

New Scientist

WEEKLY October 31–November 6, 2020

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SAILING ON THE SOLAR WIND

HOW CORONAVIRUS WRECKED THE WORLD'S BEST HEALTH AGENCIES

THE WATER ON THE MOON

CORONAVIRUS

LONG COVID

Millions of us will be left with ongoing symptoms. Here's what we now know about the long-term effects



MORE VENUS DOUBTS

Is there really any phosphine in its atmosphere?

PLUS DINOSAUR GENITALS / CARLO ROVELLI ON WHITE HOLES / CRISPR V THE SUPERBUGS / POST-PANDEMIC ECONOMICS

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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 **Elephants Alive**



Science & Survival



For 25 years, Elephants Alive has been studying African elephants, to ensure their survival and to promote harmony with humans. We work in the Great Limpopo Transfrontier Area, monitoring elephant population dynamics and movements across South Africa, Zimbabwe and Mozambique.

We have deployed over 180 satellite collars to understand elephant movements and developed an individual elephant identification database of over 2000 elephants.

Our long-term research is providing vital information for conservation management, helping to secure the future of these trans-frontier, free-roaming elephants.

We are now urgently prioritising the small, fragmented populations of elephants remaining in southern Mozambique. There are three National Parks here, Zinave, Banhine and the Limpopo National Park (which borders South Africa's Kruger National Park) – with wildlife corridors linking these reserves. However, subsistence farmers living in the reserves or the

corridors linking them, are at risk of crop-raiding by the elephants. Where income is limited, poverty may drive some locals into illegal killing of elephants for both their meat and ivory. Our research is showing that where elephants feel persecuted, they become nocturnal and may crop-raid or run through corridors under the cover of darkness to try and avoid conflict with humans.

Elephants Alive is working hard to create safe corridors, linking these Protected Areas to increase elephant habitat. We believe that to ensure the safety of these free-ranging elephants, it is critical to empower, inform and involve the local impoverished communities. Therefore, Elephants Alive is developing bee-keeping and horticultural programmes with local women in South Africa as a proof of concept to be implemented in Mozambique. Growing crops that elephants are known to

dislike in conflict areas can provide valuable income to impoverished communities that have to share their land with elephants as these crops (garlic, onions, lemon grass, chilli, sunflowers and ginger) can be sold for income. Elephants are known to be scared of bees, so bees can also be used to protect crops, increase pollination services and produce honey.

These women are being empowered to provide more effectively for their families and will be incentivised to co-exist with elephants. By recruiting "bee-lievers" living adjacent to Protected Areas, and uplifting women as social role models and community leaders, peaceful coexistence with elephants can be realised.

Please help support this urgent work to protect the elephants in Southern Mozambique and uplift the rural communities in these crucial wildlife corridor areas.

Want to help?

To make a donation see elephantsalive.org/support-us and follow us on Facebook for updates

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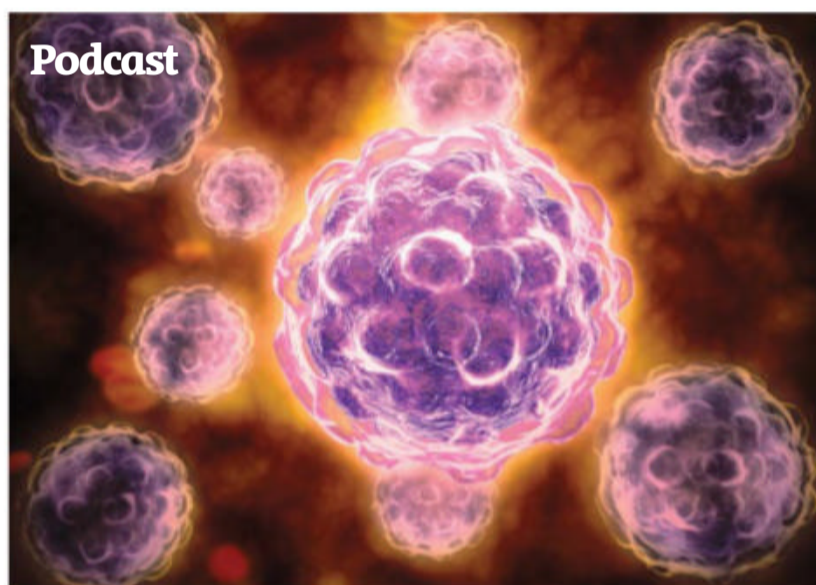
The day's coronavirus coverage updated at 6pm GMT with news, features and interviews.

[newscientist.com/coronavirus-latest](https://www.newscientist.com/coronavirus-latest)



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Newsletter

Space junk A near miss and the danger of debris in near-Earth orbit



You may have seen adverts for this in the magazine, but if not, this is just to let you know about the launch of New Scientist Academy.

As of next month, we will offer online courses for people who want to deepen their understanding of science and technology. They are aimed at adults and older teens, but younger science enthusiasts may also get a great deal from them. The first two courses on offer will be about the biggest mysteries in the cosmos and the workings of the human brain. We have plans for many more across all our most popular subject areas.

So what will they involve and who will they be for? I'll use our cosmic mysteries course as an illustration. This programme is for people who want to understand more about the universe – such as what happened at the big bang or the nature of dark matter and dark energy – but feel they don't know enough to properly get to grips with the subject. They will be led through a mixture of specially created video lessons from top physicists, carefully curated reading and interactive segments that will allow them to check on their progress. By the end, we hope participants will feel more secure in their understanding and be ready to hold their own in discussions with others!

This is an entirely new venture at *New Scientist*, and it is one we are very excited about. A group of readers has been working with us to ensure that the courses we design are right for you: thank you so much to all who have helped so far. To register your interest for one of our courses – and to qualify for a special introductory rate – do visit [newscientist.com/courses](https://www.newscientist.com/courses)

Emily Wilson
New Scientist editor

Must ~~Nice to have~~ this holiday season

The coming year will see the fight against coronavirus continue, make-or-break international agreements on climate change and biodiversity, and nations continuing to vie for supremacy in space.

And that's just the stuff we know about.



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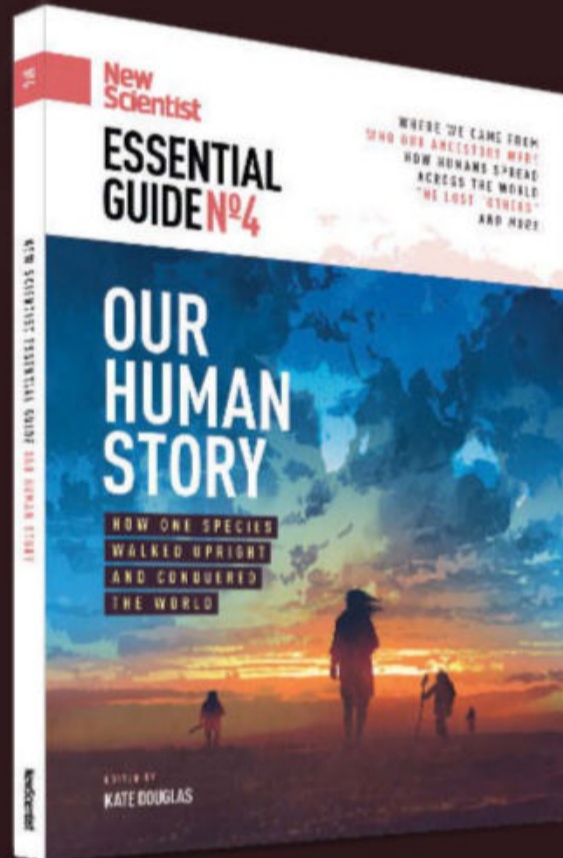
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The facts of life

Signs that phosphine may not exist on Venus show science is working as it should

LAST month, the world of planetary science blew up after the news that phosphine gas had been observed in Venus's atmosphere, which could potentially be a sign of life.

The team that spotted the phosphine, led by Jane Greaves at Cardiff University in the UK, couldn't find any mechanism for forming enough phosphine on Venus to account for these observations. On Earth, the gas is made by living organisms and industrial processes.

Now, though, that detection has been called into question. First, a look at old data by a group that included researchers who worked on the latest phosphine study found no hints of the gas. Then a re-analysis of Greaves and her team's observations by an independent group concluded that the measurements showed no signs

of phosphine (see page 18). According to the scientists behind the second study, the original analysis may have introduced false signals into the data.

While this may seem like a disappointment – the idea of life on Venus is tantalising, but if there

“The idea of life on Venus is tantalising, but if there is no phosphine, there is no reason to suspect life exists there”

is no phosphine, there is no reason to suspect life exists there – it is actually an indication that science is progressing just as it ought to.

An explosive claim – like that of a possible sign of life on a planet that seems crushingly inhospitable – must be evaluated through every

means possible. For now, with many observatories closed due to covid-19, that means combing through information that scientists have already collected on Venus in order to look for clues.

So far, none of the observations are conclusive either way. There will surely be more studies in the coming weeks and months, and while they may continue to conflict with one another, they will eventually converge on an explanation. That is simply how science works: we can make predictions, but we must continue to examine all possible evidence until there is an answer.

Perhaps that answer will come when the observatories reopen – or maybe we will have to wait to send a spacecraft to Venus and and take a closer look. ■

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CHRIS PUTNAM/SHUTTERSTOCK

Australia

Melbourne lockdown lifts

Residents in the Australian city are celebrating after their strict lockdown quashed the coronavirus, reports **Donna Lu**

CAR horns honked in the streets and declarations echoed that people could “get back on the beers”, as residents of Melbourne in the Australian state of Victoria celebrated a double milestone on 26 October.

After 111 days of lockdown – one of the longest and most stringent in the world – Daniel Andrews, the premier of Victoria, announced an easing of restrictions in the city as well as what some called a “double-doughnut day”: one with 0 new coronavirus cases and 0 deaths in the state.

“Now is the time to open up,” said Andrews at a press conference. From 11.59 pm on 27 October, bars, restaurants and retail shops in Melbourne reopened for the first time in more than three months.

The last time Victoria recorded

no new daily cases was on 9 June. A second wave of covid-19 in the state began in July, originating from Australians who had returned from abroad and were being held in hotel quarantine in Melbourne. Breaches caused the spread of the virus.

The state’s seven-day average for new daily cases reached a high of 533 on 5 August – a similar figure at the time to that of many European countries.

With the exception of Singapore, few other regions have managed to successfully suppress a second wave of the scale seen in Victoria. As case numbers soar in the UK, US and many European nations, are there any lessons to be learned

from this success story?

What is clear is that the results were hard won. A second state-wide lockdown was imposed when new cases exceeded 100 per day, and Victorians were legally required to wear face masks at all times outside the home, except while exercising.

Melbourne residents faced particularly stringent measures, including home confinement, a strictly enforced night-time curfew and a ban on travelling more than 5 kilometres away from their places of residence, except for essential work.

Victoria’s success has resulted from both clear government direction and

Federation Square in Melbourne during lockdown

high public compliance, says Stephen Duckett at the Grattan Institute, a public policy think tank based in Melbourne. “There was high-level observance of mask wearing, a high level of observance of not going outside. The streets were dead.”

The lockdown has taken a toll on mental health, employment rates and businesses. “There was

“There was acceptance that despite the costs, this was the right thing to do. We were in it together”

general community acceptance that despite those costs, this was the right thing to do,” says Duckett. “It’s been tough. We were all in it together.”

Public health policy is set by the state governments of Australia, most of which have pursued an elimination strategy in handling covid-19, even though this was generally viewed as an unrealistic goal at the outset of the pandemic.

Through a combination of border closures, lockdowns and extensive testing and contact tracing, a handful of jurisdictions have largely eliminated covid-19, including New Zealand and the Australian states of Tasmania and Western Australia.

The Australian borders were closed early in the pandemic, with entry banned to non-residents and non-citizens. Since the end of March, all returning citizens and residents have been required to quarantine for two weeks in hotels. Internal borders between certain Australian states have also been closed, with some interstate travellers also being required to complete hotel quarantine.

Andrews has warned of the risks of transmission indoors, and many restrictions still remain. Melbournians will probably support a cautious reopening, says Duckett. “We don’t want to go through this again. We know there’s been pain.” ■



Daily coronavirus news round-up

Online every weekday at 6pm GMT

newscientist.com/coronavirus-latest

Insight

US health agencies in disarray

The CDC and the FDA have lost public trust and the respect of scientists due to bad decisions and political meddling during the pandemic, reports **Chelsea Whyte**

AS THE US enters a third surge of coronavirus cases, the two agencies charged with shepherding it through the public health crisis have lost their biggest asset: trust. The impact could be catastrophic, with one expert warning that the country may be heading for a national security crisis.

“Both the FDA and the CDC rely on one common element, which is public trust and confidence,” says J. Stephen Morrison at the Center for Strategic and International Studies in Washington DC. “That is their essential asset that they have to treat as precious, and they have to guard it and sustain it through all sorts of twists and turns. As we’ve seen, that’s not very easy.”

The Food and Drug Administration (FDA) and the Centers for Disease Control and Prevention (CDC) are two arms of the US government focused on public health, both part of the Department of Health and Human Services (see “Vital roles”, right). Over the course of the coronavirus pandemic, a series of missteps by both agencies has resulted in a fractured approach to tackling the crisis. These missteps have come from within and have also been a result of political pressure and interference from the Trump administration.

A poll conducted in early September by the Kaiser Family Foundation, a non-profit organisation, found that since April, trust in the CDC among adults in the US has fallen by 16 percentage points, and about 40 per cent feel that the CDC and FDA are paying too much attention to politics when issuing guidelines and recommendations for coronavirus policy.

The problems started in the chaotic early weeks of the pandemic. “The CDC has alternated between being invisible



Protesters in the US call for safe and affordable vaccines

and actually not doing what they are charged with doing,” says Peter Hotez, co-director of the Texas Children’s Hospital Center for Vaccine Development in Houston. “They missed the entry of the virus from Europe into New York, so transmission went on undetected there for weeks.”

“The FDA created false hope and understanding in the public of potential treatments for covid-19”

Both agencies then made crucial mistakes with coronavirus test kits, which delayed mass testing. Rather than manufacture tests according to guidelines set by the World Health Organization (WHO) that other countries used, the CDC opted to devise its own test.

In January, the CDC sent its test kits to 26 labs for initial evaluation. Nearly all of them found problems

with false positives in the control portion of the test. This was later found to be due to contamination that occurred at the CDC.

By early February, the CDC had sent 200 functioning test kits, which can each analyse 700 to 800 samples, to about 100 labs around the country, distributing them evenly even though some areas had seen no cases and others, such as New York City, were already seeing spikes in hospitalisations.

Testing capabilities were also hampered by early FDA rules that prevented labs from producing test kits, so they had to rely on those from the CDC. The FDA eventually reversed this. Still, testing couldn’t keep up with the spread of covid-19. The disease had taken hold, and the FDA and CDC had lost valuable weeks.

As hospitals filled up, the search for treatments that could lessen the severity of the disease was on. This is the area where the FDA should work to limit the use of drugs and treatments that haven’t been proven as safe, effective or

appropriate. But politics got in the way. “The FDA bent to political pressure, and it created false hope and false understanding in the public of potential treatments,” says Morrison.

In a briefing on 19 March, President Donald Trump made the first of many mentions of the antimalarial drug hydroxychloroquine, suggesting that it should be tested as a treatment for covid-19. Days later, he tweeted that a combination of hydroxychloroquine and an antibiotic could be “one of the biggest game changers in the history of medicine. The FDA has moved mountains – Thank You!” He also said the pair of drugs should be put into use immediately.

Alarm bells rang among the scientific community, as there was no robust clinical evidence that this drug cocktail would limit the severity of covid-19 or help with symptoms. On 23 March, a man died after ingesting chloroquine phosphate – a parasite treatment

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for fish – that he and his wife took thinking it could protect them from the coronavirus.

But on 28 March, the FDA authorised hydroxychloroquine for emergency use to treat covid-19. “That emergency use authorisation was the FDA’s biggest mistake,” says Hotez. The agency revoked the authorisation in June after trials showed it had no benefit for treating covid-19.

Political pressure on the FDA has mounted further as the presidential election draws closer. On 15 September, Trump said in an interview with *Fox and Friends* that a vaccine could be ready in four or eight weeks, which would coincide with the election.

However, the FDA has been holding its ground on this front. “They have learned from some rookie mistakes and are now doing a really good job at holding the line and preventing the White House from exploiting the FDA for political expediency,” says Hotez.

In a webinar on 8 October, FDA commissioner Stephen Hahn spoke about the timeline and criteria for approving a vaccine. “Science will guide our decision, and I will not, and the FDA will not, allow pressure from anybody to change that,” he said.

Hahn has been backed up by the drug industry. Nine pharmaceutical companies that are developing potential vaccines recently signed a safety pledge that said they wouldn’t submit a vaccine for FDA approval until it has been shown to be safe and effective in large clinical trials.

The FDA has also brought in new rules for forthcoming vaccines, which require two months of data to ensure a vaccine is safe and effective. Trump has criticised the agency, tweeting on 6 October: “New FDA Rules make it more difficult for them to speed

up vaccines for approval before Election Day.”

An FDA spokesperson said in a written statement: “The agency will not authorise or approve any COVID-19 vaccine before it has met the Agency’s rigorous expectations for safety and effectiveness. Decisions to authorize or approve any COVID-19

54%
of people polled in the US would not get a coronavirus vaccine

vaccine or therapeutic will be made by the dedicated career staff at FDA through our thorough review processes, and science will guide any and all decisions.”

The CDC hasn’t held as firm. In May, the agency drafted guidelines for reopening schools, churches, public transport, restaurants and bars that included social distancing measures such as encouraging face coverings in churches, closing rows of seats on buses and trains, and separating schoolchildren into groups that don’t mix. The White House didn’t release those guidelines, and

subsequently nor did the CDC, leading instead to a patchwork of public health policies cobbled together by state governors.

Elsewhere, political pressure has led to a flip-flopping of CDC policies on whether asymptomatic people should be tested.

Before this year, the CDC was widely recognised as the gold standard of a high-quality public health agency. It was a repository of up-to-date information and statistics relied upon by doctors, researchers and public health officials, but that has changed.

“We couldn’t rely on CDC for our modelling,” says Hotez. “I basically gave up on CDC data about five or six weeks into the epidemic.” The CDC and White House didn’t respond to requests for comment.

Where does this leave things? Most urgently, the FDA and CDC will need to rebuild trust in order to effectively distribute a future vaccine. The pandemic has crashed headlong into a US anti-vaccine movement that has been gaining strength for years.

The Kaiser Family Foundation poll found that if a vaccine were approved before the US election

and given for free, 54 per cent of people wouldn’t get vaccinated.

“The question I get is, ‘Which vaccine are you going to wait for?’” says Hotez. “No one should wait. There should be a scientist from the CDC or FDA out there weekly explaining this to people.”

Efforts to rebuild trust cannot start soon enough, says Morrison. “The loss of trust is not just dangerous, it’s catastrophic.” He has participated in pandemic preparedness exercises in the past and says even experts who play out various scenarios don’t know how to account for the CDC and FDA losing public trust. “Pandemic war games don’t take that into account,” says Morrison. “We’re facing an uncontrolled pandemic, social instability, economic consequences and uncertainty around whether a large segment of the public will reject a vaccine. This is a national security matter.”

Digging out of this could simply mean increasing the transparency of these agencies’ work. The FDA is working to win back public trust over the approval process for coronavirus vaccines. For example, it opened up a meeting of the Vaccines and Related Biological Products Advisory Committee on 22 October to the public, instead of the usual closed-door policy.

Or it could require a full rewrite of these health agencies’ missions. That may depend, in part, on the outcome of the presidential election in November. If Trump isn’t re-elected, the heads of both the CDC and FDA may change, as they are appointed by the president. But if Trump stays in the White House, things could go on as they have. Such an outcome could have a devastating impact on a country that has already seen more than a quarter of a million deaths from covid-19. ■

Vital roles

The US Centers for Disease Control and Prevention (CDC) and Food and Drug Administration (FDA) are both arms of the US government.

The CDC plays many roles, including helping to detect, trace and monitor disease outbreaks. Scientists within the CDC, or funded by its grants, research infectious diseases, such as influenza, and non-infectious diseases, such as cancer and obesity. Public health experts at the CDC gather and share data,

including accurate disease burden statistics, and give suggestions for public health policy to stop the spread of disease.

The FDA plays a pivotal role in public health preparedness, by acting as a regulator for drugs, therapies, diagnostic tests and vaccines, as well as regulating food, cosmetics and tobacco products.

These two agencies are designed to work in concert to protect the health and well-being of people in the US.

Long covid

Symptoms that won't stop

We are finally getting a picture of how many people will have covid-19 symptoms for months, and why this happens, reports **Jessica Hamzelou**

THE argument for naturally obtained herd immunity as a solution to the coronavirus pandemic has made a return in recent weeks. But letting the virus spread among younger people, who are less likely to die from covid-19, could lead to devastating consequences. Estimates suggest that there could already be millions of people around the world living with “long covid” – what appears to be a debilitating syndrome that follows a coronavirus infection.

As personal stories of long-term problems accumulate, researchers and health bodies are learning more about what might cause these long-lasting symptoms, and how best to treat them.

Dismissed by doctors

“I’m not sure how I caught the virus,” says Heather-Elizabeth Brown, a 36-year-old corporate trainer in Michigan who has severe symptoms six months after her initial diagnosis. “I was social distancing, staying out of crowds and wearing a mask.”

Still, Brown became unwell at the start of April. After initially being dismissed by doctors, and testing negative for the coronavirus twice, Brown was admitted to hospital in mid-April, when she finally tested positive.

By then, she was feverish and struggling to breathe, and chest X-rays revealed signs of pneumonia. Within a couple of days of her hospitalisation, Brown was put on a ventilator and placed in a medically induced coma for a month, she says. During that time, she developed blood clots in her legs and her brain. “It’s a miracle I survived,” she says. She isn’t out of the woods yet.

There isn’t yet an official clinical definition of long covid, but a



growing number of people are reporting symptoms that can last for months. Prolonged chest pains, shortness of breath and fatigue are often mentioned. Some people experience lasting damage to their heart and lungs, and blood clots that can cause painful swelling or strokes.

“Everyone has fatigue and headache – that’s virtually universal,” says Tim Spector at King’s College London.

“People are getting rashes, fevers, hair loss, pins and needles, muscle pains, diarrhoea”

He has been analysing the symptoms reported through the Covid Symptom Study app, which has more than 4 million users – including people who are healthy and have yet to test positive for covid-19 – based in the UK, US and Sweden.

Shortness of breath and loss of smell and taste are also among the most commonly seen long-term symptoms among the app users, although many others have been reported. “People are getting rashes, fevers, hair loss, pins and needles, muscle pains, diarrhoea... everything on our list,” says Spector.

Shortness of breath is one of the common symptoms of long covid

Brown still gets debilitating fatigue and shortness of breath, struggling to talk for more than 20 minutes or walk up a flight of stairs. She has also started to experience “brain fog”. “I’ve always had a phenomenal memory, but sometimes I forget things... there’s a certain word that I just can’t seem to find,” she says. “It’s really frustrating.”

She has been hospitalised twice for complications related to her blood clots. She has had physical

and speech therapy and mental-health support, and says she is taking 15 different medications to manage her covid-19 symptoms and their complications.

The symptoms can temporarily resolve before making a return, and can develop in people whose initial disease was mild, as well as in people recovering from more severe cases of covid-19. Because there is such a wide range of symptoms, it isn't yet clear if long covid is a single syndrome or many conditions (see "Could long covid be several syndromes?", page 12).

A couple of recent reports by the US Centers for Disease Control and Prevention (CDC) suggest that some adults develop a multisystem inflammatory syndrome, for example. This rare outcome of covid-19 has already been observed in children. Not all of the adults who develop this syndrome had pre-existing health conditions, and many go on to test negative for covid-19 before they develop symptoms.

"There are the symptoms of not feeling well and not being able to do things, and then there's the organ damage... a scan shows cardiac inflammation or lung damage, for example," says Nisreen Alwan at the University of Southampton, UK, who still has symptoms herself months after the onset of covid-19. "Sometimes these are happening in the same people, and sometimes they're not. There's a wide range."

Betty Raman at the University of Oxford and her colleagues have examined 58 people with moderate or severe covid-19. MRI scans revealed tissue abnormalities in the lungs of 60 per cent of these people, in the kidneys of 29 per cent, in the hearts of 26 per cent and in the livers of 10 per cent. Persistent

breathlessness was a feature for 64 per cent of people, and 55 per cent had significant fatigue (medRxiv, doi.org/ffjz).

Millions of cases

Although we don't yet know how many people are affected by long covid, a handful of studies suggest that it could be common among those who contract covid-19.

One study in Italy found that, of 143 people who had been hospitalised with covid-19, only 12 per cent reported no symptoms 60 days after the onset of the disease. More than half of the participants were still experiencing fatigue at that point, and many reported shortness of breath and chest and muscle pains (*JAMA*, doi.org/gg4hvp).

A similar study in France also found that most people who had been hospitalised with covid-19 still felt effects months later. Some 110 days after the onset of their first symptoms, 55 per cent of a group of 120 individuals had fatigue. Around a third were also reporting memory loss (*Journal of Infection*, doi.org/ghdhzf).

These figures align with other post-viral syndromes. About 80 per cent of people who recover from Ebola are left with problems a year later, for example, says Janet Scott at the University of Glasgow, UK. "They have muscle aches and pains, ocular problems, headaches and a long list of other symptoms."

One long-term study of people who were hospitalised with SARS following the 2003 outbreak found that about 40 per cent said they still experienced chronic fatigue almost four years after hospital discharge (*JAMA Internal Medicine*, doi.org/c7xcvp).

Most studies conducted so far have focused on people who were

88%

Proportion of people hospitalised with covid-19 in an Italian study who still had symptoms after two months

55%

Proportion of people in a French study who reported fatigue 110 days after being hospitalised with covid-19

5%

Estimated amount of people who will have symptoms two months after the onset of covid-19

A woman receiving treatment at the Covid Recovery Ward at Royal Papworth Hospital, UK



NEIL HALL/POOL VIA REUTERS

hospitalised with covid-19, largely because these individuals would have had a test result confirming they had the virus, and would be easier to recruit for research. As a result, we still don't know much about how long covid might develop after a milder infection.

A July report by the CDC found that about one-fifth of those who test positive for the coronavirus still have symptoms two to three weeks later. Spector and his colleagues running the Covid Symptom Study app have been looking at longer-term outcomes.

They have found about 4000 people who have logged symptoms for more than a month – some of whom have had symptoms for two or three months so far. These individuals were healthy when they first started using the app, and all went on to develop symptoms and get a positive test result for the coronavirus, says Spector. Not all of them received hospital treatment.

"That has given us these rough estimates that 1 in 10 [still have symptoms] at one month," says Spector. Information collected from app users also suggests that 1 in 20 people will have symptoms two months after the onset of illness, and 1 in 50 will have symptoms three months later.

The UK government reports that, as of 25 October, 873,800 had tested positive for the coronavirus, and 58,164 had died. It is possible that at least 75,000 people who contracted covid-19 will still have symptoms a month later, and more than 14,000 will have symptoms three months after their initial infection in the UK alone. Of the 37.8 million confirmed global cases, we might expect at least 3.8 million people to have experienced long covid symptoms already. ➤

It is impossible to know for sure, because the Covid Symptom Study app data comes from people in countries that weren't testing all those with symptoms during the first wave of infections in March. There is no way of knowing how many people who weren't hospitalised had the virus. And people were reporting their symptoms through lockdown and furlough, both of which can exacerbate health issues, says Louise Sigfrid at the University of Oxford.

There are other issues with the app data, too. Users are asked to enter information every day about how they are feeling, and select items from a drop-down menu of

20 symptoms. Spector says most users don't do this daily. Some with long covid say they get bored of listing the same symptoms for weeks or months. Others say they don't bother typing in their symptoms if they aren't already included on the app's list. Spector's team is currently working to extend the list.

We don't know whether people who originally had asymptomatic infections might later develop lasting symptoms, but at least one report suggests that this might happen.

When Valentina Puntmann at University Hospital Frankfurt in Germany and her colleagues assessed heart inflammation in

100 people who had recently recovered from acute covid-19, they found that 78 individuals showed signs of heart inflammation and damage, including those who had only mild symptoms (*JAMA Cardiology*, doi.org/gg8n87).

An MRI scan of one man's heart, for example, showed "severe abnormalities" 67 days after his official diagnosis, despite the fact that he had only experienced a loss of smell and taste and a mild fever for two days.

Who is at risk?

"We're not sure what the longer-term implications of that inflammation will be," says Jennifer Ross at the University of Washington in Seattle.

We also don't yet know who is at risk of developing long covid. The studies that have focused on people who were hospitalised with covid-19 suggest that lasting symptoms are more common in those who had a more severe initial illness, particularly those who required treatment in an intensive care unit.

But there are many anecdotal reports of people who recovered well from severe disease, and others who developed lasting illness after much milder cases.

"Whether you get long covid may be due to pre-existing conditions, lifestyle influences or genetics"

"There's a lot of individual variation," says Louise Wain at the University of Leicester, UK, who is co-leading a study into the long-term health outcomes of people hospitalised with covid-19. "It could be due to pre-existing conditions they had or the influence of their lifestyle, it could

Could long covid be several syndromes?

Breathlessness, pain, fatigue, "brain fog", blood clots, organ damage – the list of symptoms and complications ascribed to "long covid" is lengthy, varied and growing. Could the condition, which seems to develop after a case of covid-19, actually be many different syndromes?

That is the suggestion raised by researchers at the UK National Institute for Health Research (NIHR). After reviewing published evidence, and interviewing 14 people with long covid, the team found that "the symptoms described may be due to a number of different syndromes".

Some of those who become hospitalised with covid-19 end up requiring treatment in intensive care units (ICU). These individuals may need ventilation to help them breathe, for example. A stay in ICU for any condition can lead to post-intensive care syndrome, which is a collection of symptoms

that result from prolonged bed rest and invasive medical procedures. Symptoms include muscle weakness, cognitive dysfunction that might resemble "brain fog" and signs of anxiety, depression and post-traumatic stress disorder.

Others might develop a syndrome closer to post-viral fatigue, which has also been observed in people recovering from many other viral infections, such as Epstein-Barr virus, which is responsible for glandular fever or mononucleosis.

People who show signs of organ damage could still be recovering from their initial covid-19 infection.

And long covid might represent another, separate syndrome. It is also possible that some people might have more than one syndrome at the same time. Until we know more about long covid, it is difficult to say for sure, say the authors of the NIHR study.



REUTERS/NACHO DOCE

be related to the treatment they had, or it could be related to their genetics," she says.

Information from the Covid Symptom Study app suggests that long covid can occur in anyone over the age of 18, says Spector. His team has noticed that lasting symptoms seem to be more likely to affect older individuals, but long covid can also affect young, healthy people.

"We see a lot of reports of people who used to be very physically active reporting it," says Alwan. We don't yet know if there is a reason for this, or whether young people who are less likely to develop severe cases of acute covid-19 are more prone to long covid. "It could be that older people are more likely to have died," says Scott.

It is also possible that younger,



A man who recovered from covid-19 in physical therapy in Spain

healthier people notice their symptoms more because “they really can’t do any of the stuff they used to be able to do”, says Alwan. “But we still really don’t know at all who’s vulnerable.”

Inadvertent damage

The causes of long covid remain a mystery, but several hypotheses are being put to the test. “I think of it in two ways,” says Wain. “There’s the direct damage that the virus can do, and then there’s the inadvertent damage that the body can do when it responds to the virus,” she says. “It’s possibly a combination of those two.”

Prolonged shortness of breath and chest pains could be the result of lung or heart damage, for example.

1 in 3

Proportion of people hospitalised with covid-19 in one study who reported memory loss 110 days after first onset of symptoms

3.8m

People who may already have had symptoms of long covid

It is possible that the virus could hide away in some body tissues, causing a “grumbling” immune reaction that continually reactivates, says Spector.

“Some parts of the body are protected from most of our immune system,” says Scott. The central nervous system, eyes and prostate could all provide a safe haven for the virus to survive in the body, for example.

Scott, Sigfrid and their colleagues are one of several teams that are starting to look for signs of this immune response in blood samples taken from people who are recovering from covid-19. So far, their ISARIC study has recruited more than 100,000 participants from 42 countries.

The team will look for immune cells, antibodies and other markers of inflammation, and see how their levels change over time. Sigfrid hopes that blood tests for such things might eventually help identify people who are at risk of developing long covid.

In the meantime, there is plenty that can be done to support people who already have long covid. For a start, doctors and health professionals need to recognise that the condition is real, and not just “in a person’s head”, which is a common complaint from people who have long covid, says Alwan.

To that end, England’s National Institute of Health and Care Excellence, along with a Scottish health body and a group that represents family doctors, is working on a definition of long covid and guidelines on how to identify and treat the various symptoms. “I hope they come up with something broad,” says Alwan. “You need a case definition for it to be measured and for it to be recognised, but it needs to be able to evolve with time. It’s really tricky.”

The definition shouldn’t be based on having had a positive covid-19 test result, says Alwan. Many people who have long covid won’t have been tested during their acute coronavirus infection, or may have received an incorrect result. And antibody tests don’t definitively clarify whether a person has had the coronavirus in the past.

The National Health Service in England has also launched a website offering advice on how to manage various symptoms,

“There’s potential for harm even in folks who don’t have an initially severe infection”

and plans to set up treatment centres that address the multiple symptoms of long covid.

At the same time, employers need to be made aware of the impact of long covid, says Sigfrid. Brown feels lucky that her employer was understanding and supportive. As a corporate trainer, much of her work involves talking, which she still finds difficult to do for an extended period of time. Her employer has enabled her to adapt her training to make it easier to carry on doing, and understands when she needs time to rest.

Alwan has found that getting enough rest has helped her. “I’ve learned not to push myself as hard as I used to,” she says.

Ross hopes that our growing understanding of long covid will put another nail in the coffin of the idea that infection-induced herd immunity is the way out of this pandemic. “There’s potential for harm even in folks who don’t have an initially severe infection,” she says. “It’s a cautionary message to all of us to do what we can to prevent infection.” ■

Space

NASA confirms there is usable water on the moon

Loyal Liverpool

WATER may be more abundant on the moon than previously thought, which could be excellent news for future astronauts.

Paul Hayne at the University of Colorado, Boulder, and his team used images and temperature readings from NASA's Lunar Reconnaissance Orbiter to map cold, permanently shadowed regions on the moon. These are thought to be the places most likely to contain ice due to their lack of exposure to sunlight.

While there is lots of evidence for the presence of water on the moon, such "cold traps" were previously thought to be restricted to large, deep craters. However, the team found that there are also micro cold traps: areas at the metre and millimetre scale that are permanently shadowed and so could contain more

40,000

Total area of lunar surface in square kilometres where water might exist

accessible ice. Altogether, the researchers estimate that cold traps occupy about 40,000 square kilometres, or roughly 0.1 per cent of the moon's surface (*Nature Astronomy*, doi.org/ffw8).

A separate study has confirmed the presence of water ice (H₂O) rather than hydroxyl (OH).

Casey Honniball at NASA's Goddard Space Flight Center in Maryland and her colleagues used the agency's SOFIA telescope – which is mounted on a plane to get a clearer view through Earth's atmosphere – to spot a spectral signature that is unique to water (*Nature Astronomy*, doi.org/ffw9).

"Water is central to human life, but is expensive to launch into space," says Honniball. "Finding water on the moon may mean we can utilise the water that is there." ■

Analysis Purdue Pharma

Record payout won't fix the US opioid crisis Millions of people in the US are addicted to opioids and an \$8.3 billion legal settlement can't turn back the clock, says Clare Wilson



Lawyers and protesters outside a court hearing for Purdue Pharma

who died of overdoses as well as by state and national agencies seeking to recoup the public health costs of the epidemic, such as funding for addiction treatment and overdose response teams.

But this latest record-breaking settlement may never be paid in full, as Purdue filed for bankruptcy last year. The US Centers for Disease Control and Prevention has estimated that opioid misuse costs the country nearly \$80 billion a year. "That \$8.3 billion doesn't really make a dent in the problem," says Joseph D'Orazio at Temple University in Pennsylvania.

Opioid prescriptions in the US have been declining since about 2012, when their addiction potential became more recognised, although they still haven't returned to the lower levels of the 1990s. Social distancing due to the coronavirus pandemic may make matters worse, as many areas have loosened rules that say doctors must see patients face to face before prescribing opioids.

While clampdowns on prescribing can lower the number of new people who become dependent, some are already stuck on prescription opioids to manage their chronic pain.

"We have millions of patients who were put on opioids for conditions where we would never use them today, like back pain and headache," says Kolodny. "Many of these patients may now never be able to come off."

There are also people who have moved on to illegal opioids. "We are now typically seeing people dying from fentanyl overdoses in their 40s and 50s who first started [on prescription opioids] in their late teens and 20s," says D'Orazio. ■

A LONG-RUNNING lawsuit against a pharmaceutical company accused of fuelling the US opioid addiction crisis was settled last week when Purdue Pharma agreed to pay out \$8.3 billion, the largest ever such settlement. The firm admitted to violating anti-kickback laws, conspiring to defraud the US and facilitating the dispensing of medication without a legitimate medical purpose.

While the size of the payout may sound like a big win, it won't reverse the US's opioid dependency problems, nor is it likely to be a sufficient deterrent to similar behaviour by drug firms in future, say critics. No individuals from the company and none of the Sackler family owners have been convicted as part of the settlement, but a criminal investigation into individuals is ongoing.

"Criminal charges against corporations don't work. They're seen by companies as the cost of doing business," says Andrew Kolodny at Brandeis University in Massachusetts.

Doctors used to be wary of giving opioids, the most potent class of painkillers, reserving them

for severe short-lasting pain like that from surgery, or for people with terminal cancer.

In the 1990s, US doctors started prescribing them more liberally, spurred in part by Purdue's marketing of a new opioid OxyContin, which the firm claimed rarely caused dependence. The firm promoted the product heavily to some doctors with free trips and paid speaking engagements.

But OxyContin can lead to addiction, and some users sought increasing doses. Over time, some

"Criminal charges don't work. Companies see them as the cost of doing business"

people switched to using illegally bought pills or injecting heroin.

Deaths caused by opioid overdoses climbed from about 9000 a year in 2000 to 47,000 a year in 2017, although such fatalities may now be plateauing. The astonishing number of fatal drug overdoses may have even lowered life expectancy in the US.

Purdue has been pursued in the courts by families of those

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CRISPR

GM bacteria vs superbugs

Bacteria armed with gene-edited weapons could kill antibiotic-resistant microbes

Michael Le Page

BACTERIA engineered to carry a weapon that infects other microbes during the bacterial equivalent of sex could help us kill off dangerous, antibiotic-resistant superbugs – if regulators approve their use. While the approach has huge promise, its reliance on genetically engineered bacteria is likely to be controversial.

“We would be releasing genetically modified killing machines into the environment. What could go wrong?” says David Edgell at Western University in Ontario, Canada.

There are two main problems with conventional antibiotic drugs. First, they often kill beneficial bacteria along with dangerous ones and disrupt microbiomes. This is why a dose of antibiotics can lead to diarrhoea. Second, many bacteria are becoming resistant to the drugs, including those considered one of the last lines of defence.

In theory, the CRISPR gene-editing technique can solve both problems. It can be adapted to kill dangerous bacteria by targeting specific DNA sequences, while

leaving bacteria that lack these sequences unharmed.

The biggest challenge is getting DNA coding for the necessary CRISPR machinery inside bacterial cells. One way to do this is to exploit the bacterial equivalent of sex, a process called conjugation during which two bacteria link up via a narrow tube and transfer circular pieces of DNA known as plasmids. Antibiotic resistance often spreads on plasmids.

Guillaume Launay at the University of Lyon, France, and his colleagues created a plasmid coding for the CRISPR machinery needed to target the genes for resistance to carbapenem, an antibiotic. They then added this targeted antibacterial plasmid to a strain of *E. coli* bacteria.

Finally, they mixed the engineered *E. coli* with other bacteria, including some that were resistant to carbapenem. As they hoped, the drug-resistant bacteria were eliminated from the mix (bioRxiv, doi.org/ffwg).

This approach could be used to prevent infections by antibiotic-resistant superbugs, as well as to

treat them. “It could serve as a preventive means to reduce the amount of resistant bacteria in the gut, for example,” says Matti Jalasvuori at the University of Jyväskylä in Finland.

Edgell’s team has used a similar approach to kill the salmonella bacterium that causes food poisoning. It could also enable the microbiomes in our guts and on our skin to be tweaked in

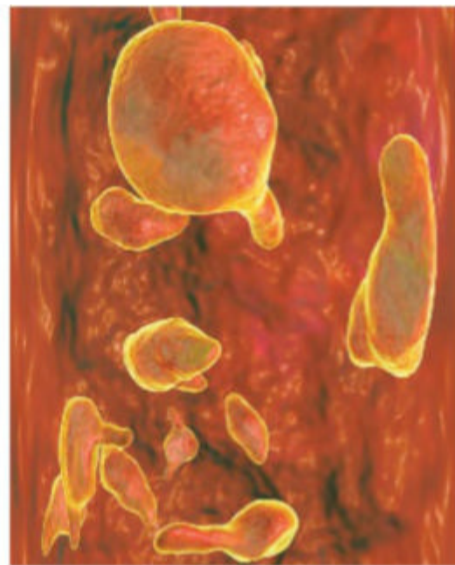
beneficial ways, he says, such as by eliminating species associated with acne.

However, it is possible that regulators may not approve such treatments unless the bacteria carrying the CRISPR plasmids, or the plasmids themselves, can be prevented from spreading in the wider environment.

The bacteria initially equipped with CRISPR plasmids are unlikely to become a permanent part of microbiomes, says Edgell. But the plasmids they carry will be passed to non-target bacteria as well as target ones and could persist indefinitely. That could be regarded as a good thing because they will continue to kill the target bacteria as long as they are present.

Nevertheless, Edgell’s team is working on various containment methods, such as creating plasmids that self-destruct if they are in an environment below human body temperature. “Public and regulatory approval will be critical,” he says. “I think it is inevitable that modified bacteria will be used in clinical or therapeutic settings.” ■

A depiction of *Mycoplasma genitalium*, a microbe with growing antibiotic resistance



KATERYNA KONVICHENKO/SCIENCE PHOTO LIBRARY

Mathematics

The quickest route has been found to visit 2 million stars

THE travelling salesman problem, an infamous mathematical puzzle that seeks the shortest route between many locations by visiting each only once and returning to the first, has been solved on the largest scale yet: the galaxy.

The problem seems simple, but it is notoriously difficult. It can be solved for certain data sets, but an algorithm to solve any instance of the problem hasn’t yet been found.

William Cook at the University of Waterloo in Canada and Keld Helsgaun at Roskilde University in Denmark analysed data from the Gaia space telescope, which measured the locations of 2,079,471 stars in our galaxy in its first data release.

The most efficient route that visits each of them is about 94,208,157.5 light years long, the pair found. They plotted this path on a 3D map. If there is a shorter route, they calculated it cannot be off by more than a factor of 0.0000074 – about 700 light years.

“This would be the fastest way

to visit every measured star in the galaxy, but you’d need your warp engine,” says Cook. At the speed of light, it would take nearly 100 million years to make this journey.

The methods Cook and Helsgaun used can also be applied to other data, such as flight scheduling and genome mapping.

“The larger a problem you can solve, the closer you can come to reality, to modelling the actual

“It is the fastest way to visit every measured star in the galaxy, but you’d need your warp engine”

world,” says Cook. Gaia has now released data on the locations of more than 1 billion stars, and the researchers are working on finding the fastest route between them.

This solution took about 200 years of computing time over two years, says Cook. In the future, quantum computers could speed up that optimisation process.

For now, though, quantum computers aren’t capable of such a large problem, so Cook is offering a monetary reward for anyone who can improve on his route between the stars. ■

Leah Crane

Dinosaur's fossil cloaca hints at mating habits

Michael Le Page

A FOSSIL dinosaur originally discovered in north-west China is so exquisitely preserved that the shape of its cloaca – the opening used for excretion and mating – is visible for the first time.

The evidence has actually been in plain sight. The *psittacosaurus* – a kind of early ceratopsian related to triceratops that lived around 120 million years ago – has been on public display at the Senckenberg Museum of Natural History in Frankfurt, Germany, for over a decade and several scientific papers have already been written about its primitive feathers and colouring.

Only now, though, has a team led by Phil Bell at the University of New England in Australia formally described the cloaca. Bell declined to discuss the finding until it appears in a peer-reviewed journal.

Birds and reptiles have a cloaca – a single orifice used for excretion, urination, mating and laying eggs – so it has always been assumed that dinosaurs had them too. The cloaca of the *psittacosaurus* confirms this.

Only the external part of the cloaca has been preserved. The vent is around 2 centimetres long, is flush with the surrounding area rather than protruding as some cloacas do, and is surrounded by darkly pigmented tissue.

Most birds lack penises and mate cloaca to cloaca, so many biologists assume dinosaurs mated this way too. The fossil doesn't definitively resolve the question, but the cloaca has a longitudinal opening like those of crocodiles, which do have penises. It isn't possible to tell the sex of this particular animal, but the cloaca's resemblance to those of crocodiles suggests that this type of dinosaur had a penis (bioRxiv, doi.org/ffjf).

"It is a triumph of discovery to have such a delicate region so perfectly preserved in a fossil so old," says John Long at Flinders University in Australia. ■

Japan's least-worst option Dumping radioactive water into the ocean might sound like a terrible idea, but the alternatives are probably much worse, says Adam Vaughan



The Fukushima Daiichi nuclear plant in Japan, by the Pacific Ocean

two years, says Ken Buesseler at Woods Hole Oceanographic Institution in Falmouth, Massachusetts. Fortunately, tritium is relatively harmless for marine life as the low-energy particles it emits do little damage to living cells, he says.

Of greater concern are other, potentially more dangerous radionuclides in the water, including strontium-90 and iodine-129. TEPCO first published a list of contaminants in 2018. While filtering has reduced their

concentrations, around 70 per cent of the water has yet to go through a secondary filtering process.

"There are major questions as to whether it will work as planned," says Shaun Burnie at Greenpeace.

Livens says filtering reduces the concentrations of non-tritium isotopes, but not to zero. Still, we shouldn't be too worried about the levels that will be discharged, says Pascal Bailly du Bois at the Cherbourg-Octeville Radioecology Laboratory in France. "The radiological impact on fisheries and marine life will be very small, similar to when the Fukushima reactors were operating under normal conditions," Buesseler says the effect on marine life – and humans who eat it – can't be known until we have a "better accounting" of the radionuclides in the tanks.

Simon Boxall at the University of Southampton, UK, says any potential risk would be from radionuclides building up in shellfish in coastal waters, but he thinks the chances of this are probably low. Further out in the ocean, the risk is extremely low, but close monitoring and adherence to scientific advice will be key, he says. ■

AROUND 1.2 million tonnes of water contaminated by radioactive substances from the 2011 Fukushima nuclear disaster will be dumped in the Pacific Ocean, as part of a plan expected to be approved by the Japanese government within weeks.

The water is sitting in around 1000 tanks at the former nuclear power station, but the amount is growing daily as rainfall and groundwater entering the site continue to be contaminated. With an average of 160 tonnes a day being added last year, the International Atomic Energy Agency expects existing capacity will be full by mid-2022.

That is why the Japanese government is reportedly going to approve a strategy of discharging the water to the ocean, as recommended by scientific advisers. The release would start in around 2022 and continue for decades. The news sparked immediate complaints from Japanese fishing groups and veiled warnings that China would ban Japanese seafood imports. But are people right to be worried about the environmental and health

effects of releasing such a large amount of contaminated water?

Much of the existing water has already been filtered by a process designed to remove more than 62 radioactive contaminants. The Japanese government and Tokyo Electric Power Company (TEPCO), the firm that runs the site, have emphasised that the main radionuclide remaining is tritium. Francis Livens at the University of Manchester, UK, says this is very hard to separate

1.2m
tonnes of contaminated water due to be dumped in the ocean

because it is a radioactive isotope of hydrogen, and so part of the water molecules themselves.

TEPCO has looked at technology to remove the tritium, but a presentation by the firm shows most methods wouldn't work for the low concentrations in the tanks. Livens points out that most operating nuclear sites release this isotope.

Tritium is light, so could reach as far as the US west coast within

RICHARD ATRERO/DE GUZMAN/LOIPA IMAGES

Alien life

More doubts cast on potential signs of life in Venus's atmosphere

Abigail Beall

THE recent signal of phosphine gas in Venus's atmosphere, which could potentially be a sign of life, has been called into question again. A new study of the data in the original paper suggests there are no signs of the gas after all.

The original work, led by Jane Greaves at Cardiff University in the UK, examined how light is absorbed as it passes through the Venusian atmosphere, leaving dark absorption lines in the light's spectrum. Greaves's team found an absorption line and identified it as phosphine.

Ignas Snellen at Leiden University in the Netherlands and his colleagues re-examined the data and found no such absorption line. The researchers say their new method of data analysis introduces fewer flaws.

This is common in astronomy, with detections seen in objects that vanish when other people reduce the data, says Christopher Conselice at the University of Manchester in the UK, who wasn't involved in either study.

The original research was done using interferometry, in which information is collected by an array of separate telescopes that

then has to be pieced together. "[This] is probably one of the most complex types of astronomical data to analyse," says Conselice.

Because of that, there are many ways to process the data. Disturbances or noise must be reduced, and Snellan and his team say the original methods used to do this introduced errors, such as the phosphine signal. When they tried to replicate it, they found that five more absorption or emission signals had been spuriously added (arxiv.org/abs/2010.09761).

"It demonstrates the fundamental challenge of working on important and exciting science when one is simultaneously working very near the limits of the data quality," says Brad Gibson at the University of Hull in the UK.

Snellan and his team's study is yet to be peer reviewed, and some astronomers have said it is too early to speculate about its

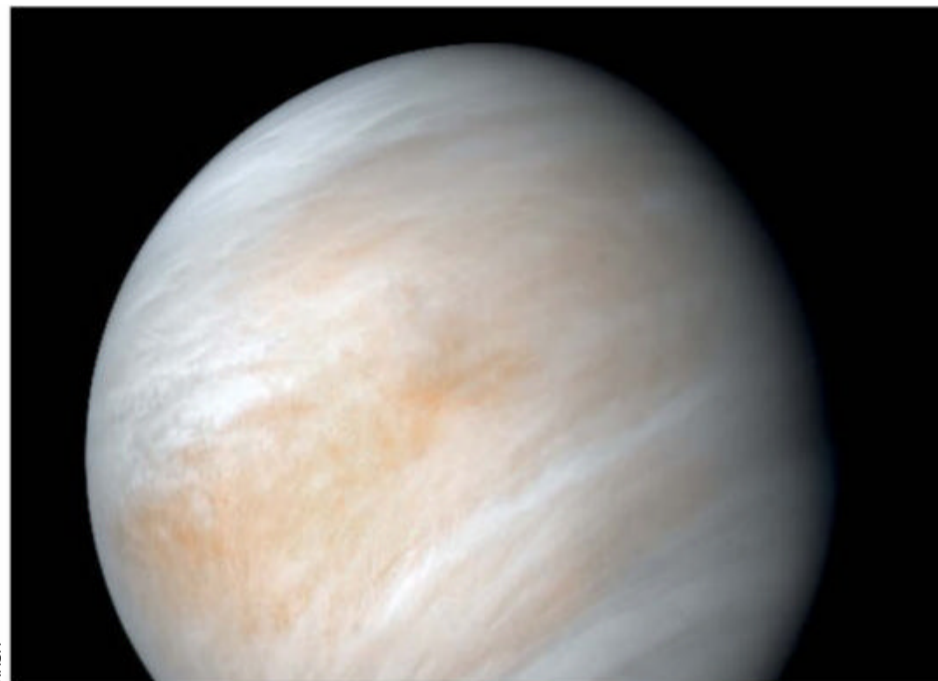
The phosphine seen in Venus's clouds may not be there after all

findings. Some believe another independent analysis is required. Others argue we need more data. "Only new observations will be able to confirm the detection of this potentially biogenic gas," says Abel Méndez at the University of Puerto Rico at Arecibo.

The study comes after another analysis led by Clara Sousa-Silva at the Harvard-Smithsonian Center for Astrophysics in Massachusetts, who was involved in the original phosphine observations, found no hint of phosphine on Venus when examining an older set of infrared data (arxiv.org/abs/2010.07817).

The original data set used by both Greaves's and Snellan's teams has been removed from the public archive where all results from the Atacama Large Millimetre/submillimetre Array (ALMA) observatory are published because of a potential problem in the early stages of data processing.

Researchers from Greaves's team declined to comment until the new processing had been applied. "Until this process is completed, we cannot say whether the issue affected the detection of phosphine reported," says an ALMA spokesperson. ■



NASA

Obesity

CRISPR gene editing turns normal fat into energy-burning fat

METABOLIC conditions linked to obesity could be treated by removing fat from a person, turning it into energy-burning "beige fat" using CRISPR gene editing and then implanting the altered fat back into the body, animal studies suggest.

"It would be a personalised therapy for metabolic disease," says Silvia Corvera at the University of

Massachusetts Medical School.

While most fat merely stores energy, some types – known as brown and beige fat – burn glucose to produce heat. People have small patches of brown fat but it only becomes active after repeated exposure to the cold.

Corvera's team previously showed that implanting extra beige fat into mice fed a high-fat diet makes them better at regulating blood sugar levels. Another team led by her colleague Michael Czech has shown that normal fat can be turned

into what appears to be beige fat by switching off a gene called *NR1P1*.

Now the two teams have joined forces. The researchers used CRISPR genome editing to deactivate the *NR1P1* gene in human fat precursor cells, which then gave rise to beige fat cells. They then implanted these cells into mice. When the animals were put on a high-fat diet, those

"This would be a personalised therapy for metabolic conditions, such as those linked to obesity"

implanted with the human beige fat put on almost half as much weight as those implanted with unedited human fat. Those given beige fat also continued to regulate blood sugar normally, whereas those with normal fat became glucose intolerant ([bioRxiv, doi.org/ffkf](https://doi.org/10.1101/2020.09.24.354444)).

Around a gram of fat from a person would provide enough fat precursor cells for the treatment, says Corvera. The method will need to be tested in non-human primates before being tried in humans. ■

Michael Le Page

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Environment

Ocean warming can predict drought on Colorado river

FORECASTING drought in the Colorado river, one of the most important rivers in the arid western US, could come down to ocean temperatures thousands of kilometres away.

The Colorado river runs for around 2300 kilometres, providing water to vast farmlands and 30 million people in seven US states and Mexico. "If we can predict the shortage of Colorado river water supply one year before, the water resource managers can develop a mitigation plan," says Yoshimitsu Chikamoto at Utah State University.

Most models that forecast water supply in the Colorado river rely on recent atmospheric and weather data, but preparing for a drought requires a longer lead time.

Chikamoto and his colleagues' model uses data on global sea

surface temperatures between 1960 and 2015, and relies on "ocean memory", or the ocean's ability to retain heat and release it slowly. While atmospheric heat is released and transferred relatively quickly, the ocean can store large amounts of heat and release it over the span of years.

According to the researchers' results, water shortages in the Colorado river were preceded by cooling in the tropical Pacific Ocean one to two years earlier, warming in the north Pacific Ocean two to three years earlier and warming in the southern tropical Atlantic Ocean three to four years earlier. They found that more distant oceans affected the river more strongly (*Communications Earth and Environment*, doi.org/ffm6).

Ian Morse

Disease

Cats cost Australia A\$6 billion a year

DISEASES transmitted by cats cost the Australian economy more than A\$6 billion (£3.3 billion) annually through their impact on human health and livestock.

Sarah Legge at Australian National University in Canberra and her colleagues analysed the economic impact of diseases such as cat scratch disease, in which a scratch or bite can cause an infection of the bacterium *Bartonella henselae*, and toxoplasmosis, a parasitic disease.

The researchers estimate that such diseases cost the Australian economy A\$6.06 billion annually in medical care, insurance, social support and lost productivity.

Toxoplasmosis also affects animals, causing miscarriages in sheep and goats. Another parasitic disease that spreads through cats, sarcocystosis, causes cysts to form in sheep meat, which reduces the

amount that can be sold. The researchers estimate that these two parasitic diseases result in annual costs to farming of about \$11.7 million (*Wildlife Research*, doi.org/ffnc).

Toxoplasmosis is caused by the parasite *Toxoplasma gondii*, which cats catch when they prey on infected birds or animals. Infected cats release *T. gondii* oocysts – an egg-like form of the parasite – in their faeces, which people can accidentally ingest, for example while gardening. The parasite enters the body, often the brain, and remains there indefinitely.

"The biggest single contributing cost is from the effects of this parasite on behaviour and mental health," says Legge.

To break the cycle of *T. gondii* transmission, efforts should be targeted at reducing feral cat populations and at keeping pets indoors, she says. **Donna Lu**

For more on the impact of domestic cats, turn to page 42

Engineering

Beetle could hold key to stronger planes

THE diabolical ironclad beetle is so tough that engineers are hoping to copy features of its exoskeleton to design more robust structures.

"You can run these things over with a car and they don't die," says David Kisailus at the University of California, Irvine. To investigate what makes these creatures (pictured) virtually uncrushable, Kisailus and his team performed compression tests on the beetle's



DAVID KISAILUS

exoskeleton, while analysing it under a microscope and by CT scan.

The researchers discovered ellipsoidal beam-like structures surrounding the beetle's exoskeleton, which combine with tiny interlocking blades that form joints between the two segments of the beetle's exoskeletal forewings, enabling the beetle to endure extreme compression.

Kisailus hopes that understanding the diabolical ironclad beetle's uniquely tough structure will help us design stronger components for use in building lighter aircraft, resulting in planes that consume less fuel and emit less carbon dioxide.

As a test, he and his team joined together a carbon-based material with a piece of metal, mimicking the joint structure of the beetle's exoskeleton. They found it was about twice as tough as a standard joint commonly used to connect similar parts when building aircraft (*Nature*, doi.org/ghf99p).

Loyal Liverpool

Really brief



Learning to walk in a simulation

A neural network algorithm designed to control a four-legged robot has been trained in a simulated environment similar to a video game that was full of hills, steps and stairs. This allowed it to learn the best way to move about without damaging the real robot, pictured (*Science Robotics*, doi.org/ffjk).

Swish of a fish's tail clears rival semen

A study of dusky frillgoby fish (*Bathygobius fuscus*) found that sneaker males, which are smaller than nest-holding males but have larger testicles, sneak into nests to ejaculate over just-laid eggs. Nest-holding males chase them away and then fan their tails to sweep out the rival semen (*Proceedings of the Royal Society B*, doi.org/ffjm).

Superwhite paint could cool buildings

A superwhite paint is so reflective that it can cool a surface to below the surrounding air temperature, even under sunlight. It could help reduce the use of energy-intensive air conditioning (*Cell Reports Physical Science*, doi.org/ffjn).

Palaeontology

First flying dinosaurs were a flop

THE first dinosaurs to take to the air had wings similar to bats, but they were bad at flying and were outcompeted by birds.

"They were badly designed gliders," says Alex Dececchi at Mount Marty University in South Dakota. "They got squeezed out."

Birds evolved from dinosaurs, and it was thought they were the only evolutionary branch to gain the ability to fly. But in 2015, Xing Xu at the Institute of Vertebrate

Paleontology in Beijing reported the discovery of a fossil dubbed *Yi qi*, meaning "strange wing" in Mandarin, with wings made of a bat-like membrane rather than feathers. In 2019, a team including Xu unveiled a fossil of another membrane-winged species called *Ambopteryx longibrachium*.

Now, a team including Dececchi and Xu have investigated the flying abilities of these animals, based partly on laser scans of the *Yi* fossil. It isn't clear exactly what shape their wings were, so the team looked at a few options, including wings connected to the legs, like in

bats, and wings more like those of birds. It was most likely something in-between, the team thinks.

The findings suggest that *Yi* and *Ambopteryx* were incapable of powered flight, and were worse at gliding than some modern animals like flying squirrels. They were almost certainly tree-dwellers that glided short distances, the team says (*iScience*, doi.org/ffnd).

There were no birds when *Yi* and *Ambopteryx* evolved. But once birds appeared, membrane-winged dinosaurs couldn't compete as birds were better fliers, says Dececchi. **Michael Le Page**

Pollution



China's air pollution cuts may save 150,000 lives each year

LEVELS of air pollution in China have fallen since 2015 due to stricter controls on emissions. China's air is still polluted, but the reduction may have prevented 150,000 premature deaths per year.

"It's probably the fastest any country has improved their air quality ever," says Ben Silver at the University of Leeds in the UK. "But it's still really bad."

Silver and his colleagues tracked levels of tiny particles, called PM2.5, using data from more than 1600 monitoring stations dotted around China. In line with previous studies, they found that levels of PM2.5 declined from 2015 to 2017.

To rule out the effect of weather on the decline, which can influence where pollutants build up, the team modelled wind patterns over China and the chemistry of the pollution. "We showed the weather was a relatively small effect, compared to emissions reductions," says Silver.

It is difficult to determine how many people are killed by air pollution. The researchers estimate that China's PM2.5 reductions have cut annual premature deaths by 150,000. But they estimate there were still 2.65 million deaths linked to PM2.5 in 2017 (*Atmospheric Chemistry and Physics*, doi.org/ffnj). **Michael Marshall**

Archaeology

The Incas may have buried llamas alive

THE remains of five llamas that may have been ritually sacrificed by Incas have been found in Peru.

"I have no way to prove it, but I think they were buried alive," says Lidio Valdez at the University of Calgary in Canada. He says the llamas don't have injuries like knife wounds to their throats, which would point to different methods of killing.

The Inca Empire dominated western regions of South America for several hundred years, until Spain invaded in the 1500s. Llamas were central to its success, providing transport, skin, fibre, fertiliser and meat. "In addition to that, the Incas believed llamas were sacred," says Valdez.

Spanish people who came into contact with the Inca reported that they regularly killed hundreds of llamas, either for feasts or ritual sacrifices to deities.

Archaeologists hadn't found evidence of llama ritual sacrifice. Now, Valdez and his colleagues have found five such llamas buried in an Inca settlement called Tambo Viejo near the coast of Peru. The llamas had no injuries, but their legs were tied together. Valdez thinks this was to keep them under control while they were buried alive (*Antiquity*, doi.org/ffnk). **MM**

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The columnist

Do tomatoes worsen rheumatoid arthritis, asks James Wong **p24**

Aperture

Silver plant portraits inspired by Victorian botany **p26**

Letters

Beware automation's ability to divide us: readers respond **p28**

Culture

An extract from Carlo Rovelli's latest book **p30**

Culture columnist

Jacob Aron on flying X-wings in *Star Wars: Squadrons* **p34**

Comment

How moral are you? No, really?

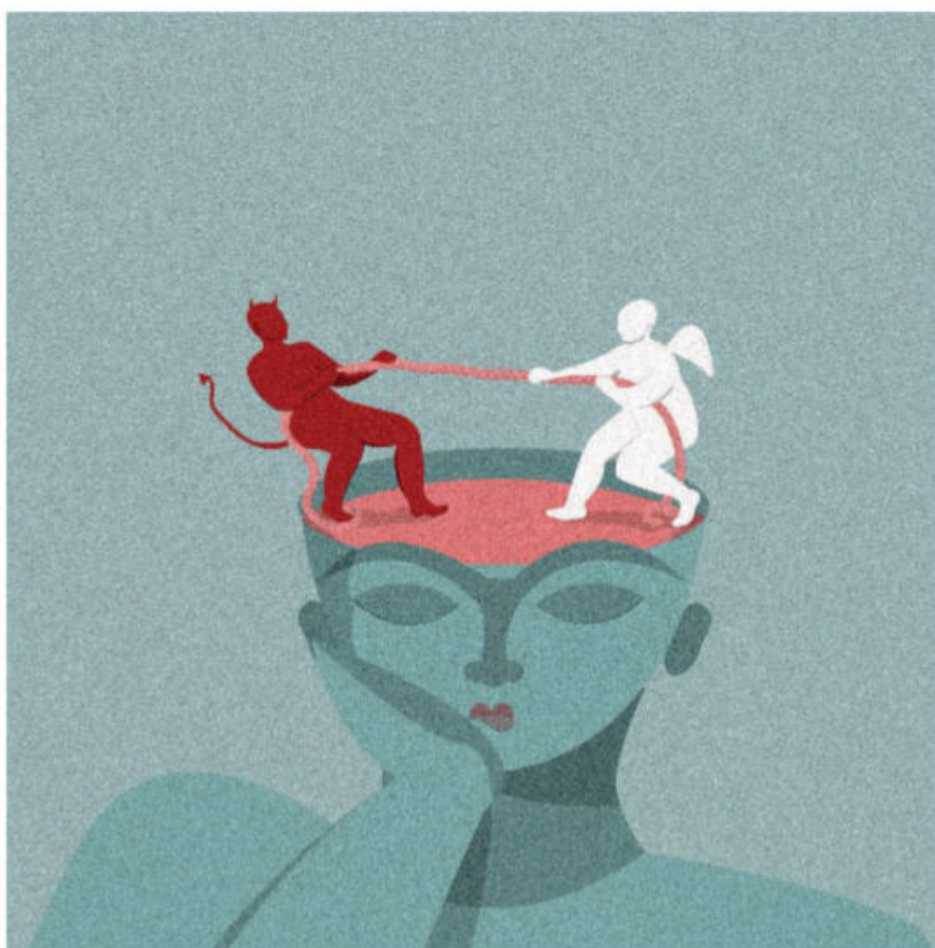
When experimenting in virtual reality, we often find people act differently to what they say is morally acceptable, says **Sylvia Terbeck**

YOU probably aren't as moral as you think. Philosophers have often asked people how they would act in a given situation when lives are on the line, but it is hard to test what they would do in practice. Now, thanks to virtual reality, we are starting to find out – and what people say doesn't match up with what they do.

There are many thought experiments and dilemmas for breaking down ethical decisions, and perhaps none is more famous than the trolley problem. The scenario begins with a runaway trolley that is on course to kill five railway workers who are stuck on the tracks. You can divert it by flipping a switch, which would kill one railway worker on an alternative track but save the other five. Is it morally acceptable to flip the switch? Most people say yes.

Now imagine the same situation, but this time you are standing on a footbridge over the tracks. To save the five workers, you would need to push a stranger off the bridge to stop the trolley, killing them but saving the five. Is that morally acceptable? In this case, most people say no, even though one person is killed to save five in both scenarios.

The trolley problem was developed by Philippa Foot, a philosopher and fellow of the British Academy born 100 years ago this month. Many studies have looked into why we find such a difference in moral intuitions between the two cases it describes.



Some researchers have suggested that people might be unwilling to push the man because of empathic concern about his situation.

My colleagues and I have studied people's behaviour in this dilemma by immersing them in virtual reality. In one such experiment, we put 100 people into a simulated version of the trolley problem.

Consider your own response. The trolley is approaching, it is getting out of control, there is a horn beeping, five railway workers screaming, and a man right in front of you. Do you push him?

Most people did. Indeed, they

pushed him even though they reported that they were very affected by the situation, and far more engaged in it than when merely reading about it. We also found that the majority of people regretted their choice afterwards. We have also developed other scenarios investigating similar moral situations, such as a confrontation with a stranger and a self-driving car steering out of control. In many of them, people act against what they say is morally acceptable.

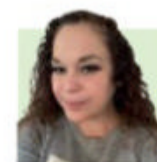
Looking back to classical social-psychological studies, we often find that people act hypocritically,

doing things they say they regard as morally unacceptable when placed in that situation.

For example, Philip Zimbardo found in 1971 that, under certain circumstances, ordinary student volunteers behave in an aggressive and denigrating manner towards their fellow student colleagues when they were given the role of prison guards in an experiment. Stanley Milgram found in 1963 that some people would be willing to inflict lethal electric shocks towards another person if told to do so by a determined authority. None of the participants reported that they would behave in this way when asked on a questionnaire. And while doubts have been raised about the validity of all these experiments' conclusions, there seems little doubt they reflect human nature. So why?

The answer to this question isn't yet known. We are still working on what the real nature of human morality could be. Is it what we say that we would do, or is it what we actually do?

We need to develop an empirical understanding of what makes our moral intuition, and we are working on experiments that could get us closer. In the meantime, we may need to look at people's moral behaviour more before believing what they are saying. ■



Sylvia Terbeck is a senior lecturer in psychology at Liverpool John Moores University, UK

#FactsMatter

You say potato... and some say “killer plant”. A toxic compound in potatoes, tomatoes and the like is rumoured to make rheumatoid arthritis worse. Is there anything in it, asks **James Wong**



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

James's week

What I'm reading

A lot of scripts for a new BBC series I am making on how developments in agriculture can help feed our growing population sustainably.

What I'm watching

Every single history documentary that Simon Schama has ever made. I'm absolutely his new greatest fan!

What I'm working on

I'm simultaneously filming a BBC farming documentary series and an online houseplant course. Busy times.

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

AS A botanist fascinated by the properties of plants, I am always curious when I uncover new claims about them. So when a colleague lamented to me about having to give up eating tomatoes (her very favourite food) over lunch the other day, fearful they would exacerbate her crippling rheumatoid arthritis, I could barely clear my plate before reaching to dig out the studies.

The first thing I discovered was that a link between tomato consumption and this painful, poorly understood degenerative condition wasn't a new idea at all, just new to me that day. It has been a staple for health writers in newspapers, books and blogs for decades.

It isn't just tomatoes either. Everything in the botanical family to which they belong, called the nightshades, including potatoes, aubergines, peppers, chillies and crops such as goji berries, is claimed to exacerbate the symptoms of arthritis.

The alleged culprit is a toxic alkaloid compound they apparently contain called the solanine. So what does solanine do in this context? To my surprise, I couldn't find a single scientific paper that addressed the question. In fact, to date there appear to have been no peer-reviewed clinical trials investigating if solanine even has any plausible connection with rheumatoid arthritis to begin with. The only reference I could find was an animal study in the *Arab Journal of Nuclear Sciences and Applications*, which involved feeding rats a special diet based largely on diseased potatoes.

Potato plants produce solanine to defend themselves against pathogens, so rotting potatoes are likely to have particularly high levels of it. This study did indeed find increased levels of some

blood markers associated with rheumatoid arthritis in these rats. But humans aren't rats and we don't eat diets based on rotting potatoes. Even if these results were transferable to humans, how do we know it was the spuds that had the effect, and not the pathogen?

The authors' conclusion, that everyone with arthritis should eliminate every plant in the nightshade family from their diets, isn't really a conclusion that can be made from testing one crop in a family of some 3000 species.

This highlights a central problem with any rationale

“Over the years, the claim seems to have cycled and been recycled so many times it is now cited as scientific fact”

behind the claim: solanine isn't really found in many plants in the nightshade family, at least not at the same levels as in rotting potatoes. It crops up mainly in the green tissues of growing potato plants. In tomatoes, it is found at far lower concentrations, down to barely measurable traces in some varieties. In goji berries, it doesn't seem to be present at all.

These plants may contain other related alkaloids, such as tomatine, which may be the source of some confusion. But picking out solanine as a clear culprit is a tough ask based on the evidence. Solanine is also found in plants outside the nightshade family, from apples to artichokes, none of which seems to be in the cross hairs of proponents of this claim. Meanwhile, some wellness writers say that nightshade plants promote inflammation because they are in the same family as the

irritant poison ivy. They are not.

When I dug back through the studies, the one that I kept coming back to as the apparent original source of this claim is one from the late 1970s, when a horticultural researcher noticed his arthritis was alleviated when he quit smoking and stopped eating all other related plants.

Yes, tobacco is in the nightshade family too. Encouraged by this personal anecdote, the researcher conducted a postal questionnaire run through magazine adverts, collated the resulting anecdotes and wrote a book based on his idea. Over the years, supported only by this shaky evidence, the claim seems to have cycled and been recycled so many times that it is now regularly cited as scientific fact.

What we do know, by the way, is that evidence does suggest a link between smoking and rheumatoid arthritis. These anecdotes may have been more to do with giving up smoking one toxic nightshade plant than no longer eating a bunch of safe ones. Go figure.

Given this lack of any solid scientific evidence for this belief, the advice from both the US-based Arthritis Foundation and the British Nutrition Foundation is that tomatoes, potatoes and the like aren't just healthy additions to our diets, but contain potentially anti-inflammatory compounds like carotenes and vitamin C that can help protect our tissues, possibly benefiting those who have rheumatoid arthritis.

In the face of really no good studies, here is my take: if lived experience has shown that eating these plants is a problem for you, of course, don't eat them. But if you have been frightened off your favourite foods because of a tabloid headline, take it, as it were, with a pinch of salt. ■

Thinking about exploring the world again?

While travel has been little more than a dream over the past few months, we know that many of you are now eager to pencil in your next adventure and as we've had so much interest from our readers recently, we've decided to start taking bookings again for later next year, with flexible deposits and safe touring protocols in place.

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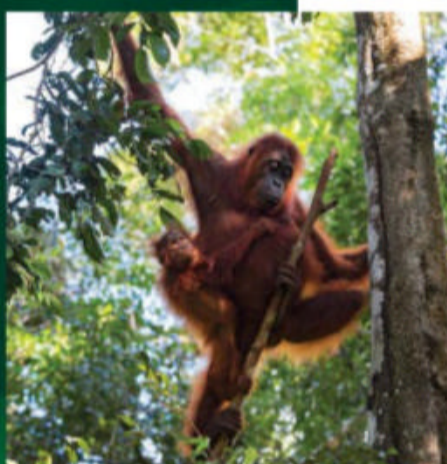
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Silvered flowers



Photographer **William Arnold**
Agency **Panos Pictures**

THESE exquisite and intricate plant portraits by photographer William Arnold are a nod to the Victorian era of botany, as well as to the rural beauty tucked away in English hedgerows and kerbsides.

Arnold gathered an assortment of plants during walks in Truro, Cornwall, before printing photos of them in monochrome using a technique called silver gelatin printing.

Developed in 1871, the process involves printing photographs onto paper coated in a gelatin layer that contains silver halides, chemical compounds sensitive to light. After exposure to a negative image (where the lightest areas appear dark and vice versa) and development with chemicals, small silver particles are tethered to the gelatin to form the final image.

This form of printing not only preserves plants in all their natural splendour, it also exposes the delicate details of petals, leaves, flowers and stems.

These images come from the 100 prints in Arnold's recent book, *Suburban Herbarium*. Clockwise from far left, they are lords and ladies (*Arum maculatum*), common honeysuckle (*Lonicera periclymenum*), cut-leaved cranesbill (*Geranium dissectum*), scarlet pimpernel (*Anagallis arvensis*) and California poppy (*Eschscholzia californica*).

Arnold's images are on show at Newlyn Art Gallery in Cornwall until 2 January 2021. He is also working with the Eden Project to involve the public in collecting local specimens across the UK. ■

Gege Li

Editor's pick

Beware automation's ability to divide us

10 October, p 44

From Alan Taman, Birmingham, UK
Sandy Ong's excellent piece on automation and its effects on employment misses one cardinal point. New technology tends to increase inequality, and the bigger the effects of the new tech, the greater the inequality that follows. Unemployment can easily come with more deprivation for many and extreme wealth for the few – which is exactly what we are seeing.

It isn't just the kinds of job that matter, it is the share of resources, power and opportunity created that are key to the kind of future we will have. That is largely a matter of political, not technological, choice. The wise option is rarely easy, but if we let free-market thinking make our decisions for us without greater control of inequality, it is all too easy to see where AI could lead.

Intensive farming has failed to solve hunger

Leader, 10 October

From Charles Merfield,
Lincoln, New Zealand

There are a number of issues raised by your discussion of using gene editing to address agriculture's climate impact.

The first is the assertion that better breeds are the best way to address climate effects. This is highly debatable. What is clearer is that well-proven agroecological techniques, such as agroforestry, have substantial climate heating adaptation and mitigation abilities, as well as a plethora of other benefits and very few downsides. The problem is they are low-tech and widely known, so aren't amenable to high-tech science and therefore prestigious publications and patents.

Next, the many sophisticated solutions offered to solve farming's problems are doomed to fail as they are based on the false assumption that underpins

intensive agriculture and the green revolution: that to feed people, we need to increase yield.

After 70 years of intensive agriculture, we still have nearly a billion people that don't have enough food, even though we have grown enough to feed every person on the planet for decades. If that is success, I would hate to see what failure looks like.

Ecological science is clear: we must manage population to levels where consumption of food and other resources is compatible with the capacity of the planet. This ventures into the ugly politics of Malthus, but it is also clear that it isn't those in low-income countries that we have too many of, but those consuming far more than their share of the planet's outputs.

Earth just can't sustain ever more consumption

17 October, p 34

From Iain Climie,
Whitchurch, Hampshire, UK

The accelerating climate change mentioned in your special report is a surprise to some, but why? Melting ice sheets reflect less solar energy, darker surfaces absorb more heat, previously frozen gases escape while fires and dying vegetation worsen matters. Temperature changes also lag behind changes in total greenhouse gas levels, so we are in deep trouble even if our emissions fall rapidly.

Many ideas to address this can also fail. More food from less space seems obvious, but some years ago, environmentalists reckoned three or four planets would be needed to give us all Western lifestyles and jobs to afford them. A more recent estimate is 11 planets for all to have well-off US lifestyles.

Maddeningly, many changes that are essential if mainstream

climate views are correct, such as producing less waste, would make perfect sense even if climate change were a damp squib or temperatures fell. Predictably, such win-win options were rejected in favour of arguing about who was right. Urgent action is needed to avoid complete disaster. One target is economic reform – conventional ideas on economic growth will end in disaster.

From Ronald Gibson,
Irvine, California, US

Your article continues the head-in-the-sand approach of virtually all publications. The pandemic and global warming are just two manifestations of the real problem: overpopulation. As our numbers continue their out-of-control growth and the attendant problems get ever worse, I ponder: are people really this stupid?

The editor writes:

■ See page 36 for economists' take on the post covid-19 future. We plan to look at population in the coming weeks.

Time mathematicians put their analogue heads on

5 September, p 36

From Guy Dauncey,
Ladysmith, British Columbia, Canada

Eddy Keming Chen has me fascinated with his thoughts about vagueness in fundamental physical laws, and the possibility that we may never be able to completely capture the objective order of the universe through mathematics.

Clearly, the laws of the universe existed long before we started measuring them. The universe we measure using mathematics may seem to be digital, and hence could be pinned down by maths,

but surely the universe is analogue, without discrete values. When Gottfried Leibniz and Isaac Newton invented calculus to square the circle, they did so because every curve – and, indeed, everything in the universe – is analogue. By putting a curve through an infinitesimal digital grinder, we can make it appear digital, sufficient for most supposed laws of physics, but who are we fooling?

From a digital point of view, it may be frustrating not to be able to know the location and momentum of a particle at the same time. Yet from an analogue perspective, not knowing is natural and obvious. Is quantum indeterminacy therefore a genuine feature of the universe or a mental category error that has resulted from the imposition of a supposed digital reality onto the universe's actual analogue reality?

If this is so, will mathematicians continue to pull their digital hairs out, or will they refocus their attention on their analogue heads and consciousness from which their digits emerged?

Another source of genetic diversity for women?

1 August, p 42

From Ralf Dahm, Mainz, Germany

Thank you for the interview with Sharon Moalem, in which he expounds why women live, on average, longer than men. He says this is thanks to having two X chromosomes, giving genetic diversity in the immune system.

Interestingly, it has been shown that cells from the developing fetus cross into a pregnant woman and can persist in her body for life. Since the fetal cells comprise half a genome from the father, they are genetically different from the mother's cells, again increasing her genetic diversity.

Compared with the other cells in the mother's body, there are very few fetus-derived cells, but immune cells can replicate significantly and make a major difference. It would be interesting to see if this also boosts longevity. ■



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When black holes turn white

In this extract from his latest book, **Carlo Rovelli** suggests that black holes sucking in all matter that strays too close may be only half the story

THERE is something paradoxical in what we know about black holes. They have now become “normal” objects for astronomers. Astronomers observe them, count them and measure them. They behave exactly as Einstein’s theory predicted a century ago, when no one dreamed that such peculiar objects could actually exist. So, they are under control. And still, they remain utterly mysterious.

On the one hand we have a beautiful theory, general relativity, confirmed in spectacular manner by astronomical observations, which accounts perfectly well for what the astronomers see: these monsters that swallow stars revolve in vortices and produce immensely powerful rays and other devilry. The universe is surprising, variegated, full of things that we had never foreseen or imagined the existence of, but comprehensible. On the other hand, there is still a small question of the kind that children specialize in when adults are overly enthusiastic: “But where does all the material that we see falling into a black hole go?”

And this is where things become difficult. Einstein’s theory provides a precise and elegant mathematical description even of the inside of black holes: it indicates the path that material falling into a black hole must follow. The matter falls ever faster until it reaches the central point. And then... then the equations of Einstein lose all meaning. They no longer tell us anything. They seem to melt like snow in sunshine. The variables become infinite and nothing makes sense. Ouch.

What happens to matter that falls into the centre of the hole? We don’t know.

Through our telescopes we see it falling, and we mentally follow its trajectory until it nearly reaches

the centre, and then we have no knowledge of what happens next. We know what black holes consist of, both outside and inside, but a crucial detail is missing: the centre. But this is hardly an insignificant detail, because everything that falls in (and into the black holes that we observe in the sky, things continue to fall) finishes up at the centre. The sky is full of black holes into which we can see things disappear...

“What happens to the matter that falls into the centre of the hole? We don’t know”

but we don’t know what becomes of them.

The roads taken to explore answers to this question have so far been hazardous. Perhaps, for instance, the matter emerges in another universe? Perhaps even our own universe began this way, emerging through a black hole opened in a preceding one? Perhaps at the centre of a black hole everything melts into a cloud of probability where spacetime



JAMIE STOKER

Carlo Rovelli is a physicist at Aix-Marseille University in France

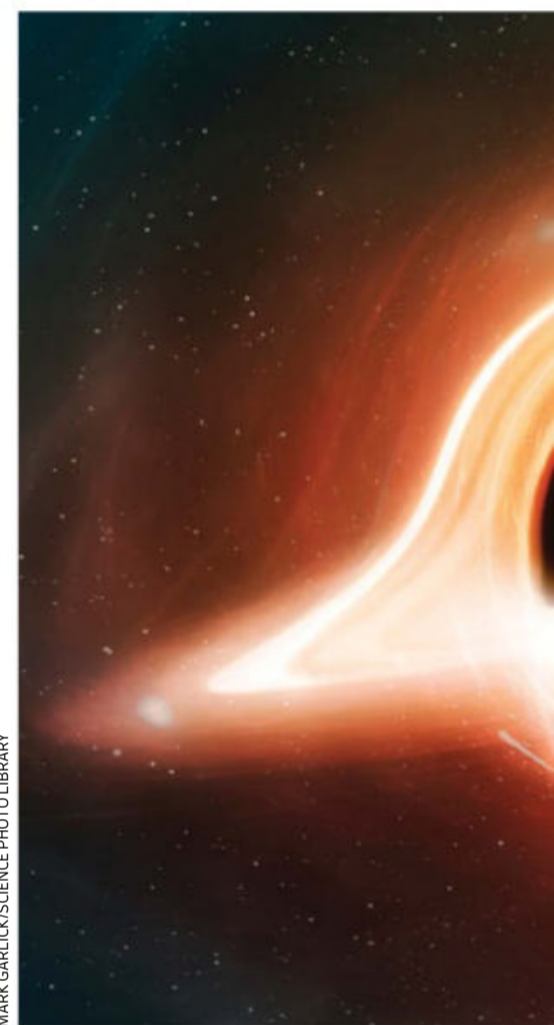
and matter no longer mean anything? Or perhaps black holes irradiate heat because the matter that enters them is mysteriously transformed, over zillions of years, into heat.

In the research group I work with in Marseille, together with colleagues at Grenoble and at Nijmegen in the Netherlands, we are exploring a possibility that seems to us both simpler and more plausible: matter slows down and stops before it reaches the centre. When it is most extremely concentrated, a tremendous pressure develops that prevents its ultimate collapse. This is similar to the “pressure” that prevents electrons from falling into atoms: it is a quantum phenomenon. Matter stops falling and forms a kind of extremely small and extremely dense star: a “Planck star”. Then something happens that always happens to matter in such cases: it rebounds.

It rebounds like a ball dropped on the floor. Like the ball, it rebounds along the trajectory of the fall, in temporal reverse, and in this way the black hole transforms itself (by “tunnel effect”, as we say in the jargon) into its opposite: a white hole.

A white hole? What is a white hole? It is another solution to the equations of Einstein (like black holes are) about which my university textbook says that “there is nothing like it in the real world”... It is a region of space into which nothing can enter, but from which things emerge. It is the time reversal of a black hole. A hole that explodes.

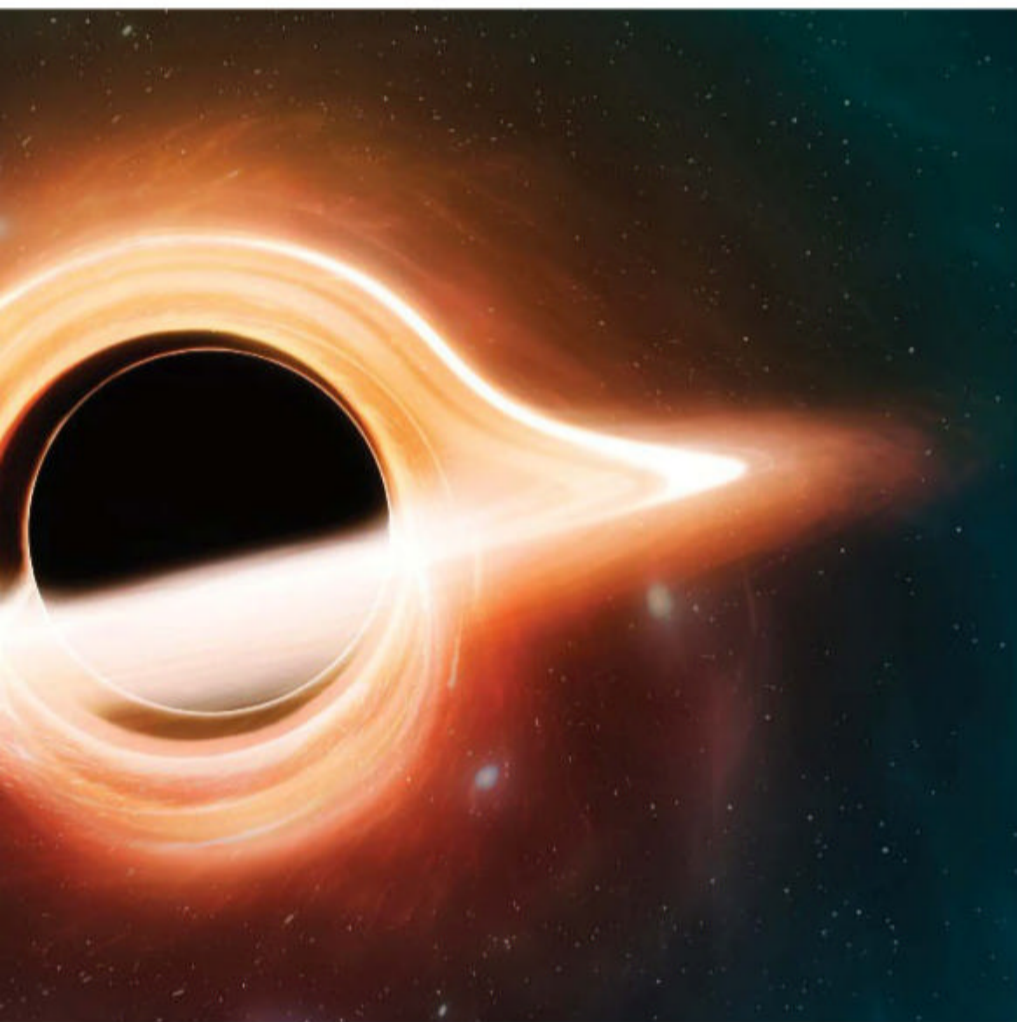
But then why do we see matter fall into black holes but do not see it immediately bouncing back out again? The answer – and this is the crucial point about what we are dealing with – lies in the relativity of time. Time does not pass at the



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same speed everywhere. All physical phenomena are slower at sea level than in the mountains. Time slows down if I am lower down, where gravity is at its most intense. Inside black holes the force of gravity is extremely strong, and as a result there is a fierce slowing of time. The rebounding of falling matter happens rapidly if seen by someone nearby, if we can imagine someone venturing into a black hole to see what it’s like on the inside. But seen from outside, everything appears to be slowed down. Enormously slowed down. We see things disappear and vanish from view for an extremely long time. Seen from outside, everything looks frozen for millions of years – exactly how we perceive the black holes we can see in the sky.

But an extremely long time is



not an infinite time, and, if we waited for long enough, we would see the matter come out. A black hole is ultimately perhaps no more than a star that collapses and then rebounds – in extreme slow motion when seen from outside.

This is not possible in Einstein's theory, but then Einstein's theory does not take quantum effects into account. Quantum mechanics permits matter to escape from its dark trap.

After how long? After a very short time for the matter that has fallen into the black hole, but after an extremely long one for those of us observing it from outside.

So here is the whole story: when a star such as the sun, or a little bigger, stops burning because it has consumed all its hydrogen, the heat no longer generates enough pressure to counterbalance its weight. The star collapses in on

The universe is full of things we had never foreseen or imagined, none more so than black holes

“A black hole is perhaps no more than a star that collapses and rebounds in extreme slow motion”

itself, and if it is sufficiently heavy it produces a black hole and falls into it. A star of the dimensions of the sun, that is to say thousands of times bigger than Earth, would generate a black hole with a diameter of one and a half kilometres.

Imagine it: the whole of the sun contained within the volume of a foothill. These are the black holes that we can observe in the sky. The matter of the star continues on its course inside, going ever deeper until it reaches the monstrous level of compression that causes it to rebound. The entire mass of the star is concentrated into the space of a molecule. Here the repulsive quantum force kicks in, and the star immediately rebounds and begins to explode. For the star, only a few hundredths of a second have elapsed. But the dilation of time caused by the enormous gravitational field is so extremely strong that when the matter begins to re-emerge, in the rest of the universe, tens of billions of years have passed.

Is this really the case? I don't know for sure. I think it might well be. The alternatives seem less plausible to me. But I could be wrong. Trying to figure it out, still, is such a joy.

In a further extract, “Copernicus and Bologna”, Rovelli writes about the value of a university education

...I also found something else in Bologna, when I studied there in the seventies: an encounter with that spirit of my generation, a generation that was intent on changing everything, that dreamed of inventing new ways of thinking, of living together and of loving. The university was occupied for several months by politically engaged students. I got involved with the friends of Radio Alice, the independent radio

station that had become the voice of the student revolt.

In the houses we were sharing, we nourished the adolescent dream of starting from zero, of remaking the world from scratch, of reshaping it into something different and more just. A naive enough dream, no doubt, always destined to encounter the inertia of the quotidian; always likely to suffer great disappointment. But it was the same dream that Copernicus had encountered in Italy at the beginning of the Renaissance. The dream not only of Leonardo and of Einstein but also of Robespierre, Gandhi and Washington: absolute dreams that often catapult us against a wall, that are frequently misdirected – but without which we would have none of what is best in our world today.

What can the university offer us now? It can offer the same riches that Copernicus found: the accumulated knowledge of the past, together with the liberating idea that knowledge can be transformed and become transformative.

This, I believe, is the true significance of a university. It is the treasure-house in which human knowledge is devotedly protected, it provides the lifeblood on which everything that we know in the world depends, and everything that we want to do. But it is also the place where dreams are nurtured: where we have the youthful courage to question that very knowledge, in order to go forward, in order to change the world. ■

These excerpts are taken from the book *There Are Places In The World Where Rules Are Less Important Than Kindness*, published by Allen Lane on 5 November in the UK. A review follows overleaf

A mind for all times

Physicist Carlo Rovelli's bestsellers show a mind seeking knowledge for its own sake. His new book reminds us why we need more Rovellis, says **Richard Webb**



Book

There Are Places in the World Where Rules Are Less Important Than Kindness

Carlo Rovelli
Allen Lane

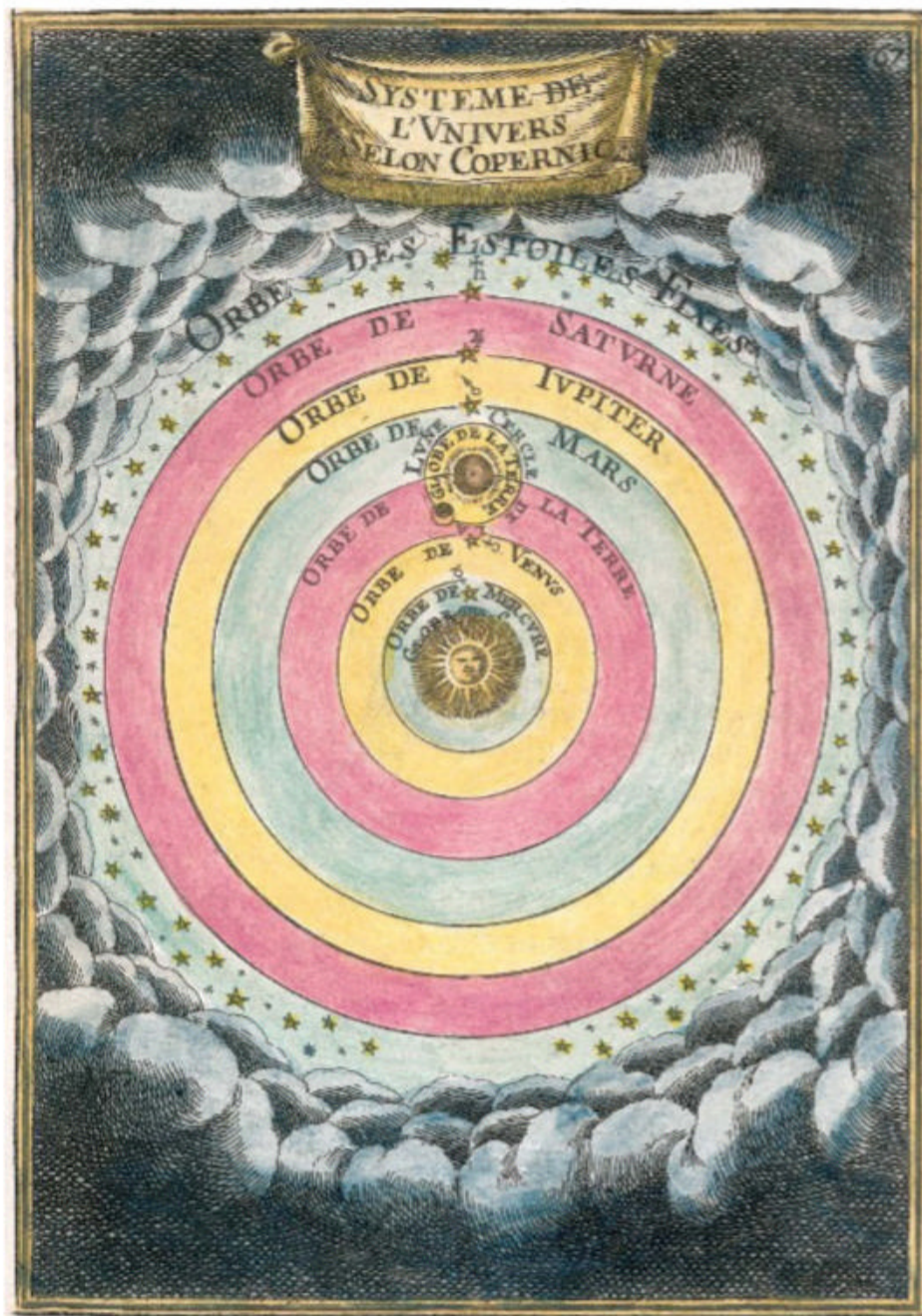
I APPROACHED Carlo Rovelli's latest book with trepidation, bordering on dread. The Italian quantum gravity researcher's previous bestsellers – *Seven Brief Lessons on Physics*, *Reality Is Not What It Seems*, *The Order of Time* – have seen him playing on home territory, where his lucid, lyrical touch won him a reputation as “the poet of physics”.

But his new book's title, *There Are Places in the World Where Rules Are Less Important Than Kindness*, suggested it might have gone to his head a bit. It is a collection of Rovelli's journalism, mainly for Italian outlets such as the daily newspaper *Corriere della Sera*, with musings not just on physics, but politics, philosophy, anthropology and the history of ideas. When physicists play public intellectual, it often doesn't end well. Best to stick to the stuff you know.

I needn't have worried, though. Rovelli does stick to the stuff he knows, but that turns out to be quite a lot. It makes for a joy of a book – enriching, illuminating, eclectic and far from a conventional science read.

Rovelli is as comfortable discussing his own work on black holes (see the extract on page 30) as he is considering novelist Vladimir Nabokov's passion for butterflies, or reflecting on his own involvement in the Italian student protests of 1977 – in which, he intriguingly lets slip, he was accused of seditious association and forced into hiding.

The mouthful of a title (a trend



DETLEV VAN RAVENSWAAY/SCIENCE PHOTO LIBRARY

“Rovelli is as comfortable discussing black holes as he is considering novelist Vladimir Nabokov's butterflies”

besetting the publishing industry) comes from the longest essay in the book, describing a day he spent in the rural environs of Mbour, Senegal.

Rovelli describes how a man insists on carrying his sandals into a mosque for him when he has committed the faux pas of forgetting to remove them. It is

one vignette in a story that showcases the light and shade of Rovelli's writing, and the passion for knowledge and curiosity that make him such an engaging writer (even if he might raise hackles by making sweeping statements about “Africa” or “the real Africa”, as if they were definable things).

In some ways, though, the book makes me a little sad. At the risk of straying from my own safe territory, the Rovellis of the world are a dying breed. A diminishing number of people, whatever their walk of life, have the freedom or receive the encouragement to let

Revolutions such as the sun-centred solar system built on what came before

their minds rove and broaden their world view, as he clearly has.

Knowledge for knowledge's sake has gone out of fashion, replaced by a utilitarian notion of education. The sort of liberal-universalist perspective that Rovelli stands for, rooted in the intellectual traditions of ancient Greece and the Italian Renaissance, is increasingly excoriated by those on the right who see it as a plot to undermine a curiously modern conception of the cultural primacy of nations, as well as those on the left who see it as an exclusionary, Eurocentric and patriarchal front.

But if we are to make progress in anything, from exploring the interior of a black hole to understanding how to best combat covid-19, we need to be able to contextualise new knowledge, to understand where it lies in relation to that already acquired and to synthesise from the broadest range of sources, not just rely on what we find in our silo or echo chamber.

It is a point that Rovelli himself makes in a different way and context in the book's first essay. He describes how Galileo built a new physics not by regarding the Aristotelian ideas it superseded as a dogma to be overturned, but by understanding where that earlier intellect came from and what motivated it – that is to say, by constructing a dialogue between spheres of knowledge.

“What interests us most is... to compare, to exchange ideas, to learn and to build from difference. To mix, not to keep things separate,” he writes. At the very least, this book succeeds in doing that. ■

All skin and bone

Why did a dying 19th-century robber want his skin to be a book cover? **Chris Stokel-Walker** finds spooky tales for Halloween



Books

Anatomica: The exquisite & unsettling art of human anatomy

Joanna Ebenstein

Laurence King Publishing

Dark Archives: A librarian's investigation into the science and history of books bound in human skin

Megan Rosenbloom

Farrar, Straus & Giroux

THE human body can fascinate and enthrall – but it can also appal. Two new books highlight our complex relationship with the body and, interestingly for the queasy 21st century, don't blink at the facts.

Joanna Ebenstein co-founded the now closed Morbid Anatomy Museum in New York. She spent years studying how we think about the body, sparked by receiving a calendar from the Mütter Museum of the College of Physicians of Philadelphia, a Pennsylvania institution that contains human specimens preserved in alcohol.

She is interested in why once-commonplace images of death and the body are now considered bizarre. "The human body is something we can all relate to, as opposed to images of botany or astronomy," she says about her new book, *Anatomica*.

Ebenstein charts the history of the body's portrayal in art and society, homing in on 1543, when Andreas Vesalius's *De Humani Corporis Fabrica Libri Septem* became the first book to look at mammal bodies based on factual dissection, rather than hypotheses.

Unlike today's body bible,

Art and anatomy were closely linked before the body became medicalised

Gray's Anatomy, Vesalius's images are playful and artistic. They are in beautiful landscapes, not laid out on slabs, says Ebenstein. That physical detachment didn't happen until the 19th century, by which time we had come to see the body as mechanical, rather than spiritual – and started to avoid taboo subjects like death.

That was also when skin covers started to spook us. In *Dark Archives*, Megan Rosenbloom, a librarian at the University of California, Los Angeles, probes what was once a normal practice.

Like Ebenstein, her interest in the corporeal was born among the 19th-century pillars of the Mütter Museum. A former journalist, her eye was drawn to a case of small books, their covers closed. There was little to indicate that these were the books' most important feature. Then she read the caption: they were made from human skin.

After that, whenever she visited a library, she asked if they had books bound in human skin. She recalls: "I was surprised more and more places said they had one." Her book tries to answer a simple question:

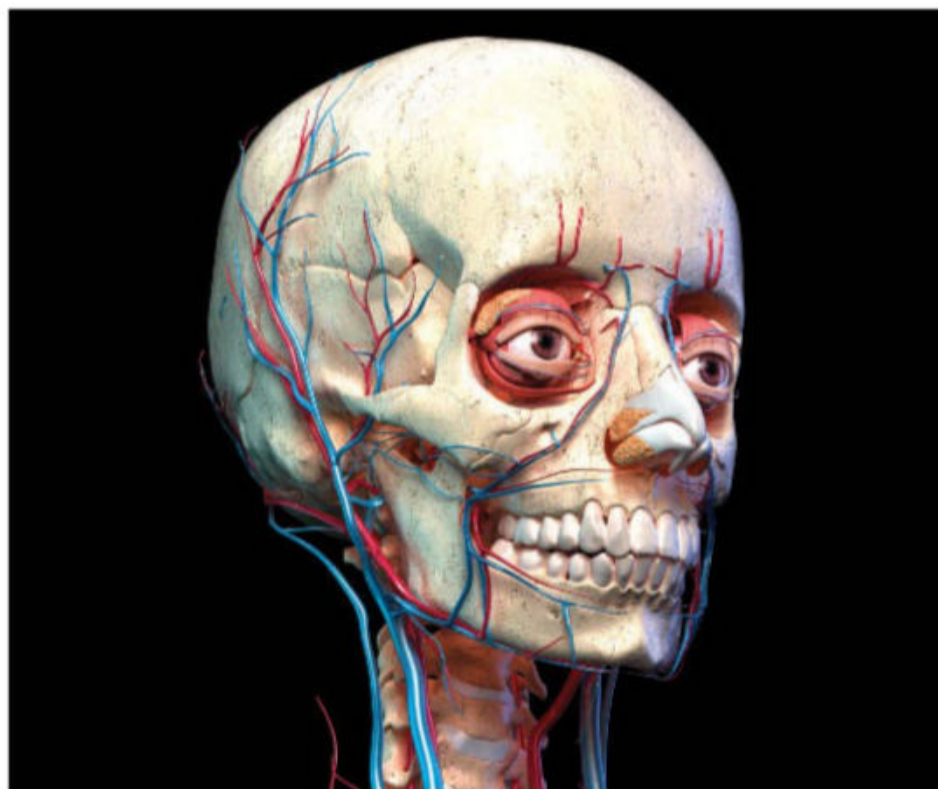
why did we flay people as leather?

The answers aren't definitive, but again show a changing attitude to the sanctity of human bodies. Most of those who owned books covered in skin were doctors. "It tells us a complicated story about the way doctors viewed patients in the past," she says. "If it's going to end up in the bucket, why not take a piece of skin and save it anyway?"

Rosenbloom tries to return humanity to the books, identifying the people who gave their skin when she can. Most were unwitting or unwilling donors, but she found George Walton, whose skin covers a book in the Boston Athenaeum.

Walton, a highway robber in 19th-century Massachusetts, was dying of tuberculosis in prison. Telling tales of his past, he lobbied to become a book cover. That wish was granted, his skin wrapping his own slim memoir. As Rosenbloom says: "To hear from someone who wanted this, in his own words, adds this amazing element." ■

Chris Stokel-Walker is a technology writer based in Newcastle, UK

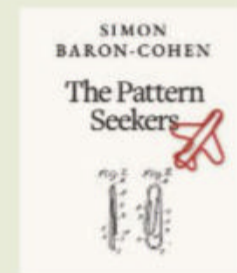


LEONELLO CALVETTI/SCIENCE PHOTO LIBRARY



Visit

The National Museum of Computing in the UK is running a virtual tour on 2 November. Quiz experts on wartime codebreaking machines and browse the largest collection of working historic computers in the world.



Read

The Pattern Seekers: A new theory of human invention

by Simon Baron-Cohen asks why the genes for finding and identifying causal patterns, an ability that has driven human progress, overlap so neatly with those we associate with autism.



Listen

Russia's Young Climate Activists, a podcast from Pushkin House in the UK, features Ada Wordsworth speaking to three activists in Russia about the action that is at last challenging their nation's prevailing culture of climate scepticism.

T&B: THE NATIONAL MUSEUM OF COMPUTING; VALERY SHARIFULIN/TASS VIA GETTY IMAGES

The games column

The Force is still with you Set after the original trilogy, *Star Wars: Squadrons* puts you inside the cockpits of the iconic X-wing and TIE fighter spacecraft. Piloting them is fun, but this is a good game rather than a great one, says **Jacob Aron**



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



In *Star Wars: Squadrons*, you move from escorting shuttles to bombing runs

and the TIE Reaper support ship – but if that means much to you, you are probably pretty far down the *Star Wars* wormhole already. The ships all felt much the same to me, despite options to customise their weapons, shields and so on.

Squadrons is broken up into missions in which you do everything from escorting shuttles to going on bombing runs against a space station. For the most part, though, you whirl around trying to get a bead on enemy fighters to take them out before they take you out.

As reflected in the films, this isn't really space combat, but aerial dogfighting transplanted into the cold vacuum. With no air resistance, there should be no need to bank into turns, but I guess it would be too difficult to ask players to control thrusters along three axes, as real spacecraft operate. Given that I find myself regularly smacking into an asteroid or a capital ship, making the controls less complicated was probably the better option.

For those who want a real challenge, the multiplayer mode lets you face off against others in five-on-five dogfights, or take part in massive fleet battles in which teams must take down larger, computer-controlled ships to win. Sadly, my attempts to be Luke Skywalker have mostly ended in failure because I have been outmanoeuvred and outgunned by players far better than me.

All in all, *Squadrons* is a good *Star Wars* game, rather than a great one – think *The Force Awakens* rather than *The Empire Strikes Back*. You will enjoy flying around in famous spacecraft, but I'm not sure it has much staying power. ■



Game

Star Wars: Squadrons
Motive Studios
PC, PlayStation 4, Xbox One

Jacob also recommends...

Games

Star Wars Rogue Squadron II: Rogue Leader
Factor 5

Nintendo GameCube

This is probably my favourite Star Wars flight game – you get to help take down the second Death Star.

Star Wars: Knights of the Old Republic
BioWare

PC, Xbox, iOS, Android

You play as a Jedi working to tackle an evil Sith lord 4000 years before the films. One of your team, sarcastic android HK-47, is possibly the best character in any Star Wars story.

WHILE the early 2000s were a dark time for *Star Wars* superfans, wounded by the disaster that was the prequel trilogy, they were actually a high point for me thanks to video games.

I was never that into *Star Wars* when I was younger, having missed the theatrical release of the original films by a good decade or so. Yet it is hard to resist the lure of the Force, and somehow I absorbed Obi-Wan Kenobi, Darth Vader and the rest through cultural osmosis.

As such, my friends and I spent many hours duelling with lightsabers in *Star Wars Jedi Knight II: Jedi Outcast* (don't get me started on how stupid these names are), while the role-playing game *Star Wars: Knights of the Old Republic* showed the franchise's creator George Lucas how prequels should really be done.

So a new *Star Wars* game will always get my attention, and I was eager to get my hands on *Star Wars: Squadrons*, which puts you inside the cockpits of the iconic X-wing and TIE fighter spacecraft. Set after the original

trilogy, the single-player mode sees you swapping between the good-guy New Republic as it tries to build a new battleship and the evil Galactic Empire, which is trying to destroy it.

Piloting the spacecraft is great fun. There are light simulation elements, allowing you to divert power to your engine, weapons

“Boosting power to the engines to escape a tractor beam makes me feel like a whizzy space fighter pilot”

or shields, the last of which can be further refined to protect the front or back of your craft.

In practice, this generally doesn't involve much strategy as you just route energy to whatever you happen to be using at the time, but boosting the engines to escape a tractor beam does make me feel like a whizzy space fighter pilot.

Along with an X-wing and a TIE fighter, you also get a chance to pilot other ships from the franchise like the Y-wing bomber

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Will covid-19 rewire

The pandemic has made the world's economic system feel more broken than ever. *New Scientist* asked six leading economic thinkers how we might want to rebuild it

THE coronavirus has unleashed an economic crisis of a kind never seen before. In just one month, from March to April, the US unemployment rate tripled to almost 15 per cent, and remains uncomfortably high. Elsewhere, only state intervention on a scale virtually unknown outside wartime has staved off the direst consequences. In the UK, gross domestic product (GDP), a measure of economic activity, fell by 20 per cent in the three months to June. To find another fall of that order, you must go back about 300 years.

The events of the past six months have brought to the boil arguments about the economy that have simmered since at least the 2008-09 financial crisis. While the size of the world's economy has quadrupled since 1970, improving the material well-being of billions, the past decade has seen many people's income stagnate and inequality rise (see "Failing system?", page 39). During the covid-19 pandemic, it has become clear some of the most crucial jobs are being done by some of the lowest paid – people who are also among the most likely to die from the virus.

Meanwhile, the focus of conventional economics on growth at all costs is blamed for the ravaging of ecosystems that both made the pandemic more likely and its impact worse. All of this raises two questions: are our economic systems fit for the post-covid-19 era, and, if not, how must they change? *New Scientist* asked six leading economic thinkers for their take on how we got to where we are now, and how we might choose to do things differently.



ROBERTO CIGNA

economics?



PROFILES



Diane Coyle is an economist at the University of Cambridge



Andy Haldane is the chief economist at the Bank of England



Cameron Hepburn is the director of the University of Oxford's Smith School of Enterprise and the Environment



Sandile Hlatshwayo is an economist at the International Monetary Fund



Tim Jackson is an economist at the University of Surrey, UK



Keston Perry is an economist at the University of the West of England

New Scientist: Does the impact of covid-19 on societies show that economics is broken?

Andy Haldane: Like all disciplines, economics evolves by trial and error. At times of crisis, when both trial and error are in plentiful supply, this tends to accelerate. The covid crisis, like the global financial crisis before it, is rightly causing us to rethink things. As one example, we have seen a raft of new economic data being developed and used in the light of the covid crisis to improve our monitoring of the economy in close to real time and at greater levels of granularity, from payments data to Google searches, from road traffic data to energy usage.

Tim Jackson: Economics is broken, but it wasn't covid-19 that broke it. Long before the pandemic, there was a growing recognition that the economy had run into difficulties. Capitalism has left too many people behind. Its impacts on the planet have gone unaccounted for. The causes of the malaise have been variously attributed to debt overhangs, the 2008 financial crisis, political populism. But the truth is that capitalism itself is responsible for its deficiencies.

Sandile Hlatshwayo: Economics is very much alive. As the crisis emerged, many of us immediately put projects on hold and began seeing what contribution we could make. We've seen researchers looking at the economic effects of containment efforts, quantifying the impact of lockdowns on voting behaviour and measuring the increase in mental health concerns. It is also inspiring to see economists like Lisa Cook at Michigan State University, Valerie Wilson at the Economic Policy Institute think tank and Damon Jones at the University of Chicago draw attention to how covid-19 has amplified racial, gender and class inequities.

The goal of economic policies is often thought of as increasing GDP. What should the objective be as we recover from the pandemic?

Andy Haldane: In a word, jobs. The risk I fear most is a return to the high and long-duration unemployment of the



Exotic economics

Negative interest rates

When a bank lends money to people, it charges them and when it stores their savings it pays them. That's the familiar concept of interest. The amount of interest paid varies according to market conditions, but it is usually a small percentage of the amount lent or saved – and, historically at least, is always a positive figure.

Since the aftermath of the 2009 financial crash, however, several countries, including Denmark, Japan and Sweden, have used negative interest rates, which means storing money incurs a cost. The way it works is that central banks charge commercial banks for storing their financial reserves. In theory, this prods those banks to lend as much money as they can, and so stimulate the wider economy. Exactly how this plays out in different contexts isn't clear though, which makes some economists nervous about the strategy.

Universal basic income

Proponents argue that this idea – essentially that states should pay all their citizens a no-strings-attached basic amount to live on – would have all sorts of benefits. It might, for instance, improve societies by giving people more of an incentive to do useful, but poorly paid, activities such as community work or caring for elderly relatives away from care homes. Detractors, meanwhile, argue that it is too expensive and disincentivises normal paid work.

As yet, there is no agreement about how universal basic income should best be implemented or how much people should get. But recent rigorous trials in Finland saw 2000 unemployed people have their welfare payments replaced with a guaranteed basic income. The results showed that people were happier – and they didn't work any less than a control group.

continued on page 40



REUTERS/JESLEI MARCELINO

Last year's fires in the Amazon destroyed precious natural capital

1980s. This blighted the careers and lives of millions of people and their families. The economic policy response to the covid crisis has in part been about seeking to avoid that.

Diane Coyle: It should be to make people better off, where that is broadly understood not only as income, but anything that contributes to people's sense of how well things are going for them. When policies are geared toward increasing GDP growth as the only measure of success, they will deliver distorted outcomes. We need to add a true balance sheet for the economy by measuring the assets we use to produce and consume, particularly natural resources.

Tim Jackson: Pursuing GDP growth for the past 50 years has justified policies that lionise short-term productivity goals and prioritise the interests of capital over those of workers, creating huge social inequalities and preventing long-term investment in people and planet. The last financial crisis exposed the financial and monetary flaws in this system. The global pandemic has exposed the social and human flaws. There have been some attempts to shift to more holistic measures of economic success, such as the UN's Human Development Index and the

Stiglitz-Sen-Fitoussi commission set up by former French president Nicolas Sarkozy. But these haven't yet had the impact needed.

Keston Perry: The objective has to be multifaceted. It's about enhancing the well-being of workers, especially women and black and ethnic minority people. It's about improving the life chances of more unemployed people, especially in the global south. It's about addressing extreme wealth and income inequality, improving welfare systems, ensuring that women have a fair stake in the future. And doing all this in a way that doesn't threaten our planet's habitability or create disproportionate suffering for some groups – as we have seen in the past few months. We cannot simply have unimpeded growth as the end goal; we need to reimagine the global economic architecture.

Another measure economists like to see rise is productivity, often described as output per worker. But that has flatlined lately. Must we keep getting more efficient?

Diane Coyle: Getting more benefit while using the same or fewer resources is how humanity escaped the Malthusian trap, the idea that population growth would inevitably hit the limit of available resources.

“Economics is broken, but it wasn’t covid-19 that broke it”

Productivity drives up living standards and means longer lives, better health, lower infant mortality, more leisure. So it’s fundamental. Productivity increases, delivered through innovation, will be essential to sustaining current living standards and increasing them without bursting planetary boundaries or causing catastrophic environmental crises. However, the way we define and measure productivity needs a complete rethink. There are no “products” for 80 per cent of the economy. What is the productivity of a management consultant or an accountant?

Andy Haldane: Productivity improvement is one of the key determinants of income, living standards and well-being over the medium term. So it would be a grave mistake to abandon that as an objective of public policy. That isn’t the same, however, as having productivity as a singular objective. There are a range of other factors relevant to our future livelihoods which need also to be weighed. As the covid crisis has revealed, that includes improving the resilience of our economies when providing the goods and services critical to its citizens, including health and social care. It also includes purposeful work, an inclusive society and a clean environment.

Some people say we need an entirely new economic system. What sort has the best chance of delivering sustainable prosperity? Should the state be more involved?

Keston Perry: We have lots of evidence that the market-led paradigm has terribly failed our societies. What we need is an alternative that is based on equality and sustainability and one that affords populations in the global south the ability to determine their own futures. The fragments left behind by neoliberalism are of no use for this purpose. But we don’t yet know what the replacement may be, what might emerge from the ruins of the past 40 years. It really depends on how different groups organise to challenge the status quo.

Diane Coyle: The state has always had a role in the economy – this is widely recognised by economists. In the UK, for instance, we have had a long-standing, but unspoken, industrial policy in support of the City of

London, from a favourable regulatory environment to building the train lines and airports to service it. The challenge is to make sure the state’s role is strategic and avoids obvious traps, such as political lobbying by big businesses to get subsidies. Assistance to companies after the pandemic should go to those most likely to survive long term, not those best able to get access to cabinet ministers now.

Many are calling for a Green New Deal, where states create jobs that would help us transition to net-zero carbon. Should this happen?

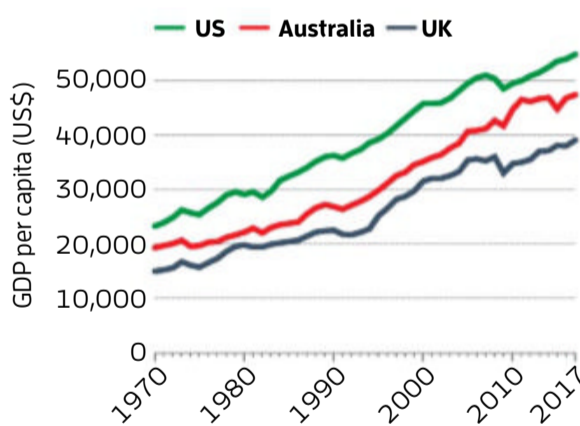
Tim Jackson: We need a Green and Social New Deal, a systematic programme of large-scale social investment to: deliver a “just transition” towards a resilient, fair and sustainable economy; create the social infrastructure of net-zero-carbon lifestyles; and invest in the ecological assets on which tomorrow’s prosperity depends.

Andy Haldane: The UK has set itself an ambitious target of reaching net-zero carbon emissions by 2050. This has provided a kick-start to various initiatives to reshape our energy, transport and housing systems. Through reduced travel and energy use, the covid crisis has provided a down payment on meeting the net-zero objective. But this is only the start. Looking ahead, it will be important to embed the net-zero objective in every policy measure taken.

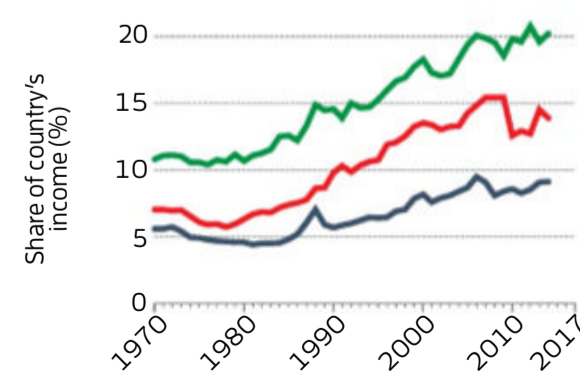
Cameron Hepburn: The world has a unique opportunity to “build back better” after this pandemic has passed. Together with several colleagues, I recently surveyed 231 economists working in central banks or finance ministries and asked which policies would offer a green route out of the crisis and be workable and highly economically effective. We identified five key policies. For example, investing in clean energy infrastructure construction will create more jobs in the short term than investing in fossil fuels. Other good options would include retrofitting buildings for better heat efficiency and restoring natural capital such as forests. Decisions made in the coming months about how to guide the economic recovery may determine whether we can avoid the worst impacts of climate change. ➔

Failing system?

The wealth of many developed nations has climbed steadily over the past four decades...



... but at the same time inequality has risen, with the richest 1 per cent accruing a greater share of income



SOURCES: OUR WORLD IN DATA; FEENSTRA ET AL. (2015) PENN WORLD TABLE 9.1; WORLD WEALTH AND INCOME DATABASE (2018)

continued from page 38

Modern monetary theory

Thanks to the general economic malaise and backing from the likes of US congresswoman Alexandria Ocasio-Cortez, this once-niche idea is getting a wider hearing.

Governments get their money by taxing citizens and issuing bonds. Government bonds are generally bought by big banks, and are effectively a way for the state to borrow. For a given government, the more bonds it wants to sell, the higher the cost of that debt will be. This increases interest rates for everyone. If governments carry on borrowing, their currency will eventually be worthless – not a good look.

Modern monetary theory says that conventional view is just wrong. Governments can issue their own sovereign currency and there is no straightforward relationship between how much they do this and interest rates. In this view, high levels of government debt are unproblematic – an attractive prospect for those who would like to see nations spend their way out of the covid-19 crisis.

Well-being economy

Maybe the goal of economics shouldn't be to make us richer, but happier? It is an idea several countries have toyed with over the years. Now it is gaining greater renown after New Zealand's government pledged to make its spending decisions on the basis of what has the most potential to boost citizens' well-being.

Doing this depends on being able to define and measure well-being. How to do this isn't universally agreed, but it inevitably involves a range of factors including people's mental and physical health, the environment and equality. Policies can then be judged against their potential to improve these measures. There is now a network of governments, including the Scottish government, working to normalise these practices. **Joshua Howgego**

Our world is highly interconnected and this helped the virus spread quickly. Do we need to curb globalisation?

Tim Jackson: The pandemic was a creature of exchange. It probably emerged from an exchange between bats, or possibly pangolins, and humans. It passed from person to person in the ordinary everyday social exchange that creates society. It spread so rapidly because of highly globalised economic exchange. And its immediate effect was to stop much of that exchange in its tracks. It's hard to conceive how fundamental that is. Exchange is supposed to be an irreducible virtue; the foundation for markets. We must now ask ourselves searching questions about the kinds of exchange that matter most. Globalisation as an unequivocal good is over. More sophisticated models of global connectivity are still possible, but will require greater attention to these dangers.

Sandile Hlatshwayo: This is a truly global crisis and so now is exactly the moment for enhanced global cooperation. Take vaccines – we have scores of them under development, but only a select group of countries have the resources to mass-produce them. This means we'll need a Herculean collective effort to manufacture and distribute vaccines around the world. There is much to be gained for everyone from this kind of cooperation because many countries will depend on the removal of travel restrictions and a rebound in global demand to get their economies going again. Plus, if collaboration on vaccines is carefully

“Globalisation should not look the way it did in prior eras – it must look far better”

navigated, it could reignite global cooperation in other important spheres, such as climate change and trade. Globalisation should not look the way it did in prior eras – it must look far better.

There are unorthodox economic ideas around at the moment, including negative interest rates, universal basic income and modern monetary theory (see “Exotic economics”, page 38). Should any of these be rolled out now?

Andy Haldane: It is important that nothing is ruled out. That has certainly been our stance

GLOSSARY

GLOBALISATION is the process of the world's increasing interconnection. International travel and trade have risen hugely in the past 50 years and this has changed the sorts of work people do in different countries.

THE GREEN NEW DEAL is a proposed scheme in which governments create jobs in

sectors that would help in the fight against climate change, such as renewable energy. It takes its name from a set of financial reforms called the New Deal that were introduced in the US in 1933.

GROSS DOMESTIC PRODUCT (GDP) is the value of all the goods and services produced in

a country. This figure is often quoted for a specific time period.

INFLATION refers to the increase in the price of goods and services – anything from a house to a back massage. Gradually rising prices aren't a problem, unless earnings fail to keep up.



Relatives hug in Brazil using kit to prevent covid-19 infection. Can post-pandemic economics take more account for such intangibles of life?

I am not quite convinced about the merits of modern monetary theory, especially in developing countries. This idea has a particular intellectual and empirical context and may be useful in one situation and not others.

Tim Jackson: As we emerge from the pandemic, the protection of people's livelihoods is paramount. Mechanisms such as a universal basic income and a reduction in working hours are legitimate instruments in this task. But we should also have job guarantee schemes in vital sectors such as care, education, renovation and the arts. The inevitable pushback against such proposals will be the question: who pays for them? This is where the insights of modern monetary theory become crucial. It argues that governments that issue sovereign currency can spend directly into the economy without raising taxes or issuing debt. The ability to finance interventions such as furlough schemes at the height of the pandemic effectively proves this point.

at the Bank of England. We continue to review the costs and benefits of all our potential tools, including quantitative easing, credit easing and interest rates. All of these are different means of achieving the same end: monetary and financial conditions sufficient to return inflation to its target, while supporting jobs and the economy.

But I am sceptical of the case for so-called modern monetary theory – permanent expansions of the central bank balance sheet to finance government deficits. If pursued at scale, they run a serious risk

of destabilising inflation, as has been found at times in the past.

Keston Perry: Negative interest rates have already helped some advanced economies in the wake of the 2009 crash. But we must acknowledge that less-developed economies don't have the same capacity to use them. We need to allow central banks and institutions in the global south leeway to manage their own recovery. The challenge is that we are relying on ideas that are past their sell-by date, such as quantitative easing.

Cameron Hepburn: We already have negative real interest rates in many countries. When this is the case, governments are being paid to borrow and it is a complete no-brainer for them to invest in natural capital.

There is a saying about modern monetary theory: the bit that is modern doesn't work and the bit that does work isn't modern. Part of the theory is about central banks printing money for the government to spend. There is nothing unusual about this. But if too much money is printed too quickly, the result will be inflation.

MONETARY AND FISCAL POLICIES

both help to shape a country's economy but they are controlled differently. Monetary policy means the actions taken by central banks, such as setting base interest rates. Fiscal policy is about taxes and spending on public services, which is a government's purview.

NEOLIBERALISM

is the term for the economic world view that has been dominant in developed nations for the past 50 years. It broadly means a deregulation of markets, limited state spending and global free trade.

PRODUCTIVITY

refers to the amount of effort

and money required to produce a given product or service.

QUANTITATIVE EASING

is when a central bank creates money and effectively loans it to the government, increasing the amount it has to spend. This also tends to encourage spending in the wider economy.

What future developments do you envisage upending prevailing economic models?

Diane Coyle: Much more data. Our current statistical models were developed before enough fine-grained economic data became available. They are improving, but we are still like weather forecasters a century ago.

Andy Haldane: Now, if I knew the answer to that... One thing that can be said with confidence is that some of the pre-covid megatrends, including climate and biodiversity issues and AI and automation, are likely to be accelerated by covid. These will reshape economies fundamentally. ■

Here kitty kitty

To stop cats killing wildlife,
we should enlist the help
of people who love them,
finds **Aisling Irwin**



SHUTTERSTOCK/EVAGAI

ARIE TROUWBORST wasn't expecting death threats when he published his paper on cats last November. An environmental law specialist at Tilburg University in the Netherlands, Trouwborst and Han Somsen, also at Tilburg University, had argued that cat owners across the European Union could be prosecuted under existing law for allowing their pets to hunt. "I routinely address controversial topics like wolf management and trophy hunting, but they all pale when compared to the vicious reactions this received," he says.

It is the latest episode in the ongoing "cat wars". From New Zealand and Australia to the US and Europe, cat owners and conservationists are pitted against each other as a growing body of research finds cats guilty of killing wildlife and squeezing out native rivals. One headline-grabbing report, for example, estimated that free-ranging domestic cats kill at least 1.3 billion birds and 6.3 billion small mammals each year in the US alone. Another study found that pet cats in the Netherlands kill almost twice as many animals as their feral counterparts.

Emotions are running high, and the angrier conservationists become, the more cat owners dig in. But there could be a better

way. "I get quite sick of the conflict focus of some conservation biologists," says Wayne Linklater at California State University, Sacramento. "The solutions lie with the people who care most about cats, not with the people who don't care about them." To that end, he and a few other social scientists are studying cat owners themselves to find out what would motivate them to change their – and their cats' – behaviour.

Nobody doubts that cats kill wildlife: it is in their nature to hunt (see "Are cats really domesticated?", page 44). Yet even experts can't agree on how significant the problem is. The UK's Royal Society for the Protection of Birds, for instance, says there is evidence that cats probably prioritise weak or sickly birds that would have died anyway. What is clear is the scale of the issue: cats are humanity's second most popular pet, with 373 million kept worldwide. If their hunting is to be reduced, wildlife advocates need to persuade

"Free-ranging pet cats kill almost twice as many animals as their feral counterparts"

cat owners to curb their furry companions' pursuit of prey.

The chasm between cat owners and conservationists becomes apparent when you ask for their views on measures to reduce hunting by cats. That is exactly what Linklater did in New Zealand, working with Edith MacDonald at the country's Department of Conservation among others. They first asked conservationists to rank the effectiveness of nine interventions. Top of their list was keeping cats indoors 24/7, followed by other restrictions such as fencing in the garden. At the bottom was neutering, registration and, finally, microchipping. They then asked vets and owners to rank the same interventions based on cat welfare and acceptability, respectively. They placed them in almost the opposite order.

These polarised views lie at the heart of the cat wars. For the researchers, exposing them was the first step in finding a solution. Social scientists know that if you want to change people's behaviour, you need to understand your audience and the things they care about. Evidence from interventions in areas such as public health shows that people are more likely to change if they like the new idea, think it is feasible and think others already do it or should be doing it. With this in mind, ►

"Cat owners love their animals and nature. But if you make them choose, they will probably choose the cat"

MacDonald, Linklater and their colleagues decided to use a technique called behaviour prioritisation to identify the intervention most likely to be considered acceptable by cat owners and effective by conservationists.

Their calculations, based on the weighting that both groups assigned to each of the nine alternatives, revealed a nightly cat curfew to be the best compromise. However, in interviews with other cat owners, the team found that only 14 per cent of people who implement a nightly curfew do so to safeguard wildlife. The vast majority cited reasons such as keeping their pets safe or comfortable or increasing family happiness. They also said they respected the opinions of vets and

relatives but not MacDonald's government department or even New Zealand's Society for the Prevention of Cruelty to Animals.

Armed with these findings, the researchers designed two pamphlets. From one beams a pig-tailed girl clutching a luxurious cat. "I love it when Fluffy sleeps on my bed," she says. "Bring your cat in at night." There is no mention of macerated geckos or dwindling kiwi populations. A vet gazes out from the second pamphlet. "Keep Fluffy safe from cars. Bring your cat in at night," he says. The team handed out the pamphlets at vet surgeries in four cities, including Wellington and Auckland, as part of a survey and gave a control group an unrelated brochure.

Six weeks later, the researchers spoke to the participants again. Spring had arrived and those in the control group were letting their cats out 10 per cent more at night than before. But the group that received the pamphlet featuring a vet hadn't increased nightly forays, and those that received the one featuring a little girl had reduced night-time cat releases by 10 per cent. MacDonald is delighted by the findings, which haven't yet been published, pointing out that behaviour is notoriously difficult to change. What's more, the team's insights have been used by several city councils in New Zealand and incorporated into the country's National Cat Management Strategy. "Never demonise cat owners," says MacDonald. "They love their animals and they love nature. But if you make them choose, they will most likely choose their cat."

Natural order

Another way to coax people to change their behaviour is to better understand what motivates it in the first place. In Australia, Lynette McLeod at the University of New England and her colleagues successfully used behavioural science to help implement campaigns to curtail or remove domestic cats from islands. They found that a variety of attitudes, perceived norms and practical constraints led people to let their cats out of the house. Solutions, therefore, needed to be tailored. For example, if cat owners believed

Are cats really domesticated?

The cat family evolved from other carnivores about 11 million years ago and, apart from size and coat patterns, cats haven't altered much since then. In 2017, Claudio Ottoni and his team at KU Leuven in Belgium and the Institut Jacques Monod in France analysed the mitochondrial DNA of some 200 cats that lived from 9000 years ago to today. This revealed two major genetic lineages. They first emerged about 11,000 years ago in the Fertile Crescent in the Middle East, when wildcats started to frequent human settlements to hunt for rodents feeding on the surplus grain produced by early farmers. These spread to Europe at least 6500 years ago. Then, during the Greek and Roman periods,

African cats from Egypt made their way to Europe. By the 8th century, their reach extended to the Baltic Sea in the north and Iran in the east.

But that wasn't domestication – it was a sort of symbiosis, in which cats and humans came to live together for their mutual benefit. Ottoni's team found no genetic evidence of humans breeding cats until the Middle Ages, less than a millennium ago. In fact, the average house cat (*Felis silvestris catus*) is almost indistinguishable, genetically, from the European wildcat (*Felis silvestris silvestris*). Cats may have close associations with humans, but they can survive on their own. They are still hunters – which is increasingly problematic today (see main story).



their pets must roam to be happy – as many did – they were shown videos of happy cats thriving indoors. Those who “just didn’t know how to do it”, meanwhile, were given the know-how and kit to contain their cats and to enrich their home. It is a question of finding the right button to push, says McLeod. “Just giving people information is not going to make them change their mind.”

Researchers in the UK are also trying to get inside the brains of cat owners, in an attempt to head off cat wars before they become acrimonious. Working with the UK charity SongBird Survival, social scientist Sarah Crowley at the University of Exeter and her colleagues have carried out numerous consultations with cat owners. The same beliefs keep coming to the fore: hunting is natural, preventing it is wrong and not much can be done to stop it anyhow. Yet the ambiguity in these ideas can be highlighted with deeper discussion, says Crowley. Even the word “natural” can have two different meanings when applied to cats. As innate behaviour, hunting is natural – but as part of the local ecosystem, domestic cats can be seen as an unnatural introduction, whose large numbers distort the “natural” balance.

Crowley’s team is also exploring potential ways to decrease hunting with cat owners. These include the use of brightly coloured ruffs, meatier cat food, prey-mimicking

Keeping cats indoors or walking them on a leash (below) are humane measures to reduce their impact on wildlife



puzzle balls and owners playing indoors with their cats to relieve domestic tedium. Crucially, it isn’t just the cats being studied – the owners’ views on the workability of different options will influence what the scientists finally recommend.

Linklater acknowledges that these sorts of approaches are slow and only achieve a modest intervention for a small percentage of owners. The power lies in incrementalism, he says. “Once you have cat owners engaged, then they are more likely to want to do the next thing, and then the next thing.” In parts of Australia, he points out, night curfews are increasingly accepted and the conversation has moved on to 24-hour confinement.

Another believer in incrementalism is Grant Sizemore, who runs the Cats Indoors programme for the American Bird Conservancy. The campaign aims to “create a social norm that can be reinforced over the years”, he says. The main tool is asking owners to sign a pledge that they will keep their pets “safely and responsibly indoors, on a leash or in an enclosure”. Sizemore admits that he doesn’t know whether the 5000 owners who have signed up so far are complying. However, MacDonald’s research shows that owners who make a public commitment are more likely to carry it out.

Sizemore encourages pledgers with regular emails and interviews with cat influencers, such as Atlas the Adventure Cat. The American Bird Conservancy also promotes kit such as cat enclosures for the garden, called catios, backpacks and leashes.

Cat owners are starting to change their behaviour, but Trouwborst worries that change is too slow. Governments are legally obliged to achieve results, he says, not just demonstrate effort, so they may need to take a different route. “Ultimately, all interventions [to change behaviour] involve national legislation at some stage,” he says. ■



Aisling Irwin is a science journalist specialising in environmental issues. She tweets @Aisling_Irwin



The new age of sail

We are on the cusp of a new type of space travel that can take us to places no rocket could ever visit, says **David Hambling**

JOHANNES KEPLER is remembered for writing down the laws of planetary motion. But the 17th-century astronomer also liked to observe comets and, one day, he noticed that their tails always pointed away from the sun, no matter which direction they were travelling in. To Kepler, it could mean only one thing: the comet tails were being blown by a wind from the sun.

The idea must have seemed exotic in Kepler's day, but he floated it in a 1610 letter to his friend Galileo Galilei. "Provide ships or sails adapted to the heavenly breezes, and

there will be some who will brave even that void," he wrote. You would be forgiven for smiling at the thought. But Kepler was right. The sun produces a wind in space and, in principle, it can be harnessed.

There is no shortage of reasons to try. Rockets may be great for blasting us into orbit, but their limitations are serious. Their finite supply of propellant puts a cap on the manoeuvres they can make. Build a solar sailing ship for space, though, and you can tap into the effectively limitless source of power that Kepler noticed all those years ago.

There is a craft demonstrating this in Earth orbit right now. With no need for fuel, this technology could also enable long-term observation posts in space. Meanwhile, NASA has advanced plans to sail to asteroids in regions of usually inaccessible space – and who knows what we might find when we begin to explore such places. We may be on the cusp of an exciting new age of sail.

When the wind touches our cheek we are feeling molecules of the atmosphere brushing against it. The wind in space is made of different stuff. First, there are particles of light streaming from the sun constantly, each carrying a tiny bit of momentum. Second, there is a flow of charged particles, mostly protons and electrons, also moving outwards from the sun. We call the charged particles the solar wind, but both streams are blowing a gale.

In 1924, Friedrich Zander, a scientist working in the Soviet Union, developed the first serious solar sail concept. He imagined harnessing light, not charged particles, because all that would be required is a huge mirror for photons to nudge along. Decades before space travel became possible, Zander understood that sailing would provide a unique way of getting around up there.

Today, rockets are the workhorses we rely on, whether for a short hop to the

“With its steady acceleration and enough time, a solar sail can catch up with anything”

International Space Station or a mission to Pluto. A rocket operates on the principle of action-reaction: as it fires out propellant in one direction, a force moves the craft the other way. Beyond our atmosphere, there is no friction, so a rocket will stay on the same trajectory unless affected by another force, such as the gravitational pull of a large object. This means that if a rocket wants to slow down or change direction it must expend propellant. The size of the fuel tank limits how much of this it can do.

This is why spacecraft routinely exploit the gravity of planets, orbiting a few times then briefly firing their thrusters to slingshot themselves in a new direction. But this tactic has limits. For one, it means that craft can only launch during a time window when the alignment of the planets is right. Plus, it only works within the narrow plane that our solar system's planets orbit in, known as the ecliptic.

There are other intriguing bodies that orbit in different planes. Take Eris, a dwarf planet that is more massive than Pluto. Or Pallas, the third largest asteroid we know of, which orbits at a wild angle of 34 degrees to the ecliptic. The off-kilter tracks of these bodies show that they have a different history to the

The sail of NASA's Near Earth Asteroid Scout probe is small and tidy when packed up



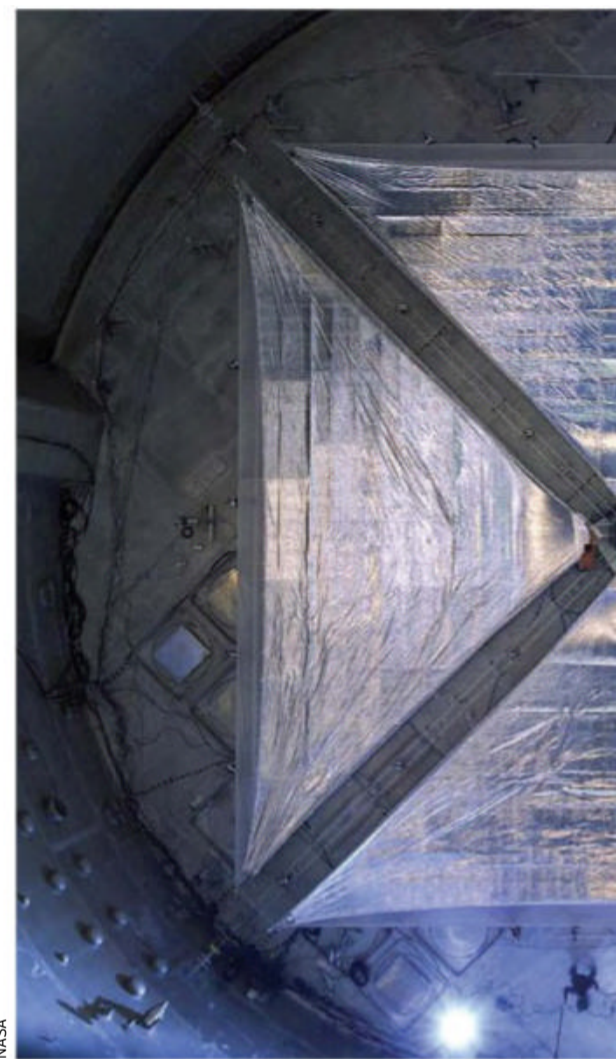
rest of the solar system. Visiting them to learn about it would require a prohibitive amount of rocket fuel – but sails have no such limitation. “Solar sails can get you to places that you can't get to with conventional propulsion,” says Les Johnson at NASA's Marshall Space Flight Center in Huntsville, Alabama.

Sailing in space

Catching the solar breeze demands a sail that is wide but paper-thin, to net as many particles of light, or photons, as possible without being too heavy. But you can't have a delicate sail flapping around during a launch into space. This means sails must be packed up and unfurled beyond the atmosphere – a devilish challenge. We only showed this could be done in 2010, when JAXA, the Japanese space agency, launched its IKAROS probe. It reeled out a tape that was then stretched into a 0.007-millimetre-thick square sail measuring 20 metres diagonally.

A sail that size wasn't large enough to noticeably move the probe it was attached to. Then along came CubeSats, tiny, cheap satellites that could be controlled from the ground. “CubeSats made it financially viable for an organisation like us to demonstrate the technology,” says Bruce Betts at the Planetary Society, which is dedicated to space advocacy. After a failed attempt in 2015, the society's LightSail 2 mission was launched last year. At first, operators struggled with the sail, which is about the size of a boxing ring, and the craft tumbled. But after some adjustments, they established control and showed that a craft could manoeuvre using light pressure alone.

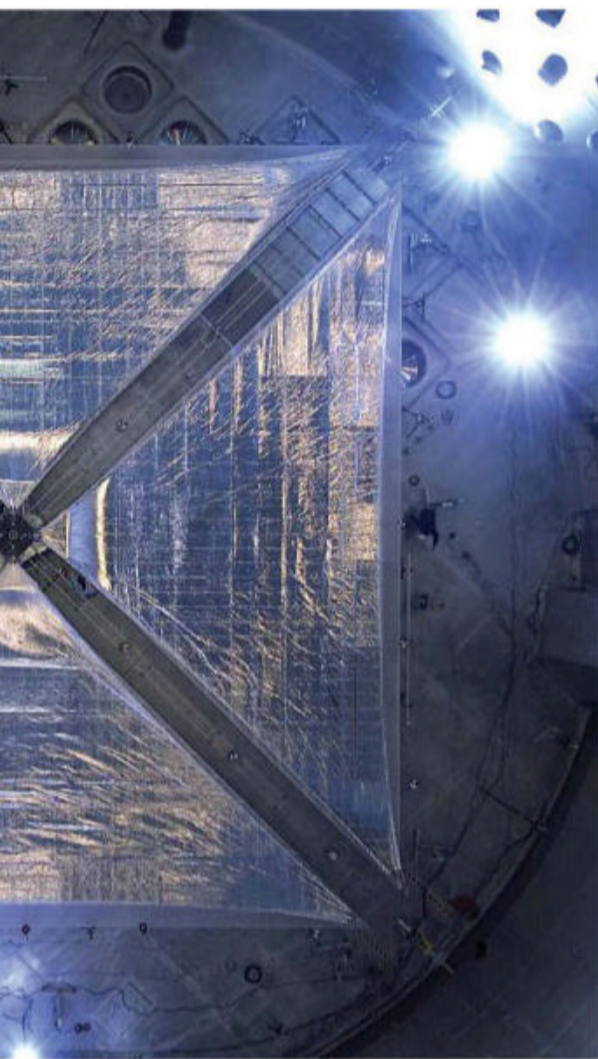
LightSail 2 was expected to last a year, but it has experienced less wear than anticipated and is still going. “We didn't know how it would work out,” says Jennifer Vaughn, also at the Planetary Society. The craft has successfully shown that the sail can be used to change its orbital height, by up to 2 kilometres so far. The biggest surprise has been how hard it is to steer. To sail steadily, the craft's centre of mass must line up exactly behind the centre of thrust provided by the



NASA

sail. The lack of friction in space means this can easily slip and, if left uncorrected, the craft gets out of control. LightSail 2 has been in so-called “de-tumble mode”, correcting the alignment, for a third of its time in orbit.

Johnson has plans for much more ambitious voyages. First on his destination wish list are asteroids on oval-shaped orbits that pass close to Earth before zipping off into the outer reaches of the solar system. We have never visited such objects because they speed past us so quickly that a rocket can't catch up. But Johnson is planning a mission called Near Earth Asteroid (NEA) Scout, due for launch in 2021, which might do it. “With its slow, steady acceleration, and given enough time, a solar sail can catch anything,” he says.



The exact target isn't yet decided, but it could be an object measuring about 12 metres across called 1991 VG, which veered close to Earth in 1991 and 2017. Such objects could hit our planet, so finding out more about them – for instance, whether they are sturdy boulders or piles of loose rubble – could help us protect ourselves. The NEA Scout team is learning lessons from LightSail 2; the NASA craft will have a special mechanism to keep its sail and centre of mass aligned.

The next step for space sails could well involve staying perfectly still. That is more useful than it might sound. A spacecraft perched in interplanetary space could make long-term observations, for instance of solar storms surging towards Earth. Johnson is

planning to test this idea with a proposed mission called NASA Solar Cruiser. On its first leg, the probe would slip into a spot called the L_1 Lagrange point. Here, the gravitational pulls of the sun and Earth balance out. The trouble is that staying there is like trying to balance on a needle; whatever you put there would need to apply small forces to stay in position. A rocket would eventually exhaust itself, but a craft with a light sail can, in theory, remain there indefinitely.

After attempting to hover at the L_1 point, Solar Cruiser would tack towards the sun. Most rockets we send this way approach using gravity assists to slow down and so must stay in the ecliptic. This wouldn't be a problem for Solar Cruiser, which would drift upwards and try to hover over the solar poles. These are thought to be critical to the sun's weather, but they are hard to study, being out of sight from Earth. The only effort that aims to do something similar is the European Space Agency's Solar Orbiter, which launched in February. Its goal is to get the first pictures of the poles by slipping into an inclined orbit around the sun, but this will take a huge amount of fuel.

Johnson's sails would be pushed by light – which is fine if you are exploring around the sun. But as light spreads out it gets more diffuse; a solar sail in the depths of the solar system just won't have as much light to fill it. This is why Pekka Janhunen at the Finnish Meteorological Institute thinks we need to sail not just with photons, but with the solar wind, the flow of charged particles.

It is true that the solar wind also gets more diffuse as it streams away from the sun. But in 2006, Janhunen came up with an idea for how to harness its power even quite far out. The electric sail, or e-sail, would consist of dozens of wires many kilometres long radiating from a hub. The whole thing would spin slowly to keep the wires straight. Each wire would carry a positive electric charge so that when positively charged protons in the solar wind bump against them, they repel the sail and give it a push. But here is the nifty part: closer to the sun, the powerful solar wind would mostly rifle through the gaps

ESO/L. CALÇADA AND NICK RISINGER (SKYSURVEY.ORG)



An artist's impression of Eris (above) where solar sails might take us. A 20-metre wide sail tested at a NASA facility (centre)

between the wires. Further away, the solar wind is gentler and would catch the sail nicely. This counter-intuitive bit of physics could provide a way to sail in the outskirts of the solar system.

The first Finnish e-sail mission in 2013 failed, but Jaan Praks at Aalto University, also in Finland, says the team is working on successors called Foresail-1 and 2. The aim of these missions is to use a single wire design to apply a slowing force and de-orbit a satellite at the end of its life. It is a finger in the wind that could help get us to bigger and better e-sails. NASA is also interested in this technology and is developing the concept into the Heliopause Electrostatic Rapid Transport System. Ground experiments suggest this could reduce the transit time to the edge of the solar system by 60 per cent compared with a conventional rocket.

As any sailor knows, the wind isn't a perfect source of propulsion because you can only sail so close to it before you have to start tacking and gybing. This means any cosmic sailing ship would clip along nicely when going away from a star, but would struggle to turn back.

Still, this won't impede the dream of people like Johnson, who want to use these new techniques to set a course for worlds currently far beyond our reach – namely the planets orbiting our nearest star, Alpha Centauri. To do that we would need to accelerate a solar sail to about a fifth of light speed, which, if not easy, isn't impossible. "My career goal is for my work on the solar sail to be a footnote when they write the history of the exploration of Alpha Centauri," says Johnson. "I want to see a future where we are exploring other stars." ■



David Hambling is a technology journalist based in London



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Science of gardening

How to hack your hydrangeas

From pale pinks to deep blues, hydrangeas come in many shades. Use cunning chemistry to choose their colour, says **Clare Wilson**



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

What you need

A hydrangea plant
A soil pH test kit
Aluminium sulphate
or garden lime powder

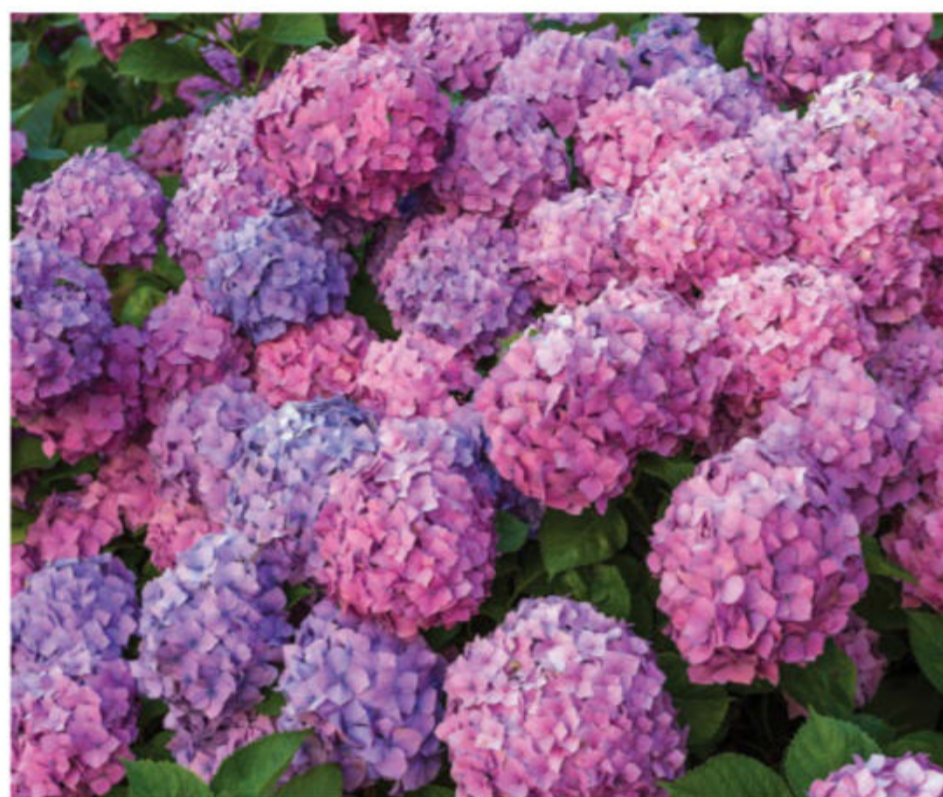
RECENTLY, my friend emailed me with a question: "What's happened to my hydrangeas?" She had been given a bush with beautiful blue flowers, yet within a few months they had turned a drab green.

Hydrangeas are a group of plants that are usually a wonderful addition to a garden as they bear large, striking flowers for several months from midsummer. Some popular varieties also have a unique quality: the colour of their blooms is remarkably sensitive to their growing conditions.

Depending on soil chemistry, these hues can range from dark red through pink and green to the deepest blue. While this may be annoying if you have your heart set on one colour, it also lets canny gardeners play with their palette.

Hydrangeas' malleability stems from a pigment in their flowers called delphinidin-3-glucoside that is blue when it binds to aluminium and red when it doesn't. Under acidic conditions with a pH of around 5 or below, the plant can take up more aluminium from the soil, making the flowers blue. With neutral or alkaline conditions, less aluminium means pinker flowers.

Many home remedies are said to alter soil's pH, like sprinkling epsom salts or coffee grounds on it, but these don't always work well. Better to buy commercial products such as aluminium sulphate, which both lowers pH and boosts aluminium, or garden lime powder for alkalinity. It is easy to find your soil's pH using test kits sold at garden centres.



CHRISTOPHE COURTEAU/NATUREPL.COM

It isn't all plain sailing, though. There are many different species and varieties of hydrangea, and some incline more to one hue than others, so check the label before you buy if you have a particular colour in mind.

Soil in some areas can also be stubborn. "If you garden on a chalk soil or limestone, no matter how acid you try to make the soil, it will act as a buffer and restore to alkaline," says Guy Barter at the UK's Royal Horticultural Society. "In those situations, a container is your best bet." Be sure to use a planting compost with the right pH, too.

Back to my friend. By the time I replied to her message, her flowers had changed colour again. She lives in Oregon and her plant had been subjected to showers of ash

from the wildfires that are ravaging the western US states.

Within days, her hydrangeas were multicoloured, with different parts of the same flowers now pink, white and green. That is because wood ash contains compounds that make soil alkaline, although I am surprised how quickly they acted in this case, as colour changing often takes months.

My friend plans to continue pinking up her flowers in this rough and ready way by applying wood ash from her home fireplace, rather than buying products from a store. This is fine as long as the wood hasn't been treated with preservatives. ■

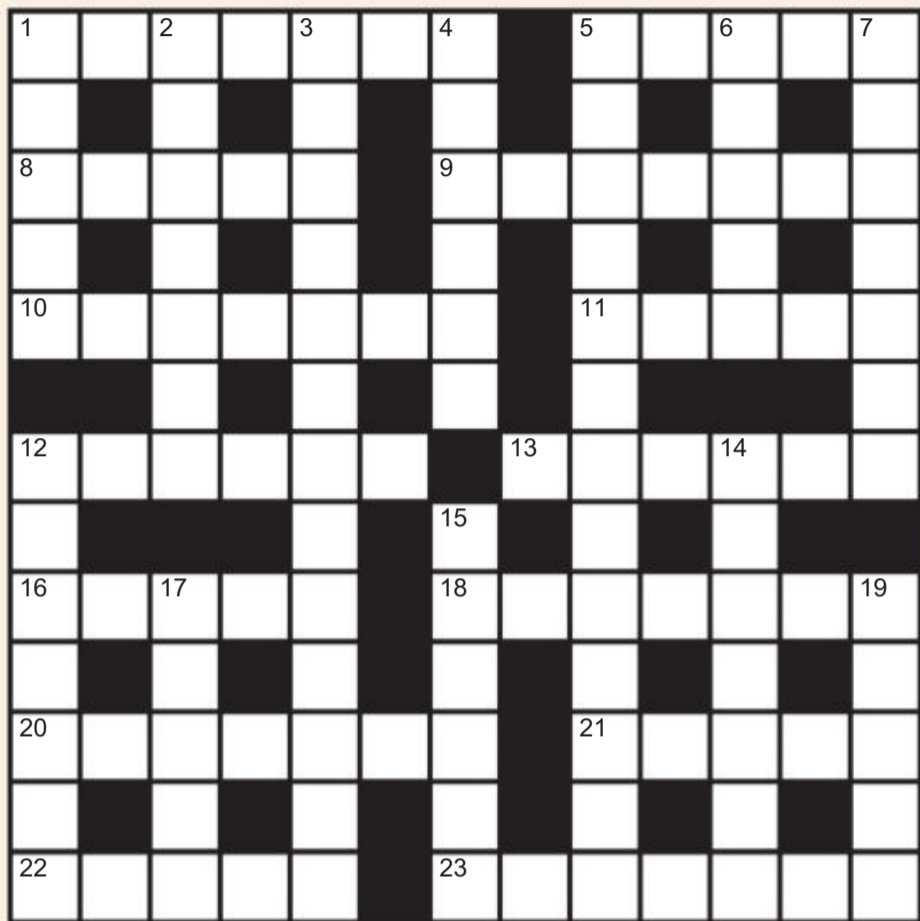
The science of gardening appears every four weeks

Next week

Science of cooking

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

Cryptic crossword #43 Set by Rasa



Scribble zone

Answers and the next quick crossword next week

ACROSS

- 1 Bright spot in the night sky is new to grads (3,4)
- 5 Provoke gander for the audience (5)
- 8 Burn top of marshmallow for one flavour of 6 Down (5)
- 9 Cost to ride American ferry initially absorbed by Stark (3,4)
- 10 "Vaguely informal" is not accepted aboard jet (7)
- 11 Become irritating after the first joint (5)
- 12 Design pro gymnast's surface (6)
- 13 Tyrant posted in a deranged fashion (6)
- 16 A swelling cell component (5)
- 18 Illuminated drone protects current example of 7 Down (7)
- 20 Algebra illegibly obscures tactile writing (7)
- 21 Had in mind average temperature (5)
- 22 Type of stress that woman disparages, essentially (5)
- 23 Almost effortless to supervise part of London (4,3)

DOWN

- 1 Joe, an unexciting sort, stood before flipping (5)
- 2 Starting to goad less industrious tradesperson (7)
- 3 The Doctor, for example, spilled litre over New York ballplayer and Bolero composer (4,9)
- 4 Steak and bread contaminated with iodine and beryllium (6)
- 5 Petty officer mounts and packs collectible items (7,6)
- 6 German cheese, one that comes in six flavours (5)
- 7 Table item: elect to replace head of company with multiple guys (7)
- 12 Sets alight bit of furniture with innocents covering up error (7)
- 14 Say, human liver spread around outer edge (7)
- 15 Gene is celeb not taking sides after all (6)
- 17 Make speech with zero merit (5)
- 19 After upsetting verbal stumble, talk organiser is silenced on a Zoom call (5)

Quick quiz #75

- 1 The majority of Earth's ozone is found in which layer of the atmosphere?
- 2 Gorillas appear to exclusively have what blood type – A, B or O?
- 3 In what year was the Petri dish invented?
- 4 Where would you find the world's largest megalithic stone circle?
- 5 What name is given to the spinning ring of gas, dust and other material that surrounds a black hole?

Answers on page 55

Puzzle

set by Colin Wright

#83 Albatross

Perched on top of the ship's mast, the albatross winked at his nemesis Captain Pugwash, who was lying on the deck below. "I'll get that wretched bird," cursed the captain, seizing a catapult and loosing a stone. It was a perfect aim, but at the moment the stone was released the albatross started to fly away horizontally. The stone passed through where the albatross had been and rose a third as high again.

"Drat," said Pugwash, but his disappointment turned to joy when the stone struck the bird on the way down. "Perfect hit," said Mr Suvat the navigator, reaching for his astrolabe, watch and ruler to work out how fast the stone was moving horizontally to be able to hit the bird.

"No need for any of that," said Tom the cabin boy. "Albatrosses fly at 10 knots and the path of the stone was a parabola. That's all you need to know."

What was the horizontal speed of the stone?

Answer next week



Our crosswords are now solvable online

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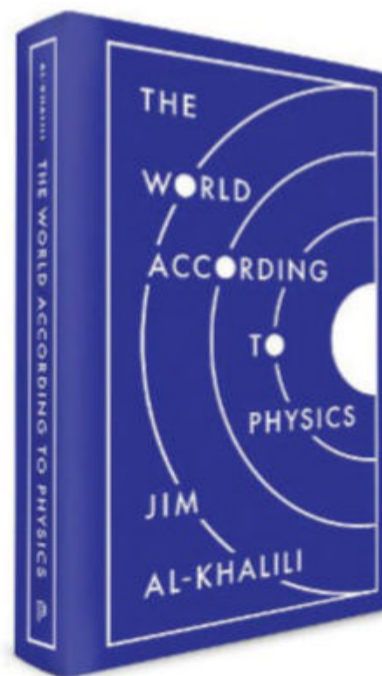
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Birdily functions

Are there any species of bird that hiccup? If so, why would they do this?

Richard Jones

*Avian Veterinary Services,
Northwich, Cheshire, UK*

Hiccups are caused by involuntary contractions of the diaphragm. Birds don't have a diaphragm, so it is technically impossible for a bird to hiccup in this manner.

Birds' lungs don't expand and contract as they do in mammals. They are essentially a pair of spongy structures that are ventilated by a series of air sacs. When the bird "breathes in", the intercostal muscles between its ribs raise the sternum to suck air into the air sacs. I haven't come across hiccup-like spasms in birds, but I suppose it could be possible for an involuntary spasm of the intercostal muscles to result in the avian equivalent.

However, I wouldn't be at all surprised if a parrot mimicked a human hiccup. I have seen many

"I wouldn't be surprised if parrots could mimic a human hiccup. I have seen many that imitate their owner's cough"

parrots – usually grey parrots – that seem to have nasty coughs when, clinically, they are absolutely fine. Then I hear an identical cough coming from the owner in the waiting room...

Nina Dougall

Malmsbury, Victoria, Australia

I have kept domestic hens for years and have noticed that they often appear to hiccup after eating large amounts of food too quickly.

Luce Gilmore

Cambridge, UK

Sage grouse make hiccup-like noises, but do so voluntarily in a "lekking" courtship display, because other grouse find it sexy.



JACKFROST/GETTY IMAGES

This week's new questions

Fifty shades of green Why are tree leaves so many different shades of (mainly) green? *Howard Watkins, Goring-on-Thames, Oxfordshire, UK*

Squeaky bite Why does halloumi cheese "squeak" against your teeth when you bite into it? I don't know of any other food that does this, including other cheeses. *Richard Jackson, Coldstream, Berwickshire, UK*

Cloud control

On a still day, clouds move slowly across the sky. How much of this is due to Earth's rotation? Do clouds seem to move faster at the equator?

Peter Burszty

Barrie, Ontario, Canada

Clouds move in response to the local winds. Although the air immediately around you may be still, the winds are far stronger thousands of metres higher up. That is why clouds are usually in motion, even on apparently windless days. But part of a cloud's motion is indeed governed by Earth's rotation.

Strong solar heating at the equator causes the air above it to expand, forming a zone of low pressure, causing air to move in

from the north and south. These "trade winds" are then deflected due to Earth's rotation, in a process known as the Coriolis effect that explains how objects move on the surface of a rotating body.

The equatorial surface moves faster east than the wind – the velocity of the land at the equator is an astonishing 1670 kilometres per hour – so what began as a north-south wind appears to be blowing from the north-east. The same effect occurs in the southern hemisphere, so the southern trade winds blow from the south-east.

Anthony Woodward

Portland, Oregon, US

Earth's rotation has some influence on the direction in which the clouds move, but isn't the cause of their movement.

Why do the leaves of trees come in so many different shades of green?

Fortunately for us, the main bulk of the atmosphere moves in sync with Earth itself. Otherwise, we would be swept off our feet when trying to stand up.

I live in Portland, Oregon, which is close to 45° latitude, so I am moving at about 1180 kilometres per hour around Earth's axis. I don't notice this because the atmosphere is moving at the same speed as I am. Yet portions of the atmosphere can move in relation to the surface of Earth, giving us winds. The major cause of these winds is the differential heating of Earth's surface.

Mike Follows

*Sutton Coldfield,
West Midlands, UK*

People used to believe that Earth was the centre of the universe, and reasoned that a wind would blow in the opposite direction to that of a moving Earth. Some who think we live on a flat Earth may share this belief. The clouds, however, allow us to see global air circulations, particularly if we have time-lapse satellite images. They show us that air moving across Earth's surface is subject to the Coriolis effect, one of the most persuasive pieces of evidence that we live on a spinning globe and not a flat Earth.

Cover-up

When you wash a duvet cover, why does other washing end up in it? (continued)

Jill Breivik

Balbriggan, Co. Dublin, Ireland

I believe the answer to this puzzle is in the washing machine, not the duvet cover or even the socks.

My late washing machine – a famous sock-eater – often turned the duvet cover inside out and, in the process, engulfed every other item in the drum. The result was a huge lump of fabric that was almost impossible to get out.



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When that machine finally passed away, it was replaced with a new electronic one that has utterly failed to leave the duvet cover anything other than lying idly among the other laundry, regardless of whether it is inside out or not. Washing day is calmer, but a little dull.

Peter Slessenger

Reading, Berkshire, UK

It isn't just duvet covers that surround other items in the washing machine. When I wash a flat sheet, the other items in the wash sometimes end up in a bundle completely enveloped by the sheet. None of my pillowcases seem to ingest anything. Perhaps they are too small for solid food.

Charlie Wartnaby

Cambridge, UK

This weekend, not only did our elderly duvet cover ingest every other item in the wash, it engulfed the remainder of itself, leaving a poorly spun wet object resembling a giant apple. Its only orifice was a taut, inwardly sucked whorl of its

“A duvet cover doesn't behave like a black hole for washing. Its opening is no event horizon, but both entrance and exit”

own fabric, resembling a navel.

It was so tightly closed thanks to the friction of the sopping fabric that we couldn't get it undone, so we had to resort to tearing it open to free the rest of the wash.

Paul Coyne

Glasgow, UK

This issue has bothered me for years. The best answer I can find is that there is some probabilistic threshold at play. In randomly placed washing churning around in a machine, there is a probability that something will end up enclosed in a duvet cover. I assume that the probability that an item inside will then migrate to the outside is slightly lower.

This, I surmise, is because a sock outside a duvet cover has many directions in which

it can move relative to the cover. An item inside the duvet cover, on the other hand, has to move in a specific direction in order to escape.

David Muir

Edinburgh, UK

I carried out some tests to investigate this phenomenon. I put 10 assorted socks in the washing machine with a duvet cover on a low-temperature cycle, and then repeated this five times. The duvet cover trapped an average of 4.6 socks. When I carried out this test with the socks placed inside the cover at the outset, an average of 5.6 socks escaped.

Despite urban myths, a duvet cover doesn't behave like a black hole for washing. Its opening is no event horizon, but instead both entrance and exit.

Brian King

Barton on Sea, Hampshire, UK

I thought that it was well known that duvet covers were textiferous (the textile equivalent of a carnivore). ■

Answers

Quick quiz #75

Answers

- 1 The stratosphere
- 2 Type B
- 3 1887
- 4 The UK – it is part of the Avebury prehistoric site in Wiltshire
- 5 The accretion disc

Quick Crossword

#69 Answers

ACROSS 8 Pulp, 9 Covid, 10 Lucy, 11 Foetal, 12 Dredging, 13 Muriatic, 15 Ice age, 17 Vinegar, 19 Network, 22 Gemini, 24 Nineteen, 26 Eleventh, 28 Exhale, 30 Derv, 31 Level, 32 UNIX

DOWN 1 Bubo, 2 Spitfire, 3 Ocelot, 4 Oviduct, 5 Adhesive, 6 Plague, 7 Scan, 14 Urine, 16 Gorse, 18 Avian flu, 20 Watt-hour, 21 Anchovy, 23 In vivo, 25 Needle, 27 Leek, 29 Leia

#82 Dogmandoo

Solution

It rained on 17 afternoons. The chance of no rain all day = 1/3. On no day did it rain morning and afternoon. Let days with morning rain be a, afternoon rain be b, and days with no rain be c. Then $b + c = 37$; $a + c = 43$; and $a + b = 40$. Adding these gives $2(a + b + c) = 120$; so $a + b + c = 60$. By subtracting each two-letter equation from this we find: $a = 23$, $b = 17$ and $c = 20$. Chances of a day without rain are given by $c/(a + b + c) = 20/60 = 1/3$. It rained on 23 mornings, 17 afternoons and was fine all day on 20 days. “Hairy” Potter was clearly away for 60 days.

A pile of old bull

Rifling through a particularly dust-ridden pile in our extensive piling system in search of inspiration and a garibaldi biscuit we thought we last saw there, we encounter an old paper from the journal *Applied Animal Behaviour Science* by Cassandra Blaine Tucker at the University of California, Davis, and her colleagues, entitled "Laterality of lying behaviour in dairy cattle".

With gaze averted from a co-author named Daniel Martin Weary, we move on to the abstract – the meat, so to speak – of the research. "Dairy cattle spend, on average, between 8 and 15 h/d lying down", the authors begin with magisterial authority. "Our objective was to describe the laterality of lying behaviour and assess several internal and external factors that may affect laterality." Those factors include "time spent and time since eating or lying before choosing to lie down again" and "the slope and the amount of bedding on the lying surface".

The grounds for such research, we learn, is a long-running debate as to whether cows prefer to lie on their left side or, in fact, swing neither way (right-wing cows are apparently not a thing). Sadly, the authors are unable to take a side. "Laterality in lying is shifted to the left in some groups but not others," they conclude.

Still, not all is lost. "Cows are also much more likely to terminate long lying bouts and we speculate that continuous lying may become uncomfortable when bouts are longer than 80 min, indicating that cows may switch sides to alleviate this discomfort," they write.

Feedback is entranced by a vision of researchers with clipboards sitting on picnic stools in fields, licking their pencils in anticipation of their subjects' next move. From our current semi-recumbent position, which hasn't shifted in at least an hour, we feel this sort of analysis could be usefully extended to other species. Many would, we suspect, leap at the chance to be part of human trials.

Twisteddoodles for New Scientist



Got a story for Feedback?

Send it to feedback@newscientist.com or

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Consideration of items sent in the post will be delayed

Lateral thinking

This reminds Feedback of the old joke about an engineer, a physicist and a pure mathematician who see a black cow lying in a field shortly after crossing the English-Scottish border on a train (subeditors please note: whether at Gretna Green or Berwick-upon-Tweed isn't specified). The engineer exclaims: "Look – Scottish cows are black!" The physicist replies: "No – some Scottish cows are black." The pure mathematician reacts with irritation. "There is at least one field, containing at least one cow, of which at least one side is black," she says.

Old, we said, not good. All we can say is that it looks like the cow won't be moving any time soon – though a mathematician might quibble that this statement has purely statistical validity.

In a roundabout way

Still entranced, Feedback's attention is drawn to the website of Erin R. Davis, "Data Stuff – It's stuff I made with data", and particularly her application of data science to ascertain the relative frequency of roundabouts in different parts of the world.

The deliciously circular story of how roundabouts conquered the globe – except the US, where they were invented – will be familiar to regular readers (21 December 2019, p 65). Erin's work confirms this: while 1 in 107 intersections are roundabouts in the UK and Ireland, it is a mere 1 in 636 in the US.

What drew Erin to this wholesome subject? "The roundabouts project grew out of a related project I did to find the distance to the nearest pub across

the UK and Ireland," she says. We've been there, Erin, and we understand completely.

HEADLINE FAIL! Failure in headline

The name of Erin's website reminds us of a 2009 cartoon by Stephen Collins featuring covers of *Vague Scientist*, "the magazine for people who try to have conversations about science news".

This is assumed by many at *New Scientist* Towers to be a gentle parody of our own esteemed organ at its arguable best. One favourite detail is the cover line "ARMY CATS! Cats in the army". This serves as an excellent warning to those writing the two-part gems that adorn our cover to avoid circular thinking, thus creating a headline that is repetitious, in that it says essentially the same thing twice.

A list of the logical ellipses and other headline fails that have graced our cover is inscribed on a tablet in the cell at the far end of the office from Feedback's stationery cupboard in which, in more normal times, the editor-in-chief is kept. Don't be backwards in coming forwards with further examples of deficiencies here or elsewhere – not that you were.

Of which...

Robert Milne of Twickenham in the stubbornly extant county of Middlesex, UK, distracts himself from the lack of international rugby to point out a line in our article on the dark-skinned, lactose intolerant inhabitants of Stone Age Ireland (17 October, p 11): "The Bengorm population may well have living ancestors in Ireland today."

We concur with Robert's hope that they had a good pension plan. Alternatively, we have just sneaked in from watching Christopher Nolan's palindromic blockbuster *Tenet*. We are now mumbling about a turnstile that inverts entropy and reverses time buried in the mountains of County Mayo. ■

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