin D levels are lower than those of northern Europeans, yet their skeletons show no signs of rickets.

Vitamin D is biologically inert and is converted into its active form by a chemical reaction in the liver and kidneys. Even though a single exposure of UVB produces less vitamin D in darker-skinned people than in those with lighter skin, it appears that the former have adapted to be better at converting vitamin D into its active form. This may explain why nearly half of African Americans are classed as having a deficiency in vitamin D, yet they show fewer signs of the health impacts that would usually result from this.

David Muir
Edinburgh, UK
The traditional diet of Arctic coastal indigenous people, like the Inuit, is high in protein and fat from marine mammals and fish. Berries, roots and seaweed can supply carbohydrate, but so does fresh meat in the form of glycogen when the meat is eaten raw.

Vital vitamins and minerals are present in Inuit diets. More than adequate amounts of vitamins A and D are found in the livers and oils of cold-water fish and mammals, so the synthesis of vitamin D in the skin through exposure to the sun isn't vital.

As the richest natural sources of vitamin C are fruits and vegetables, you would think that getting enough of this might pose a problem for Arctic indigenous communities. Once again, the consumption of raw meat comes to the rescue: vitamin C is present in uncooked caribou liver, seal brain and muktuk, a traditional food of frozen whale skin and blubber. If these were cooked, the vitamin C would be destroyed.

ANN & STEVE TOON/NATUREPL.COM

How many rainbows can you get all at the same time?

This week's new questions

Rainbow riot **I have seen many double rainbows, but can you get triple or quadruple ones? If so, where are the best places to see them? What is the maximum number that could occur at the same time?** ***Carys Slack****, Barry, South Glamorgan, UK*

Shedding tears **What is the biological advantage of crying when emotional?** ***Gary Greene****, London, UK*

Cycle logic

A triplet bike is lighter and has less resistance per person, so is more efficient than a tandem, which is more efficient than a regular bike. Does this trend hold however long the bike? (continued)

Peter Mynors
London, UK
In 1962, I was one of five undergraduates who cycled from the UK to Greece – two of us on a tandem and three on a triplet bike.

On level roads and moderate uphill slopes, the triplet was noticeably more efficient than the tandem. On steeper hills, the main influence on progress was how soon one of the riders needed to pause for breath and that team had to stop.

Restarting either a tandem or triplet on a steep uphill section can be difficult, so we often continued pushing that bike all the way to the top. With a solo bike, you can more easily remount and ride on, which is one reason why tandems are often regarded as poor for climbing hills.

On the unsurfaced roads through Yugoslavia, the longer wheelbase of the triplet gave a generally more comfortable ride, at least for the middle rider.

With a well-matched team of riders on the triplet, we found it more efficient to have the pedals displaced by 60 degrees relative to the rider ahead, rather than the usual arrangement for tandems in which both riders' downstrokes occur simultaneously, as the 60 degrees setting provides constant power.

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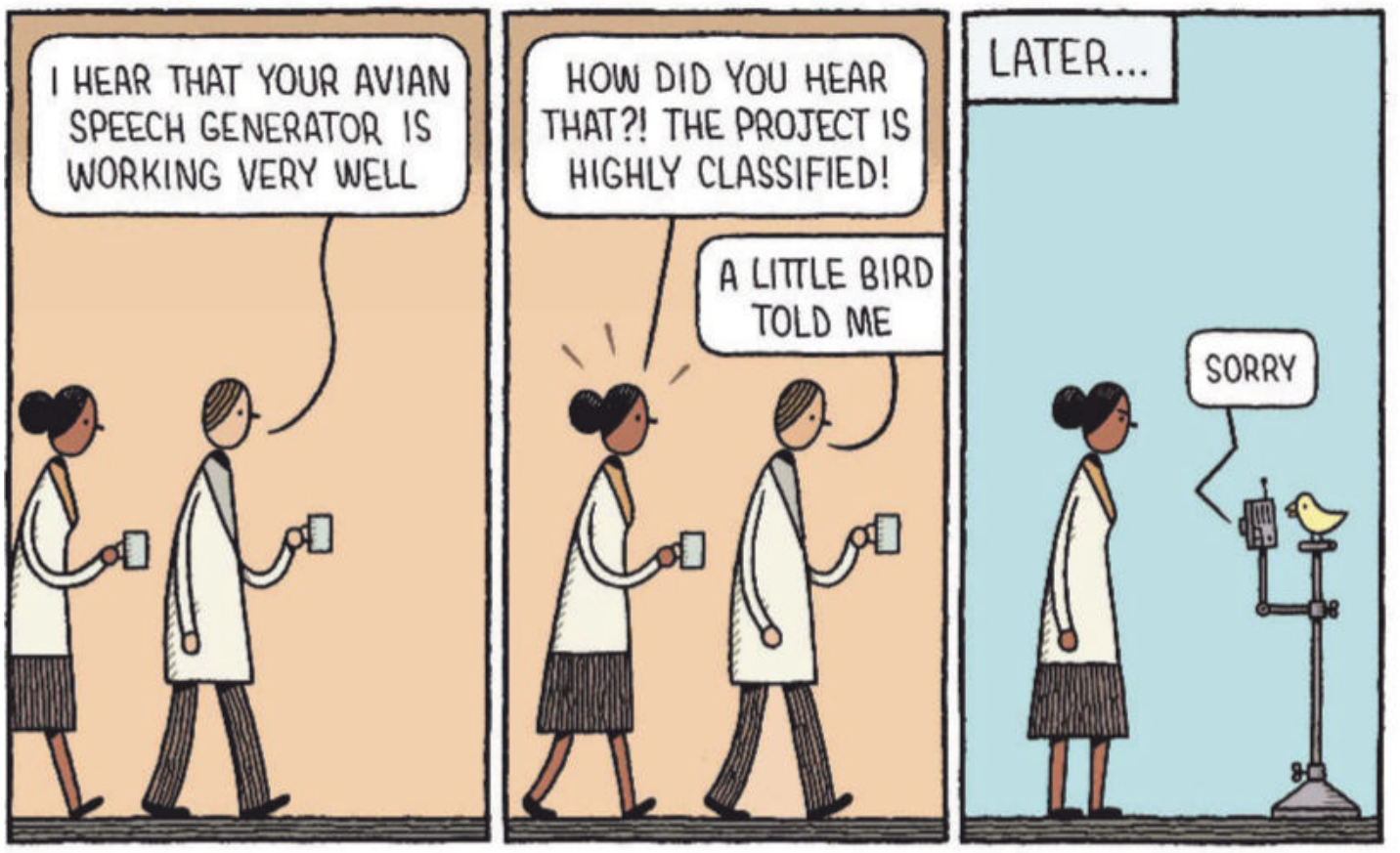


Matt Chamings
Barnstaple, Devon, UK
Steering is one problem associated with extending a bike for more than one person. Turning a bike involves leaning into the turn. With more weight shifting off the centre of balance, the person holding the handlebars would need enormous strength to stop the whole thing toppling over.

Adam Osen
Harlow, Essex, UK
The previous discussion on tandems focused mainly on the hardware. The software is important too. A few years ago, my daughter and I rode a tandem. When we got back, I remarked that it was surprisingly hard. She smiled. Apparently, I had been doing all the work, while she enjoyed the ride. On the other hand, when I rode up a hill with my son on the back, it was like having an electric motor. Perhaps an app that displayed the power being provided by each rider might help the efficiency gains of the tandem to be better realised.

"On steeper hills, the main influence on progress was how soon one of the riders needed to pause for breath"

Richard Ellam
Bristol, UK
The discussion about multi-person bicycles assumes that triplets are more efficient than tandems, which in turn are more efficient than solos. Practical experience suggests that this isn't always the case. The truth of the claim rests on the definition of "efficiency".

A tandem bicycle with its riders will be lighter than the same riders on two solo bikes and will have roughly the same air resistance as a solo. So, with about twice the power available, it can be ridden faster than either rider can comfortably pedal a solo when air resistance is dominant, for example on flattish roads and when riding into a headwind. But not when it comes to hill-climbing.

The ability to climb steep hills depends on the power-to-weight ratio of the bike and its rider or riders, not on the power-to-air resistance ratio, because most of the riders' efforts are devoted to increasing gravitational potential energy, not pushing the air aside.

The fact tandems climb poorly suggests that their actual power-to-weight ratio is less than that of good solo bikes. That is probably because of increased losses in the transmission due to the chainsets being coupled and difficulties in the riders synchronising their physiological efforts, despite being mechanically coupled.

My wife and I rode a tandem for several years. When riding with solo cyclists, it was common for the solos to pass us on climbs.

On the descent, we would catch up and overtake them in short order as we were much faster downhill. Even with very low gear settings, climbing our local hills, which we can do quite comfortably on our solo bikes, could be pretty purgatorial on the tandem. ▮

Answers

Quick quiz #70
Answers

1 Australia. It was detonated in a lagoon of the Montebello Islands, an archipelago off the country's west coast, on 3 October 1952

2 Ammonia

3 53. The chip's 54th qubit failed

4 Hyperbolic planes – surfaces where the space curves away from itself at every point

5 The ear

Cryptic Crossword #40
Answers

ACROSS **1** Peat, **3** Price war, **9** Algebra, **11** Testosterone, **13** Sirius, **15**/**10** Alfred Nobel, **17** Osteoporosis, **20** Oxeye, **21** Truffle, **22** Halloumi, **23** Pans

DOWN **1** Phantasm, **2** Aegis, **4** Reacts, **5** Control group, **6** Webinar, **7** Roll, **8** Absolute zero, **12** Odysseus, **14** Roswell, **16** Sputum, **18** Sofia, **19** Moth

#77 Sir Prancelot's archers
Solution

The eight archers at the turret must alternate odd/even, so the napping archer must be an odd number. The four evens at the turret add to 20, so the four odds, which must also sum to 20, can only be 1+3+7+9, meaning the napping archer is number 5.

There are two possible arrangements of these eight archers around the turret: 12389476 and 12983476 (clockwise or anticlockwise).

"Everybody has won, and all must have prizes." Feedback subscribes fully to the Dodo's verdict on the Caucus race in *Alice's Adventures in Wonderland*. Equally, however, some have won more than others, and they must have further prizes.

From this angle, we approach, gingerly, the scientific world's top looking-glass awards, the Ig Nobels. Now in their 30th year, the prizes for "achievements that first make people laugh, and then think" were announced last week in a ceremony all the more glittering for being held entirely in the pixels of the internet.

Feedback attended the virtual red carpet, slightly faded and bearing a couple of nasty stains (the carpet, that is).

Bite worse than bark

This year's acoustics prize was awarded for inducing a female Chinese alligator to bellow in an airtight chamber filled with helium-enriched air.

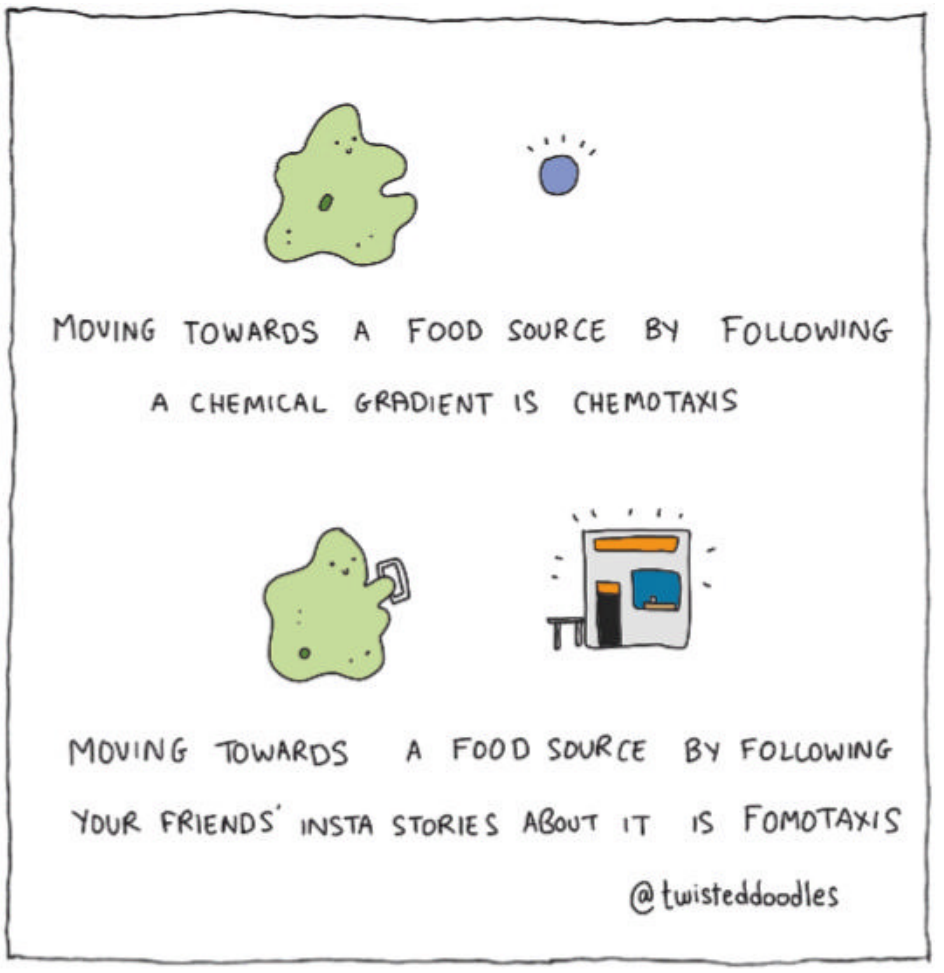
Crocodilians are among the most vocal non-avian reptiles, notes the team from Austria, Japan and an alligator farm in Florida, deftly sidestepping the scaly question of how one accurately defines a reptile (see page 49 for a full-frontal assault on that).

There remains, however, the delicate matter of what the loud bellows they produce, which are particularly frequent during the mating season, are for. Is their purpose – and we hesitate to say the word – *sexual* in any way?

By demonstrating the presence of "formant" frequencies created by the shape of the vocal tract, which are increased by breathing helium, the researchers suggest yes: the calls may advertise an appropriate body size to potential mates.

Feedback applauds the integrity of those behind the work, who return triumphantly with these new insights from the crocodilian interior. Simultaneously, we surreptitiously add an entry to "mating and dating strategies" in the relevant place in our extensive piling system.

Twisteddoodles *for New Scientist*



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Kiss 'n' tell

Speaking of which, the economics prize went to a group of researchers from Australia, Brazil, Chile, Colombia, France, Poland and the UK for trying to quantify the relationship between different countries' national income inequality and the average amount of mouth-to-mouth kissing.

They found that the two were locked in a passionate embrace: the higher a nation's Gini coefficient, a measure of economic inequality, the higher its self-reported kissing frequency. Team member Christopher Watkins was unsurprised by the result, as all sorts of research points to a committed partner being seen as more important when resources are tight. Nevertheless, certain facets of the work puzzle Feedback, such as the fervour with which the frigid but unequal British apparently kiss compared with the French, whose *égalité* seems to exceed both their *liberté* and their *fraternité*. All in all, though, we can only recommend the allaying of mutual economic insecurity as an excuse for anyone caught in flagrante.

Nails on board

The award for medicine went to a team at the University of Amsterdam in the Netherlands for adding a new term to the manual of psychiatric conditions: misophonia, or an impulsive and aggressive response to annoying sounds made by fellow humans. Team member Damiaan Denys was first moved to propose it after treating someone who became aggressive whenever she heard someone sneeze. "It was spring and I suffer from hay fever, so I was very tense during the diagnostic interview," he says.

A less extreme version of getting annoyed by annoying sounds, and the possibly annoying people who make them, is a human near-universal. So, at least, Feedback's banishment to the stationery cupboard would suggest. Denys and his colleagues have since developed a therapy programme that involves mixing annoying sounds with ones that evoke pleasant responses, which has a success rate in soothing frayed nerves of over 50 per cent. Our colleagues should please note.

The worm turned

What happens to an earthworm when you vibrate it at a very high frequency? The answer, according to the recipients of this year's physics prize, is that its entire body adopts a standing wave form known as a Faraday wave.

Ivan Maksymov and Andriy Pototsky at Swinburne University of Technology in Melbourne note that this happens because "it is plausible to consider the worm to be a liquid drop enclosed by a thin elastic skin".

Feedback applauds this significant step closer to that holy grail of physics, a model organism that actually conforms to equations. Move over, spherical cows in a vacuum.

The eyebrows have it

Finally, visibly moved by her success is Miranda Giacomin at MacEwan University in Edmonton, Canada. She and Nicholas Rule at the University of Toronto won the psychology award for devising a method to identify narcissists through their distinctive eyebrows.

The research was very data-driven, she explains: they looked for facial cues that seemed to predict narcissism and, "after systematically breaking down the components of the face, the data led us to the eyebrows", she says.

Feedback makes no comment, and merely raises one of our distinct, shapely and quite frankly glorious pair. More Ig Nobels the same time next year, possibly.

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