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Holiday special

Vol 248 No 3313/3314
Cover image: Rob Snow

Welcome, dear reader, to your bumper holiday edition of *New Scientist*, packed full of stardust-sprinkled festive treats. We very much hope you enjoy.

On behalf of everyone at *New Scientist*, I would also like to take this opportunity to wish you the best possible holiday season under the strange circumstances in which many of us find ourselves. Thank you for reading *New Scientist* and making what we do possible. I (somewhat nervously) raise a glass of "instant whisky" (see page 73) to you all!

Emily Wilson
New Scientist editor

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Brighter prospects

As 2020 draws to an end, vaccines give us a shot at returning to normality

ACELYA AKSUNKUR/GETTY IMAGES

Several covid-19 vaccines are likely to be available in the new year

THIS has been a year that will live long in the memory, mostly for the wrong reasons. More than 70 million people have fallen ill with a virus that we didn't even know existed this time last year. More than a million and a half have died. Millions more are struggling with the long shadow of the disease.

At the same time, daily life for huge numbers of people changed to an extent that few would have thought feasible as we wassailed towards the last festive period. The way many people work, travel, shop, eat, entertain themselves and socialise have all been radically disrupted and re-engineered, at least temporarily.

It is easy to forget how quickly this has all happened. Just under a year ago, we ran an online story about a "mysterious pneumonia" circulating in China, which at that point looked like a "small earthquake in Chile, not many dead" type of story. A month later, we were nervously tearing up our plans for the magazine and putting coronavirus on the cover – the first of 15 coronavirus cover stories so far. Was it really such a big story? Would readers care? Yes, and yes.

Plenty of people had predicted that a pandemic was coming. Even so, it took a while for it to dawn on the world that this was really it. In part, this was because the coronavirus kept springing surprises. At first, it looked like a standard respiratory virus, but soon revealed its true identity as a stealth operator and attacker of multiple organ systems. The level of asymptomatic spread wasn't in the textbook, nor were the many different manifestations of the disease.

But science stepped up and, after a long 11 months in the trenches, there is light. Vaccines aren't panaceas, but they are our best – indeed our only – shot at returning to normality. Without a vaccine, we are fated to endure wave after wave of infections and reinfections, and repeated lockdowns. With one, we have a genuine exit strategy. The onus is now on scientists, medics and politicians to fathom out how best to navigate us towards it.

Of these three groups, two have had a good war and one a frequently lousy one. It is worth spending a moment over the holiday period to remember the tireless, courageous, selfless and brilliant efforts of medics and scientists all over the world. Spare a thought especially for the many thousands – the number still isn't certain – of healthcare workers who have died on the covid-19 front line.

As for our political leaders, for many, there is much room for improvement. One thing they must learn is that if you fail to prepare,

you are preparing to fail. And they should be aware that the next pandemic could be worse. Back in 2015, we ran a feature about a future pandemic. It included a checklist of the four attributes a virus needs to be truly devastating: high fatality rate, rapid spread, infectiousness before symptoms, and no vaccine. "We are yet to face a virus that ticks all the boxes," we said.

We still haven't. The fatality rate of SARS-CoV-2 is mercifully quite low. And the fourth box is being rapidly unticked.

We struck it lucky in other ways too. The virus has other weaknesses in its armour. Its genome is remarkably stable, so we haven't faced waves of mutants that could have been more aggressive. It also turned out to be a fairly routine challenge for vaccine development, which isn't always the case. That isn't to downplay the skill and speed of the vaccine developers, but they could have had a much harder job.

Indeed, the fact that a vaccine exists already will go down as 2020's crowning achievement. It took just 324 days from the viral genome being sequenced to the first emergency approval of a fully tested vaccine. That process has never taken less than four years before.

Already, however, the feared drumbeat of vaccine nationalism is growing louder. What we need is for countries to start

"The fact that a vaccine exists already will go down as 2020's crowning achievement. That process has never taken less than four years before"

working together towards enforcing equitable global access to the vaccine based on need, not nationality. Unfortunately, that looks like a distant prospect as rich countries predictably hoover up more than their fair share of doses.

That is a blot on the horizon. But there is no doubt that we go into 2021 with brighter prospects than we had any right to expect in March, when the World Health Organization declared a pandemic. Hard yards still lie ahead and the events of 2020 reveal the folly of making predictions. But we can allow ourselves a muted holiday cheer. And three rousing ones for science. ▮

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Vaccination begins in the US

The mammoth logistical task of mass vaccination against covid-19 is under way in the US and Canada, reports **Michael Le Page**

VACCINATIONS against the coronavirus have begun in the US and are expected in Canada within days after both countries last week authorised the vaccine developed by pharmaceutical companies Pfizer and BioNTech for emergency use.

The vaccine roll-out in the US coincides with the country reporting more than 3000 deaths in one day for the first time, on 10 December.

"Yesterday marked another tragic, preventable milestone in our fight against COVID-19, but this news is a bright light," President-elect Joe Biden said on Twitter on 11 December after a US Food and Drug Administration panel voted to green-light the Pfizer/BioNTech vaccine.

Officially, nearly 300,000 people have died of covid-19 in the US (see page 8), but this is thought to be an underestimate of the true toll.

More countries are expected to authorise the Pfizer/BioNTech vaccine for emergency use in the coming days, but supplies remain limited. The US has had an initial shipment of around 3 million doses. Canada has received about 30,000 doses, and is expecting around 250,000 in total this year.

Two other coronavirus vaccines, one developed by Moderna and the other by AstraZeneca and the University of Oxford, could be authorised for emergency use soon in Europe, North America and other regions. Some other vaccines have already been authorised in China, Russia and elsewhere.

In the US, the Pfizer/BioNTech vaccine is being distributed to hundreds of hospitals. Healthcare workers at high risk of being infected should get vaccinated first, the US Centers for Disease Control and Prevention's vaccine advisory panel has recommended. Nursing home residents are next in line, and are due to start getting vaccinated from next week.

White House officials were due to be among the first to get the shot. But the Trump administration seems to have backtracked in the face of criticism.

Mass vaccination could be a particular challenge in the US because it lacks a centralised healthcare system. Different states and hospitals can make different decisions on who gets the vaccine.

There is also concern about the rate of uptake, even though the vaccine will be free. Only half of US adults say they will get vaccinated, according to a recent survey. Another quarter are unsure and the remaining quarter say they won't take it.

In the UK, almost 70 per cent of adults say they are likely or very likely to get vaccinated, with around a quarter saying they are unlikely to and 10 per cent undecided, according to a survey done in November. ■

Containers of the Pfizer/BioNTech vaccine at a Kentucky airport

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United States

How the US can beat the virus

What can incoming US president Joe Biden do to stop the surge of coronavirus cases across the country? **Cassandra Willyard** reports

ALMOST 300,000 people have died of covid-19 in the US, and 200,000 more are expected to succumb to the disease by April. Coronavirus cases are spiking across the nation and hospitals are at or near capacity in many communities.

US president-elect Joe Biden has outlined a science-based approach to combating coronavirus that is a striking contrast to the actions of his predecessor. President Donald Trump downplayed the severity of the virus and flouted public health recommendations such as wearing a face covering and avoiding large gatherings.

"Winning the war against covid-19 is going to happen one conversation at a time"

Biden has already assembled a covid-19 advisory board and named a new health secretary, surgeon-general and covid-19 czar. He has also asked Anthony Fauci, director of the National Institute of Allergy and Infectious Diseases and current member of the White House Coronavirus Task Force, to stay on and become his chief medical adviser. That is a relief to Ali Mokdad at the University of Washington in Seattle. These are "smart people who know what they are doing", he says.

Quelling the latest surge of covid-19 won't be easy for Biden's administration, however. "They're going to walk into a raging epidemic, where there's distrust," says Georges Benjamin at the American Public Health Association in Washington DC. "There are still people that don't believe the disease exists."

New Scientist spoke with public health experts, epidemiologists, physicians and social scientists to see how Biden might turn the tide.

REUTERS/KEVIN LAMARQUE

Joe Biden will become US president on 20 January 2021

1.5 million
People in the US currently tested for covid-19 each day

Win hearts and minds

Biden's toughest challenge might be persuading the people who didn't vote for him to adopt behaviours that curb the virus's spread, such as wearing masks.

The most basic public health recommendations have become political flashpoints under the Trump administration. "It's not just that they're being silent on the guidelines, it's that they're actively advocating for citizens to violate public health guidelines," says Jay Van Bavel at New York University. His research suggests partisanship is one of the biggest predictors of behaviour (*Nature Human Behaviour*, doi.org/fmw2). "That, to me, is the hardest part of it to overcome," he says.

During the 2020 campaign, Biden and his advisers adopted public health tactics that they are advocating, but role models won't be enough to convince sceptics. "Winning this war against covid-19 is going to happen [...] one block at a time, one conversation between a trusted school nurse and a parent at a time," says Lindsey Leininger at Dartmouth College in New Hampshire.

Mandates on masks

One of the best tools to slow the spread of covid-19 has been promoted since fairly early in the pandemic: wearing a face covering. "It is really a pillar of pandemic control," says Monica Gandhi at the University of California, San Francisco. Models developed by researchers at the University of Washington, which project 200,000 extra deaths by

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1 April 2020, predict that if 95 per cent of people in the US wore a face covering, it could save 66,000 lives by the same date.

Biden has said he will require masks in federal buildings but won't issue a national mandate on face coverings. Even if he did, it isn't clear if a federal mandate could withstand a legal challenge. Instead he has pledged to persuade leaders in states that don't require masks to enact mandates. And if the governors won't listen? "Then I go to every mayor. I go to every councilman," said Biden in a televised interview on 15 October. "And I go to every local official and say 'mandate the mask'."

> **"The real driver of whether a vaccination programme lowers cases is the speed at which it's rolled out"**

Convincing some people in the US to comply will be a tough sell. The decision to wear a face covering has become linked to people's political identities, says Monica Schoch-Spana at Johns Hopkins University in Maryland. Some Trump supporters see requirements to wear masks as infringing their individual rights.

Ramp up testing

Trump has falsely claimed that rising case numbers are only due to more testing. Public health experts argue that expanded testing is key to bringing the pandemic under control, because if people know they are infected, they are more likely to isolate and limit the spread of the virus.

The US is currently testing more than 1.5 million people a day. But in many places, tests are still hard to come by and people often have to wait days to get their results. Public health officials recommend that people with symptoms of covid-19, or who have had close contact with someone who has the virus, stay at home, but the longer the wait for results, the more difficult that becomes.

Biden has pledged to double the number of drive-through testing sites – the country currently has about 800. He has also promised to invest in rapid tests. The slower tests, which are the most widely available type in the US, detect even tiny quantities of viral RNA and must be processed in a lab. Most rapid tests detect pieces of viral protein and are less sensitive but offer near immediate results.

Michael Mina at Harvard University has been a vocal advocate for rapid, at-home testing, which is rare in the US. The only covid-19 test approved for home use that gives fast results requires a prescription and costs about $50. If half the population screened for covid-19 every four days, the pandemic would fizzle out because most contagious individuals would stop spreading the virus unknowingly, Mina argued in *Time* on 17 November.

People queue in Los Angeles, California, for covid-19 tests

FREDERIC J. BROWN/AFP VIA GETTY IMAGES

Mass testing would also allow for more tactical application of lockdowns and other restrictions, says Ana Bento at Indiana University. Critics have argued that rapid antigen tests aren't sensitive enough to catch every case and come with a risk of false positives, but Gandhi says they could still have an enormous impact. "We're making perfect the enemy of the good," she says.

Bolster the supply chain

The pandemic response in the US has been hampered by persistent supply-chain issues. A November report by the US Government Accountability Office (GAO) revealed that as many as half of US states have shortages of rapid point-of-care tests, reagents and testing instruments. Shortages of personal protective equipment haven't been as severe as they were in spring, but some states still have little confidence in their ability to procure nitrile gloves and boot covers. A third of states said in a survey that they were concerned about supplies needed to administer covid-19 vaccines, especially syringes.

Addressing those shortages may require greater use of the Defense Production Act of 1950, says Benjamin. The law gives the president authority to compel companies to produce supplies in an emergency. Trump employed the act to beef up production of medical masks and ventilators in March, but Biden has pledged to use it more aggressively.

Support vaccine roll-out

The Pfizer/BioNTech covid-19 vaccine has been granted US emergency use approval, and Moderna has applied for this for its own vaccine. Vaccination of healthcare workers had just begun as this issue went to press (see page 7). Those shots seem to be "effective beyond our wildest dreams", says Gandhi.

But efficacy is only part of the story. "The real driver of whether a vaccination programme really leads to large reductions in the number of cases is the speed at which it's rolled out," says Jason Schwartz at Yale University. How fast the virus is spreading also matters. "If you've got a virus just spreading like wildfire throughout a community, it makes it that much harder for a vaccine to help us turn the page," he says.

It could take months before enough people are vaccinated to meaningfully affect transmission, says Mokdad. Both vaccines require two doses spaced three to four weeks apart, and some worry that people won't return for their second dose.

Although states will be in charge of delivering the vaccine, the federal government has a crucial role. Schwartz says many local and state health departments don't have the financial resources for a huge vaccination campaign. "It's an incredible responsibility that is complicated and costly," he says. ■

Vaccines

Will vaccine immunity last?

The latest results offer cautious optimism that vaccines will give us the kind of immunity we need to end the pandemic, reports **Graham Lawton**

LESS than a year after a new kind of coronavirus started spreading around the globe, we have several vaccines that seem to be very effective at producing strong enough immune responses to protect people from developing covid-19.

Despite this great news, however, critical questions remain about how our immune system responds to the virus. Speaking at an online conference, Devi Sridhar at the University of Edinburgh, UK, listed some of the gaping holes in our knowledge. "How long does immunity last? Can you get reinfected? Is a vaccine going to provide immunity, for how long?" Immunity remains the pandemic's "million dollar question", she said.

Actually, make that $12 trillion, which is the amount governments have collectively spent propping up their ailing economies, according to Gita Gopinath at the International Monetary Fund. That financial haemorrhage will only stop once we have high levels of immunity in the population. "Either vaccine-induced immunity or some level of natural immunity is the only way out," says John-Arne Røttingen, co-founder of the Coalition for Epidemic Preparedness Innovations (CEPI).

Mixed early results

Throughout the pandemic, immunologists have been working hard to answer these questions. But the results have been mixed. On the key question of the duration of the immune response following infection, for example, some early studies concluded that it looked set to last for months, but others that it would be very short-lived.

The vaccine trial results have enlightened us somewhat. According to a scientist who has worked on teams developing vaccines at drug companies, who spoke to *New Scientist* on condition of anonymity, vaccine developers usually aren't that interested in the fine details of the immune response. Clinical trials are typically designed with one thing in mind – to apply for approval, and for that they only need to show that the vaccine is safe and protects against disease for the trial's duration. The World Health Organization (WHO) and the US Food and Drug Administration have said they would like to see a minimum of six months' protection.

With covid-19 vaccines, however, the drug companies have been gathering and releasing relevant data. A spokesperson for AstraZeneca told *New Scientist* that the vaccine it is developing with the University of Oxford induces a strong response in all the important elements of the immune system: antibodies, B-cells and T-cells, and memory cells. Pfizer and BioNTech have said that their vaccine activates antibodies, B-cells and T-cells. Moderna published data showing a strong antibody response in 34 volunteers 90 days after receiving the second shot of its vaccine, but didn't say anything about T-cells.

Academic research on natural immunity is also progressing and results are encouraging. "It's not completely nailed down yet," says Paul Klenerman at the University of Oxford. "But there's emerging data from different groups, which is always good, that you can keep detecting measures of immunity over at least six months."

He points to one project that studied the immune responses of 185 people who had covid-19, including 41 who had it more than six months ago. Every measure the team looked at, including antibodies and T-cells, pointed to robust and lasting immunity. "They have a measure of everything and it looks pretty solid," says Klenerman.

Other teams are finding similar things, he says. A project

A hospital in Wales has become one of the UK's covid-19 vaccine hubs

90%
The expected drop in immune response six to eight weeks after an infection

6 months
How long the WHO and US Food and Drug Administration want covid-19 vaccine immunity to last

5-10%
Proportion of people who don't seem to get protection from the vaccines in clinical trials

by Public Health England and the UK Coronavirus Immunology Consortium, for example, looked at 100 people who had mild or moderate covid-19 more than six months ago, and found they had a strong response in some memory

"Every measure the researchers looked at pointed to robust and lasting immunity"

cells, which are important for long-lasting immunity.

Eleanor Riley at the University of Edinburgh agrees that the picture is looking increasingly rosy. "There are papers following people who had the virus back in March and April. The antibody levels have dropped a bit, but they've stabilised and the T-cell responses seem to be pretty persistent as well," she says.

The reason for the contradictory results earlier in the pandemic is probably that insufficient time had elapsed, she says. It is quite normal for an immune response to spike early on, then fall away precipitously, only to plateau after six to eight weeks. It then decays very slowly over months or years.

"I've done a lot of work over the years following people's immune responses over time, and we see this over and over again, a 90 per cent drop from the peak to the plateau. But the plateau is what matters. This is why we now say it's long-lived," says Riley. Exactly how long-lived isn't yet known, but Riley's hunch is at least a year.

There are still some open questions. One is whether someone who has only a very mild or asymptomatic case also develops long-lived immunity. "We don't quite know yet how much immunity you need to protect you," says Klenerman. According to Riley, our current model of immunology predicts that mild or asymptomatic cases should produce only short-lived, local immunity in the lining of the airways rather than a vigorous response in the bloodstream, known as a systemic immune response, which is considered the most protective kind. "It does look as though people [who] have had asymptomatic infection, some of them make a rather trivial immune response," she says. "That's what we expect, but we're still a little bit uncertain."

The immune response of the airway lining is a neglected area of study, says Michael Russell at the University of Buffalo in New York. This is the initial site of attack and must play a key role in fending off the infection, but has so far taken a back seat to work on the systemic immune response. "We think it is a serious omission to ignore it," says Russell. Understanding it better might hasten the development of nasal spray vaccines that could be easier to store, transport and administer, he says.

MATTHEW HORWOOD/GETTY IMAGES

JUAN GAERTNER/SCIENCE PHOTO LIBRARY

Antibodies responding to a coronavirus particle (orange)

Low reinfection risk

It also isn't totally obvious what is going on with reinfection, but both Riley and Klenerman say this doesn't look like a serious problem, even though there have been some reported cases. "Exactly why that happens is not clear," says Klenerman. "But, fortunately, it doesn't seem to be a major clinical issue at this point."

Another apparent non-issue is immune-enhanced disease, where an initial immune response from infection or vaccination paradoxically makes people more susceptible to severe illness during a second bout. "Nobody has seen it," says Riley. "That doesn't mean it won't happen, but if it does, my guess is it's going to be very uncommon."

All of which adds to the growing optimism over the ability of vaccines to end the pandemic. "It has followed the textbook, basically, and generated the kind of immune response you'd expect," says Klenerman, though he warns that the trial results don't tell us everything. In trials, vaccines didn't work in around 5 to 10 per cent of people. "There's a certain fraction of people that didn't appear to get good protection in those trials. And we don't understand why," he says.

Another remaining unknown is whether any of the vaccines produce sterilising immunity, meaning they stop the virus from invading cells rather than just helping the body fight it off. This is important for herd immunity as sterilising immunity halts transmission and so can grind the disease to a total halt.

But according to Sarah Gilbert of the Oxford team, sterilising immunity isn't necessary to slow the pandemic. A vaccine that somewhat reduces transmission – as the Oxford/AstraZeneca one appears to do – can slow the spread significantly, she says.

Riley is even more upbeat, especially about the duration of immunity. "I think the worst-case scenario is that people might need an annual booster, which they'll almost certainly get as a combined flu-coronavirus vaccine."

"Exactly why reinfection happens isn't clear. But, fortunately, it doesn't seem to be a major clinical issue"

She says she was always confident that a vaccine would be possible and nothing she has seen in recent weeks has changed her mind. "This always looked like a pretty straightforward virus to vaccinate against." ■

Field notes: Fish Creek, Nevada

Corralling wild horses in the US

Should birth control replace round-ups to control wild horse populations?

Adam Popescu

FROM my home in Los Angeles, California, it is just a few hours' drive into the deserts of Nevada to see wild horses. If you are lucky, as I was, you might see a lone mustang on the range, galloping over powdery snow, just a few hundred metres from the highway.

According to the US Bureau of Land Management (BLM), there are about 95,000 wild horses and burros – small donkeys – on public lands across the US, half of which are in Nevada. I planned to join a round-up in Fish Creek in which the wranglers are in helicopters. The use of these vehicles is part of the controversy over managing wild horses in the western US.

Wild horses are seen by some as a nuisance and by others as animals in need of protection. Drought and wildfires have shrunk their habitat, sparking conflict with ranchers, oil firms and miners. While the BLM has tried to corral the horses, experts say its methods aren't working.

"What you have right now is a history, since 1971, of using round-ups as the sole solution," says Greg Hendricks, who spent seven years at the BLM before joining the American Wild Horse Campaign (AWHC). "BLM isn't set up to do fertility control." Helicopters are often used in round-ups to chase herds into pens, which causes panic, injury and even death, says Hendricks. Most captured horses never return to the wild. Some are shipped to crowded pens where they are auctioned or adopted.

The argument for corralling the horses is that mustangs regularly eat themselves to starvation, leaving the land barren. They graze for an average of 16 hours a day and travel wide. Yet Kate Wall at the International Fund for Animal Welfare says there is no evidence that the horses starve. What's more, they also have a high reproduction rate, which suggests they are thriving.

KIMERLEE CURYL

Round-ups of wild horses in the US may not be as effective as once thought

Herds can double in just three years, so regular thinning makes sense. But it isn't easy or cheap – in 2020, the programme's budget was $101 million. Doug Furtado, the BLM's district manager in Battle Mountain, Nevada, says the aim of round-ups is to "protect the range from the deterioration associated with overpopulation".

Horses and burros really are hard on the land – I could easily see that in the deep hoof prints and chunks of grass they regularly kick up – but a recent research review found that this isn't all bad (*PNAS*, doi.org/ggq6tz). One benefit of burros are the small wells created when they dig and tap into desert springs for a drink, which are also used by other species.

95,000

The number of wild horses and burros on US public lands

A 2013 US National Academy of Sciences report that was funded by the BLM found that round-ups are "expensive and unproductive", partially because herds actually grow faster after them. The report concluded that fertility control would help, but nearly a decade on, using helicopters to wrangle them is still seen as a panacea.

Grace Kuhn at the AWHC calls round-ups "archaic", and says they are more to do with ranchers and miners wanting access to the land than horse health. The BLM has previously denied this.

In small towns like Eureka, Nevada, round-ups are big entertainment. Ranchers, looky-loos and the odd journalist cluster on Highway 50 at dawn, trailing BLM agents with binoculars at the ready. At the last minute, the Fish Creek round-up I am due to attend is cancelled after one of the helicopter pilots tests positive for covid-19. With the cold getting colder and snow soon to pile up, Jess Harvey, the BLM's regional public affairs specialist, says he isn't sure when the next round-up here will be.

The original plan was to release 60 of the horses captured in the round-up. The mares were to be injected with a birth control drug called porcine zona pellucida (PZP). Not many captured horses are currently given PZP.

Attempts to mandate fertility controls for wild horses have been making their way through the US Congress, but efforts have stalled. Across Nevada, some ranchers and groups like AWHC aren't waiting. They have bought land adjacent to the federal land where horses roam and they are administering birth control themselves.

"There's hope on the horizon," says Hendricks, who is overseeing a pilot programme funded by the BLM that is working with ranchers to dart 1300 mares with PZP on more than 1200 square kilometres of private land. "We're getting ranchers to do fertility control – who better to have skin in the game? If the government was smart enough, it'd pay each time a ranch hand darts a horse. It could save billions," he says. ■

Archaeology

Ancient humans may have hibernated during glacial winters

Colin Barras

SOME ancient humans living in Europe half a million years ago had a remarkable strategy for dealing with winter: they hibernated. At least, that is the claim made by two researchers.

Sima de los Huesos – the "pit of bones" – lies in northern Spain and is one of the world's most important sites for studying human evolution. Excavations at the site have led to the discovery of more than 7500 fossils belonging to at least 29 ancient humans, often placed in the species *Homo heidelbergensis*. The bones, and fragments of DNA they contain, have been studied in great detail, revealing that the ancient humans were ancestral to Neanderthals.

But earlier studies missed one important point, according to Antonis Bartsiokas at the Democritus University of Thrace in Greece. He says the bones show evidence of a suite of diseases associated with poor availability of vitamin D. Among them are renal osteodystrophy and rickets, which Bartsiokas diagnosed on the basis of unusually thick deposits of bone above the eye sockets and from the presence of distinctly bowed leg bones. He says that collectively, the pathologies suggest that the ancient humans routinely spent months on end in dark environments where, robbed of sunlight, their bodies were unable to generate vitamin D (*L'Anthropologie*, doi.org/fm24).

"At first I was at a loss," says Bartsiokas. Rickets and vitamin D deficiencies have been described in historical populations, particularly in dense urban centres where accessing sunlight can be a challenge. Never, to his knowledge, have such ancient humans been diagnosed with vitamin D deficiencies. As he dug deeper into the subject, he realised that the same suite of diseases is often seen in animals that hibernate in caves, including bats.

He and his colleague, Juan Luis Arsuaga at the Complutense University of Madrid in Spain, argue that the bones show that these ancient humans hibernated in caves too. Bartsiokas argues that this is the only way to explain how they might have spent enough time in the dark to develop vitamin D deficiencies.

"This idea may sound crazy, but it is crazy enough to be true," says Bartsiokas. He points out that some of our primate relatives, including the grey mouse lemur (*Microcebus murinus*), hibernate for days. And a 2019 study suggests that the Sima de los Huesos humans are between 440,000 and 455,000 years old, so lived through one of the most severe glacial periods of the last million years. Bartsiokas argues that the conditions may have acted as an extreme selective pressure that encouraged rapid adaptation, over the course of perhaps 50,000 years, to a hibernating lifestyle.

Many ancient humans lived in caves, but did they hibernate in them?

GORODENKOFF/GETTY IMAGES

Megan Brickley at McMaster University in Canada isn't convinced. Her research focuses on metabolic bone disease and vitamin D deficiency, and her first impressions are that the ancient bones from Sima de los Huesos don't show clear evidence of rickets. Some of these humans may well have had some other form of metabolic bone disease during life, she says, but she doesn't believe there is evidence to suggest a hibernating strategy.

This doesn't mean the idea that ancient humans hibernated is unthinkable. It may even be possible to trigger a hibernation-like response in living humans, says Kelly Drew at the University of Alaska Fairbanks, who is exploring the idea as a strategy to help treat conditions including stroke or cardiac arrest. ■

Cosmology

The magnetic fields at the start of the universe

ASTRONOMERS are on the hunt for magnetic fields in our galaxy that were born in the very early universe, because they could provide a new way to study the big bang.

Magnetic fields are thought to play an important role in star formation within galaxies, and the Milky Way is home to various types of field. Some come from stellar explosions, others from black holes, while some, known as primordial magnetic fields, are believed to come from rapid inflation thought to have occurred fractions of a second after the big bang.

We have never been able to tease these ancient fields apart from the others, but Sergio Martin-Alvarez at the University of Cambridge and his colleagues say they have found a way to do so.

The team modelled the evolution of recent and primordial magnetic fields in the Milky Way. The group found that primordial magnetic fields always seemed to survive throughout time and could stay far stronger than previously thought (arxiv.org/abs/2011.11648v1). "I was so surprised that they survived," says Martin-Alvarez.

The primordial magnetic fields seem to be distributed more towards the centre of the galaxy, while those that come from stars and black holes are more evenly distributed. The team hopes soon to calculate what astronomers will need to look out for to distinguish these ancient fields.

"You could potentially measure the primordial magnetic field of the entire universe"

That could have big implications. If you can measure primordial magnetic fields in one galaxy, you could potentially measure the primordial magnetic field of the entire universe, says Martin-Alvarez. "This is something that we did not think would ever be possible."

"If we find primordial magnetic fields, they offer a new window on the big bang cosmology, because it would take some unusual event to produce them in the early universe," says Alexander Kusenko at the University of California, Los Angeles. ■

Jason Arunn Murugesu

Archaeology

The original dollar

Ancient shell beads may have been the first money used in the Americas

Colin Barras

PEOPLE living in what is now California may have been the first Americans to invent money, according to a new analysis of shell beads produced 2000 years ago by the Chumash, a Native American community.

There is general agreement that money existed in the Americas before Europeans arrived. The Chumash's beads, fashioned from the shells of purple dwarf olive sea snails (*Olivella biplicata*), are seen as a classic example of this.

"Almost all the scholars who focus on the Chumash have agreed that the shell beads were money," says Lynn Gamble at the University of California, Santa Barbara. But while previous studies have dated this use to about 800 years ago, she now suspects that Chumash money has a much deeper history.

Gamble says there are four features that archaeologists should look for to identify ancient money. Unlike other signifiers of wealth, such as jewellery, currency shouldn't necessarily be decorative or eye-catching, but it should be labour-intensive to produce. It should also be highly standardised in terms of its physical dimensions. Finally, currency should be widely distributed among the population.

2000

The age of shell beads that may be the first money in the Americas

Gamble confirmed that a type of Chumash shell bead shaped like a cup that was in use about 800 years ago possessed all of these features, aligning with previous studies. However, she realised that a form of saucer-shaped bead produced about 2000 years ago also had the same characteristics (*Journal of Anthropological Archaeology*, doi.org/fm4k).

GRANGER HISTORICAL PICTURE ARCHIVE/ALAMY

The type of beads used in Chumash necklaces may also have been currency

For instance, these earlier beads were more standardised than the 800-year-old cup beads, and have been discovered in their hundreds of thousands across California, even though analysis of the beads suggests that most were created in what is now a southern corner of the modern state.

Eleanor Fishburn, a member of the Chumash community and an anthropologist, appreciates the work of researchers like Gamble – although she says the Chumash's relationship with the scientific community isn't always easy. "A lot of pain and a lot of hurt gets brought up." But she thinks the new work is fascinating. "Reading this paper, I really put myself in that time and place," she says.

The earliest known money was used in Mesopotamia in Asia more than 4000 years ago, but Gamble's analysis would make the Chumash beads the earliest known money in the Americas, before civilisations like the Mayans.

In 2018, Joanne Baron at the Bard Early College Network in New Jersey suggested that the Maya people began using cotton textiles and cacao beans as currency 1400 years ago. "You had these two powerful kingdoms – Calakmul and Tikal – and they were increasingly competing for influence over their neighbours," says Baron. They did so by attracting more households to buy and sell in their marketplaces. As households chose to participate, cacao and textiles – items that hadn't previously been bought and sold – became commodities. Rulers eventually started requiring them in tribute payments as well, solidifying them as a currency.

Chumash beads were made from the shells of sea snails

STUART WILSON/SCIENCE PHOTO LIBRARY

Significantly, Gamble's study suggests money might emerge in the absence of powerful kingdoms, as the Chumash operated as a complex hunter-gatherer society at the time.

But other researchers are unconvinced that the evidence from the shell beads alone can tell us that the Chumash had money 2000 years ago. Robert Rosenswig at the University at Albany in New York takes a contrasting view that defines money as an accounting system that powerful authorities use to keep track of tribute payments or taxes from the population and that the existence of currency-like objects isn't, on its own, evidence of money.

Rosenswig thinks Gamble's research convincingly shows that Chumash money dates back 800 years because we have a sense of how Chumash society functioned then. But he says the idea that the Chumash had money 2000 years ago isn't persuasive because we don't know how the shell beads were used then. "If you could demonstrate there were powerful chiefs extracting tribute that far back, and show how the beads function in that system, for me, that would be more convincing."

Baron argues that this way of defining money is too restrictive. "The history of money has been studied primarily in Eurasia, so it predisposes us to look for money only in certain situations, in state-like societies," she says. "If we broaden the definition of money to include non-state societies, then I certainly think there's room for archaeologists to look for evidence of it elsewhere." ■

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Animal behaviour

Tasmanian devils with cancer may shun others

ANGUS MCCOMISKEY/ALAMY

A DEADLY, contagious cancer that develops in Tasmanian devils seems to make infected individuals less likely to interact with others.

The condition, known as devil facial tumour disease (DFTD), is transmitted through bites and causes tumours in the jaw. It can lead to death in less than a year. Tasmanian devils (*Sarcophilus harrisii*) often fight for mates and food, which can exacerbate the spread of DFTD, which has wiped out more than 80 per cent of the population in the past 20 years.

This cancer can make it hard for devils to feed as the tumours tend to displace an animal's teeth. "Animals that are diseased can isolate themselves from other individuals to conserve energy and recuperate," says David Hamilton at the University of Tasmania in Australia.

To see if this affects how DFTD is spread, Hamilton and his team fitted 22 wild devils with tracking collars that can detect when animals are less than 30 centimetres apart. The team found that as their tumours grew, infected devils were less likely to interact with others.

Three of the Tasmanian devils observed showed symptoms at the start of the study. Six months later, almost half the population was infected with DFTD (*Proceedings of the Royal Society B*, doi.org/fmzc).

"We think that those spreading it are likely to be those in the earlier stage of infection," says Hamilton. At that stage, devils with the tumour are still fit enough to fight and transmit the disease. The disease has nearly driven these animals to extinction, but they are starting to adapt to the threat. **Ibrahim Sawal**

Environment

Human-made stuff outweighing nature

THERE may be more buildings than trees and more plastic than animals, in terms of mass, as humans are creating things faster than nature can produce biomass.

Ron Milo and his colleagues at Weizmann Institute of Science in Israel have estimated the mass of all artificial and living things on the planet. They say that 2020 may be the year in which humanity's creations outweigh the biosphere.

"We are really at the cusp of the transition where around us are more human-made things than living things," says Milo.

The team says that in 1900, the mass of human-made objects was only 3 per cent of the total mass of all living things, referred to as biomass. Now, the mass of artificial objects is on course to be triple that of living biomass by 2040.

Most of the human-made mass is in infrastructure, such as buildings and roads, whereas trees and shrubs make up 90 per cent of living biomass. For example, the team estimates there are 1100 gigatonnes of buildings and 8 Gt of plastic on the planet, compared with 900 Gt of trees and 4 Gt of animals, including humans.

The researchers say the total mass of living things on Earth has remained roughly the same since 1900, while the mass of human-made objects has doubled about every 20 years. They don't know exactly when artificial mass overtook or will overtake biomass, but say it is probably between 2014 and 2026 (*Nature*, doi.org/fmzv).

The biggest surge of artificial objects followed the second world war during a period of widespread development known as the "great acceleration", the team says.

"This [study] serves to strongly underline the need for wise and informed human stewardship of the environment," says Jeremy Woods at Imperial College London. **Krista Charles**

Technology

Dog bots find their feet with AI's help

ROBOTS can pick themselves up after a fall, even in an unfamiliar environment, thanks to an artificially intelligent controller that can adapt to new scenarios. It could make four-legged robots more useful for work after natural disasters, such as earthquakes.

Zhibin (Alex) Li at the University of Edinburgh, UK, and his colleagues used an AI technique called deep reinforcement learning to teach four-legged robots a set of basic skills, such as trotting, steering and fall recovery. This involves the robots trying different ways of moving and being rewarded with a numerical score for achieving a certain goal, such as standing up after a fall, and penalised for failing. This lets the AI recognise which actions are desired and repeat them in similar situations in the future.

YANG ET AL, SCIENCE ROBOTICS

The team then tested the robots in a range of environments to see if they could combine these skills and quickly react to new scenarios. The robots could get up after a fall and adapt their movements to stairs, slippery surfaces and gravel, despite not being programmed to navigate these (*Science Robotics*, doi.org/fmzr).

This ability could prove useful in emergency situations like earthquakes and fires. "We can deploy these robots to do the search and rescue for us when it is too dangerous for humans," says Li. **Karina Shah**

18+

WHAT IS AVAXHOME?

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Plastic pollution has easier access to cells

Microplastic particles that are exposed to fresh water or salt water for several weeks are more likely to be absorbed by mouse cells than those kept in purified water, suggesting that environmental microplastics may be able to enter cells more easily than we thought (*Science Advances*, doi.org/fmw8).

Crabs could help save coral reefs

Damaged Caribbean coral reefs are being taken over by seaweed, which blocks light and prevents young corals from growing. However, introducing coral crabs (*Maguimithrax spinosissimus*) to the reefs resulted in an 80 per cent decline in seaweed, as the crabs ate it (*Current Biology*, doi.org/fm4b).

Plant growth hope for climate fades

Satellite images have shown that the extra plant growth expected from rising carbon dioxide has been overestimated, possibly due to limits on nutrients. This means that plants may soak up less CO_2 than hoped and that larger reductions in emissions will be needed to limit warming (*Science*, doi.org/fm4c).

Insects

Bees gather dung to fend off killer hornet

ASIAN honeybees collect animal faeces and dot their hive entrances with it as a defence against mass attacks by giant hornets.

Heather Mattila at Wellesley College in Massachusetts and her team have studied the behaviour of Asian honeybees (*Apis cerana*) in northern Vietnam. The bees are preyed upon by giant hornets (*Vespa soror*), which launch group attacks that can kill thousands of worker bees, sometimes resulting in the loss of an entire colony.

Asian honeybees have various defence strategies, including hissing, visual displays and enveloping intruders in a ball of bees until they overheat. However, when the researchers observed three apiaries, they found that the honeybees collected small balls from piles of animal dung near the colonies. The bees transported the dung and applied it to spots close to the entrances to their hives.

The behaviour occurred after visits or attacks by giant hornets and continued for days afterwards even if the hornets didn't return. Visits from *Vespa velutina* hornets, a smaller species that will kill single bees but doesn't attack en masse, didn't elicit the behaviour.

Moderate and heavy deposits of faeces at hive entrances lowered the incidence of group attacks by giant hornets and cut the chances of the hornets chewing on the entrances to enlarge openings (*PLoS One*, doi.org/fmzx).

It is still unclear whether the animal faeces are inherently a deterrent to the giant hornets or whether they contain a particular compound that repels them. **Donna Lu**

Astronomy

MPE/IKI

Vast gas balloons may have been created by black hole

A PAIR of giant bubbles extending above and below the Milky Way that emit X-rays have been spotted. They may be the result of a powerful event in our galaxy's centre.

Andrea Merloni at the Max Planck Institute for Extraterrestrial Physics in Germany and his team found the bubbles of hot plasma using the eROSITA X-ray telescope aboard the Spektr-RG space observatory. The spheres extend more than 45,000 light years above and below the galaxy, which is about 105,000 light years across (*Nature*, doi.org/fmzn).

Astronomers had already spotted the bubble above the galaxy, but we didn't have any X-ray telescopes sensitive enough to see the more tenuous southern one.

Previously, we couldn't be sure whether the northern bubble came from the centre of the galaxy or if it was actually a closer structure that we happened to be viewing from an angle that gave us that impression. The new observations mean it is almost certainly the former, but we still don't know why the southern bubble is less dense, says Merloni.

The bubbles probably formed when matter fell into our galaxy's central supermassive black hole, releasing an extraordinary blast of energy. Leah Crane

Palaeontology

New clues in hunt for pterosaurs' ancestor

WE FINALLY have a clearer picture of how pterosaurs – a group of extinct flying reptiles – evolved. The creatures shared dozens of key traits with a long-extinct group of dinosaur-like reptiles that might have been skilled tree climbers, according to a new analysis.

Pterosaurs evolved about 220 million years ago. Yet figuring out which group of reptiles they evolved from has been difficult.

Martín Ezcurra at the Bernardino Rivadavia Argentine Museum of Natural Science in Buenos Aires and his team think the answer lies with a little-known group of reptiles – the lagerpetids.

They used recent fossil discoveries and closer looks at previous finds to show that lagerpetids are most closely related to pterosaurs. For instance, pterosaurs and lagerpetids are the only reptiles around at that time with a relatively large floccular fossa – a part of the brain involved in coordinating eye, head and neck movements (*Nature*, doi.org/fmzz). The anatomy of their inner ears is also very similar, and resembles that of birds, says Ezcurra. Characteristics like these were thought to have evolved as pterosaurs took to the air. **Michael Le Page**

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Goodbye to 2020

As one of the most extraordinary years of modern times draws to a close, *New Scientist* looks back at the ongoing coronavirus pandemic, the possibility of life on Venus and more

2020 in pictures

Rise of the face mask

Although more common in many Asian countries, masks and face coverings were an unusual sight in most places before the pandemic. Now, despite initial uncertainty over their efficacy and a desire by some people not to be "muzzled", they are near ubiquitous, as seen in this line of New Yorkers on 24 October 2020 waiting to cast an early ballot for the US elections.

REUTERS/JEENAH MOON

Coronavirus

How we got to know a new enemy

In an extraordinary year for science, research into covid-19 has shed a bright light on the unknown, reports **Graham Lawton**

A YEAR ago, nobody had even heard of SARS-CoV-2 and the disease it causes, covid-19. Today, they are household names all over the world, thanks in no small part to an unprecedented scientific heave.

"Doing research in an outbreak is really challenging," says Trudie Lang at the University of Oxford. "But it has moved super quickly. It's been amazing."

In just less than 12 months, scientists and medics have filled many of the urgent knowledge gaps, from basic virology and immunology to how to save lives in hospital. "Research scientists worldwide have generated an astonishing total of pandemic-related biomedical papers," says John Inglis, executive director of Cold Spring Harbor Laboratory Press in New York.

According to an ever-expanding database compiled by the US National Institutes of Health, more than 75,000 peer-reviewed research papers on covid-19 and SARS-CoV-2 have been published since January. About 10,000 more preliminary papers have been posted on the bioRxiv and medRxiv preprint servers, both co-founded by Inglis, with more elsewhere. Another database, the Covid-19 Research Project Tracker, lists more than 5000 active covid-19 projects with over $2.2 billion invested in them.

The research effort hasn't just been big, it has also been clever. Much of the science has been guided by a to-do list written by the World Health Organization (WHO) in February. With confirmed cases in 28 countries but a pandemic not yet declared, it convened a panel of hundreds of experts on 11 and 12 February to agree a set of research priorities.

The resulting document – published on 12 March, the day after the pandemic was declared – identified the gaps in our knowledge and laid out a road map for filling them. According to Alice Norton, head of the Covid-19 Research Coordination and Learning Initiative, it is an "unprecedented galvanising document for global research collaboration".

The road map is divided into nine major areas, each detailing a long list of unknowns. At the time it was compiled, a few urgent queries already had some answers. The disease-causing agent was known to be a novel coronavirus and its genome had been sequenced, while a market in Wuhan, China, had been identified as a possible ground zero, although that has since been called into doubt. Some basics of the illness, including its incubation period and R number – the average number of people an infected person goes on to infect – had also been estimated.

Yet there was still a stack of crucial questions. To name just a few: how is the virus transmitted? What is the mortality rate? What is the full range of symptoms? Are survivors immune? Is a vaccine possible?

According to Lang, who wasn't part of the WHO team but keeps tabs on the road map, some of those urgent queries have now been ticked off. We know, for example, that the virus is spread mostly through airborne

2020 in pictures

Covid-19 patients in an intensive care unit at the Gilberto Novaes Hospital in Manaus, Brazil, in May

A year that shook the world

Clare Wilson recaps how a handful of infections in China led to a global pandemic

December 2019
Cases of a mysterious form of pneumonia are reported in Wuhan, China. Doctors rule out some known viruses as the cause, suspecting it is a new microbe. Some of those affected work at Huanan Seafood Market, where live animals are also sold.

31 December 2019
China notifies the World Health Organization (WHO) of the cluster of pneumonia cases. At this stage, officials say there is no clear evidence of transmission between people. Huanan Seafood Market is closed for disinfection the following day.

MICHAEL DANTAS/AFP VIA GETTY IMAGES

droplets and aerosols, and is transmitted more easily indoors. We also understand that most people who get the virus don't fall ill but can still spread it, that people do have an immune response and so a vaccine is feasible and that a few existing drugs help but many don't.

Yet we still don't know exactly where the virus came from, how it is affected by temperature and humidity, how long immunity lasts, the precise fatality rate and which public health measures – such as face coverings and lockdowns – work best.

Some new questions have also been added and partially answered, including the disease's long-term health impacts. Other unexpected queries will probably arise too.

Overall, though, progress has been commendable. "The road map was written very early on," says Lang. "But it was exactly what we needed to do." Well, so far, so good. But there is still a long and hard road ahead. ▮

Graham Lawton is a staff writer at *New Scientist* and author of *This Book Could Save Your Life*

Coronavirus

Vaccines made in record time

ON 10 January 2020, the first genetic sequence of the new coronavirus, SARS-CoV-2, was published by an international consortium of scientists, and the race for a vaccine began. It wasn't a moment too soon, as the first death from infection with the virus was reported in Wuhan, China, the next day.

Remarkably, it has taken less than a year from this initial discovery to the development of several vaccines that have, in trials, far exceeded all expectations. At the time of going to press, a vaccine developed by US company Pfizer and its partner BioNTech had been approved for emergency use in the UK and roll-out had begun. Canada and the US had also approved it, with roll-out imminent. There is little doubt that approval from other countries – and for other vaccines – will follow.

The Pfizer/BioNTech vaccine is the first mRNA vaccine to be approved, a technology that has scope for tackling many diseases beyond covid-19. Elsewhere, Russia has approved its Sputnik V vaccine, albeit from more limited trial results. In China, several vaccines are being administered, though they haven't completed rigorous trials.

A massive challenge lies ahead in getting the vaccine to the billions of people who need it. Many questions remain, not least how long immunity lasts. Even so, to achieve in a year what normally takes a decade or more has been heralded a huge medical success, one that offers a glimpse of the end of the pandemic. ▮

Catherine de Lange is *New Scientist*'s coronavirus editor, based in London

9 January 2020
China identifies the microbe responsible for the outbreak as a new coronavirus – the same kind of virus that caused the deadly SARS outbreak of 2002 to 2004. Soon, researchers publish the first draft of the new virus's genome, an initial step towards making genetic tests.

Mid January 2020
The new coronavirus spreads outside China, with cases reported in Thailand, Japan and South Korea. Those infected had caught the virus in Wuhan, but some reported that they hadn't been in contact with animals, suggesting that the virus is now passing between people.

Late January 2020
Several studies make it clear that the new coronavirus, probably originating in animals, is now being passed between people. The WHO declares a public health emergency of international concern on 30 January, as 18 countries beyond China confirm cases of the virus.

February 2020
Several outbreaks in ski resorts in Austria and Italy lead to travellers taking the virus home with them. One resort, Ischgl in Austria, was linked to thousands of cases in 45 countries. Hasty evacuation of some resorts in crammed buses may have added to the spread.

2020 in pictures

The world ground to halt

MORE than half of Earth's population was under some form of lockdown by mid-April. Usually bustling city centres fell quiet as governments asked or ordered people to stay at home and businesses to shut. This unprecedented change in behaviour has left a lasting impact.

Before the pandemic, global daily average carbon emissions were expected to rise by about 1 per cent in 2020. But by 7 April, they were down by 17 per cent compared with 2019. Across 2020 as a whole, researchers estimated that we will see a 4.2 to 7.5 per cent decrease – the biggest drop in emissions since the second world war.

Under lockdown, many people began working from home, accelerating the adoption of digital technology. Microsoft reported a record-high figure of 2.7 billion daily meeting minutes on its online video conferencing platform, Teams, in April.

The need for social distancing drove a rise in digital health services. According to a US survey by Ipsos, just 10 per cent of doctors had seen patients remotely prior to the pandemic, jumping to about 70 per cent in July.

Restrictions on daily life took a heavy and unevenly distributed toll. A UNICEF report found that at least 463 million of the almost 1.5 billion school children affected by classroom closures at the height of lockdowns had no access to remote learning. And the global economy was forecast to shrink by 5.2 per cent this year, according to the World Bank, with a rise in the number of people in extreme poverty for the first time in more than 20 years.

Layal Liverpool is a *New Scientist* reporter based in Berlin

Clockwise from top left:

Workers treat areas near the Christ the Redeemer statue in Rio de Janeiro, Brazil; Westminster Bridge, London, in March; a very quiet Times Square, New York, also in March; a stage in South Korea is disinfected as some venues reopened in July

11 March 2020
The WHO officially declares a pandemic. Cases are rising so quickly in northern Italy that some hospitals are starting to run out of ventilator beds and have to draw up rules for how to allocate them. Meanwhile, hospitals in New York teeter on the edge of their capacity.

Mid March 2020
Many countries bring in unprecedented restrictions in an effort to curb the spread of the virus, such as ordering people to stay at home unless they must travel for emergencies, to do essential work or to buy food, medicines and other supplies.

April 2020
The tide turns in favour of the public wearing face coverings, which had been contentious outside some Asian countries in the early days of the pandemic. The US Centers for Disease Control and Prevention recommend that people wear masks when possible.

8 June 2020
New Zealand declares it is free of covid-19 and will lift most restrictions, showing that countries can eliminate the virus with strict enough measures – although it has since seen cases imported from elsewhere that required implementing further lockdowns.

CLOCKWISE FROM TOP LEFT: MAURO PIMENTEL/GETTY IMAGES; SIMON DAWSON/BLOOMBERG/GETTY IMAGES; CARLO ALLEGRI/REUTERS; JEON HEON-KYUN/EPA-EFE/SHUTTERSTOCK

Coronavirus

The countries that tamed covid-19

A handful of nations have achieved something thought almost impossible, reports **Michael Le Page**

UNTIL 2020, many experts thought it was impossible to halt the spread of a respiratory virus once it started to spread out of control. During the course of the year, many countries have shown it is possible to contain the coronavirus even without the help of a vaccine – but only a few have managed to keep it contained.

By late January, the crowded metropolis of Wuhan in China was reporting thousands of new covid-19 cases every day. It seemed inevitable that the outbreak would spread throughout the country of 1.4 billion people, especially as it was becoming clear that the virus can be infectious even when a person shows no symptoms.

Instead, China took decisive action. It halted all movement into and out of the city, closed public transport and most shops and quarantined those who tested positive. In February, a World Health Organization mission there led by epidemiologist Bruce Aylward called it "perhaps the most ambitious, agile and aggressive disease containment effort in history".

It worked. "China did something that many people thought… impossible," Aylward told *New Scientist* in March.

At the time, many researchers still doubted that the same could be achieved in Western countries. But by late March, with death rates soaring, many nations in Europe were forced to introduce lockdowns too, which did greatly reduce case numbers.

The harder part is preventing a resurgence. New Zealand, which has a population of around 5 million, managed to eliminate the virus for a while by quickly imposing a tough lockdown and shutting its borders, but has had a small number of cases since, after another outbreak began in August. Other places to eliminate the virus are isolated islands with small populations.

Only a few countries with large numbers of people have successfully prevented major outbreaks, including Thailand, Vietnam, Taiwan and South Korea. In fact, South Korea has done so well that its economy began growing strongly in the second half of the year after smaller declines in the first half than most places.

Testing, tracing and isolation has been central to South Korea's strategy as well as "very stringent lockdown-type measures", says Amy Dighe at Imperial College London.

China, meanwhile, has prevented another major outbreak. Its strategy has included mass testing of entire cities, including 11 million people in Wuhan. ▮

Michael Le Page is a *New Scientist* reporter based in London

June 2020
Dexamethasone, an existing steroid drug that quells a counterproductive response by the immune system, becomes the first medicine for covid-19 shown to save lives. The antiviral agent remdesivir also shows signs of speeding recovery, though this remains inconclusive.

August 2020
During the northern hemisphere's summer, many countries see much lower rates of infections and deaths, and many restrictions are eased. In the UK, the government funds discounts on food bills to give people an incentive to go to restaurants.

October 2020
Many countries in Europe and parts of the US see second waves of infections that eclipse their first waves, and new lockdowns or tighter social restrictions are brought in. But the state of Victoria in Australia declares victory over the virus when non-imported cases drop to zero.

November 2020
Positive results are released for three vaccine candidates: one by Pfizer and BioNTech, one by Moderna and one by the University of Oxford and AstraZeneca. The first two are based on mRNA, which tells cells to make the virus's surface protein, triggering an immune response.

Astronomy

Life on Venus? We're still looking

Clara Sousa-Silva spent much of the year sitting on a huge secret. She spoke to Leah Crane about how it felt

ONE of the biggest news stories of 2020 was the apparent sighting of phosphine in Venus's atmosphere. On Earth, this gas is only produced by living organisms, and there seems to be no other way to make it on Venus, so this was interpreted as a sign that life may be floating in the Venusian clouds. *New Scientist* spoke with Clara Sousa-Silva at the Harvard-Smithsonian Center for Astrophysics, who was part of the team involved in the discovery.

Clara Sousa-Silva

Leah Crane: How did you get involved with this team?
Clara Sousa-Silva: At the end of 2018, I had just submitted a paper on phosphine with a body of evidence that it was associated with biology and was potentially detectable on exoplanets. A few months after that, Jane [Greaves at Cardiff University, UK, the leader of the collaboration] reached out to say: "Hey, we think we found it on Venus."

How did you react?
I did freak out a little bit, but primarily I was very cautious. I did want to find phosphine, I did expect it to be found eventually, but I didn't have any hopes that it would happen in my lifetime.

You and your colleagues made an enormous list of the possible ways phosphine could be made on Venus if it wasn't coming from living things. What was it like figuring out that none of them could explain the observations?
You make this list so long, you think surely you're going to run out of things to consider. And yet it's so hard to prove a negative, to prove that nothing but life could have created this gas. You're searching in this dark space of possibilities, trying to shine a light in every corner and hoping that you're able to light up everything, but you can't tell when the room ends.

What was the public reaction like for you, after keeping this a secret for so long?
I went through stages of thinking that this would be a really big deal, and then

2020 in pictures

SpaceX makes history with crewed flight

On 30 May, SpaceX used its Crew Dragon capsule atop a Falcon 9 rocket to launch two NASA astronauts, Bob Behnken (pictured just after returning to Earth) and Doug Hurley to the International Space Station. This was the first time a private company had carried humans into orbit. The pair spent 64 days in space and both arrived back safely.

The successful mission marked a return to human space flight for the US, which hadn't launched any crew into orbit with home-grown craft since the space shuttle programme came to an end in 2011, instead having to purchase rides aboard Russian Soyuz spacecraft.

NASA/BILL INGALLS VIA REUTERS

Energy

A sign of progress for nuclear fusion

Efforts to develop a clean source of power advanced despite the coronavirus pandemic

Progress on nuclear fusion, which attempts to produce energy in the same way as the sun, made some important headway this year.

The world's biggest nuclear fusion power project, ITER in southern France, began its "assembly phase" on 28 July. The milestone was welcomed by world leaders, including the then Japanese prime minister Shinzo Abe, who said it will help bring about a "sustainable, carbon-free society".

But that green society is still a way off. Assembly is scheduled to take around four more years, followed by two decades of experiments. ITER's commercial fusion power plant isn't expected until 2054.

Smaller fusion projects had mixed fortunes. There had been plans for the Joint European Torus, a European project at Culham in Oxfordshire, UK, to run the first fusion test of its kind since 1997, using the hydrogen isotopes deuterium and tritium. The experiment was delayed from November 2020 until May to August next year as a result of the coronavirus pandemic.

However, a separate, newly built tokamak – the chamber where fusion reactions take place – tested its first plasma at Culham on 29 October, and on 2 December, the UK Atomic Energy Authority launched a search for a site to build the world's first prototype nuclear fusion power station by 2040. **Adam Vaughan**

thinking: "Clara, it's a big deal for you, but the world is a big place. This is not a priority for people. There's a pandemic, there are elections and revolutions, California is on fire." And then it turned out it was a very big deal that lots of people were excited about.

Other research is now questioning your results. Is that dispiriting?
I'm glad we're not doing this alone any more and there are so many people using disparate analyses to look at the same data. It's exactly how science is supposed to work. This is all positive, but right now my main feeling is impatience: I want to know the truth, and I want to know it right now! But that's not how it works.

How will you feel if it turns out that phosphine isn't in Venus's atmosphere after all?
Even if it's not there, at least people know about phosphine and they will consider it as a potential sign of life. I hope this will be an era of thinking about more molecules that could be associated with life – not just the obvious ones associated with life that's familiar and pleasant, but also life that's different from us, that we avoid, that smells bad or lives somewhere horrible.

What will you be working on in 2021?
We're working on getting more data that will tell us if phosphine is there, and where and how variable it is. These questions will be answered in the near future. ▮

Leah Crane is *New Scientist*'s space and physics reporter, based in Chicago

Economics

A time for universal basic income?

Once a fringe prospect, the idea of paying everyone regular sums is growing in popularity

With the coronavirus pandemic causing a sharp rise in unemployment, one idea is rapidly growing in popularity: universal basic income (UBI), in which the government pays people a regular sum, no strings attached.

A Finnish study published in May (although carried out in 2017 and 2018) with 2000 unemployed people found that UBI boosted recipients' financial well-being, mental health and cognitive functioning, and also modestly improved employment rates.

People who received €560 per month, rather than regular unemployment benefits, reported higher levels of confidence in being able to control their future. The researchers involved say that regular guaranteed payments could alleviate stress in periods of uncertainty, such as the pandemic.

Elsewhere, the idea is also gaining traction. A recent analysis suggests that giving all Australians earning less than $180,000 annually a payment of $18,500 a year would reduce wealth inequality by 20 per cent. The study's authors estimate that UBI would cut poverty by 1.9 per cent, lifting half a million Australians above the poverty line.

Meanwhile, in the US, 25 cities are launching pilot UBI initiatives across the country to support low-income families, funded by philanthropic donations. Donna Lu

Must ~~Nice to~~ have this Christmas

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.

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Climate change

A whirlwind of extreme weather

While our attention was elsewhere, the global climate crisis continued, says **Adam Vaughan**

THE year began with extreme weather in Australia. Bushfires in the nation, made possible by a severe drought, produced apocalyptic scenes of ships rescuing people from beaches, dry thunderstorm clouds and wildlife fleeing beneath orange skies.

The fires pumped three times the amount of smoke into the stratosphere as anything seen before, and they burned an unprecedented 58,000 square kilometres of forest in New South Wales and Victoria. While partly due to natural cycles, the weather conditions that enabled the fires were found to be made more likely by human-made climate change.

It wouldn't be the last extreme weather event of 2020 linked to climate change. Though it didn't affect heavily populated areas and so grabbed less attention, Siberia's months-long heatwave was one of the most striking incidents. Temperatures were 10°C above average in some parts of the region in May, and one town in the Arctic circle hit 38°C. An analysis found the event would have been "effectively impossible" without the warming that humans have caused.

That heat also contributed to the very low levels of Arctic sea ice on the Russian side of the region, resulting in total Arctic sea ice for the year falling to its second lowest extent on record. This year, October – when the region begins to freeze – saw the lowest extent ever recorded for the month. Heat in the region also fostered a second year

2020 in pictures

Our warming world

Left: Melting glaciers in Svalbard, Norway, following record high temperatures in the Arctic circle during July

Middle: A kangaroo passes a burning house in New South Wales, Australia, in January

Right: Flooding in Karachi, Pakistan, in August

LEFT TO RIGHT: SEAN GALLUP/GETTY IMAGES, MATTHEW ABBOTT/PANOS PICTURES, AKHTAR SOOMRO/REUTERS

Astronomy

When Earth acquired a new moon

An object about the size of a car was briefly spotted in orbit around our planet

For a brief period this year, Earth had an extra moon. The object, called 2020 CD3, was spotted hurtling across the sky in February. After calculating its orbit, astronomers found it had probably been gravitationally bound to Earth for about three years before anyone noticed. By studying its brightness, they calculated that it was probably between 1.9 and 3.5 metres across – about the size of a car.

At the time, it wasn't 100 per cent clear whether this was a natural object or just a piece of artificial space debris. Now we are fairly sure that it was natural, says Grigori Fedorets at Queen's University Belfast in the UK. His team has also confirmed its diameter is about 1.2 metres.

"It left the Earth-moon system on 7 March, and has been too faint to be observed by even the largest telescopes since around July," he says.

Shortly after 2020 CD3 became invisible to us, astronomers saw another object, called 2020 SO, approaching Earth. It, too, was temporarily captured in our orbit, but astronomers were unsure whether it was a natural or artificial object. Further analysis in December confirmed that 2020 SO is actually a discarded rocket booster from the 1960s, leaving 2020 CD3 as only the second temporary minimoon we have ever found. Leah Crane

of record CO_2 emissions from Arctic fires.

In August, wildfires along the US west coast saw hundreds of thousands of people evacuated. California was hit by five of the six largest fires in the state's history, which were triggered early in the region's fire season by lightning strikes. More than 16,000 square kilometres of land were burned across California, twice the previous record. Higher temperatures as a result of climate change are drying out the vegetation, making it easier to burn.

This year, the US was hit by 16 disasters that each caused more than a billion dollars of damage, tying it with 2011 and 2017, according to Adam Smith at the US National Oceanic and Atmospheric Administration. The 2020 Atlantic hurricane season exceeded the record 28 storms seen in 2005, as Theta and Iota became its 29th and 30th storms in November.

On the other side of the world, Typhoon Goni (known locally as Rolly) in the Philippines reached wind speeds of 310 kilometres per hour, the year's strongest storm globally. And in Europe, a rare "medicane" – a Mediterranean hurricane – hit Greece.

Overall, global temperatures are well above the long-term average. "2020 is highly likely to be in the top three warmest years and may be the warmest year for Europe," says Samantha Burgess at the Copernicus Climate Change Service. ▮

Adam Vaughan is chief reporter at *New Scientist* and is based in our London office

Software

Computers party like it's 1920

The Y2K bug made an unexpected comeback after a lazy fix backfired 20 years later

The year began with digital havoc, when a computer glitch known as the Y2020 bug took payment systems, parking meters and a wrestling video game offline.

Y2020 arose from a lazy fix to the Y2K (or millennium) bug. This was the concern that computer systems that saved years as two digits – 99, say, instead of 1999 – would treat 00 as 1900 rather than 2000. Thanks to mass patching in 1999, this didn't happen. Yet it turns out that an estimated 80 per cent of computers solved this using a cheap and quick method known as "windowing", in which all dates from 00 to 20 would be treated as the 2000s rather than the 1900s. When January 2020 rolled around, those systems reached the end of that window and reset to 1920.

The issue now seems to be under control, but 19 January 2038 was set to be the next troublesome date for Linux computers, which count the date in seconds from 1 January 1970. The date is stored as a 32-bit integer, and its storage capacity would be exceeded at this point.

However, a potential solution emerged this October, postponing the problem for another 400 years: an increase to the effective size of timestamps. The feature will mean that dates beyond 2038 won't pose a problem until 2486 – the next year to worry about. **Donna Lu**

Technology

Tech titan tussles

Global technology firms dominate our lives, but 2020 saw governments try to claw back power, says **Donna Lu**

THIS was a year in which governments went head-to-head with big tech firms. As we went to press, US regulators were suing Facebook over its historic acquisitions of Instagram and WhatsApp, asking the courts to consider breaking up the company.

An executive order signed by President Donald Trump in August, banning the use of Chinese-owned apps WeChat and TikTok, has also led to a break up – TikTok's parent company ByteDance is working on a deal to sell its US operations to Walmart and Oracle.

Across the Atlantic, the UK government also clashed with a Chinese tech company, banning telecommunications giant Huawei from providing equipment for its 5G network and forcing UK mobile providers to strip out any existing Huawei equipment by 2027. The decision followed a US ban in August on supplying chip technology to Huawei, amid claims the firm could be used by the Chinese government for spying.

Meanwhile, in Australia, the government proposed laws that would require firms such as Facebook and Google to compensate media outlets whose news content is shared on the platforms of the online giants. In response, Facebook said it would ban users in Australia from sharing news content, while Google ran local advertisements warning that its free services could be at risk. ▮

Donna Lu is a reporter for *New Scientist* based in Brisbane, Australia

2020 in pictures

RK STONE/UNIVERSITY OF WASHINGTON

See it from the beetle's point of view

IN JULY, researchers at the University of Washington in Seattle unveiled a camera with a difference – it can stream live video from the back of an insect as it wanders around.

While the researchers have no control over where the Pinacate beetle (pictured) goes, a swarm of them could be used to easily map locations, they say. Plus, beetles are better for this than robots, as they don't need batteries, says the team, which would make the camera more bulky.

Climate change

Tree-planting ambitions yet to take root

Talk of reforestation to combat climate change hasn't been matched by action

In January, the World Economic Forum, backed by US president Donald Trump, announced the One Trillion Trees initiative to plant or protect a trillion trees by 2030, bolstering the estimated 3 trillion that already exist. The scheme joins existing reforestation efforts such as the "Trillion Trees" project launched by conservation groups in 2017.

One Trillion Trees didn't respond to requests for comment on progress, but a US version of its website says that 855 million trees have been pledged by US-based authorities and other bodies. It is unclear how many of those have been planted.

Separately, the National Forest Foundation, a US non-profit organisation, said it had planted 5 million of 7.8 million seedlings it hoped to put in the ground this year, hampered slightly by the pandemic.

In the UK, Guy Shrubsole at Friends of the Earth says there has been little sign that mass tree-planting pledged during the 2019 general election campaign there has turned into action. Figures show that between March 2019 and March 2020, 134.6 square kilometres of new woodland were planted, down 1 per cent on the previous year. Most was in Scotland, with only 23.3 sq km in England, implying a government target for England of 300 sq km by 2025 will be missed without a major ramp-up.

Adam Vaughan

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Columnists

An extraordinary year

As 2020 draws to a close, ***New Scientist***'s columnists reflect on what's important for them, from race justice to plant power, family to hope for the future

Chanda Prescod-Weinstein is assistant professor of physics & astronomy, University of New Hampshire

MICHELLE D'URBANO

ON MY desk in my home office I have a few items that keep me focused and inspired. I have an autographed photo of myself with *Star Trek: Discovery* star Sonequa Martin-Green, the first Black woman to helm a *Star Trek* series. Next to that, I have a Barbie Uhura in the box, autographed by Nichelle Nichols, the Black woman who played the first Black *Star Trek* character, along with an autographed, black-and-white picture of Nichols in costume. I also have a woodcarving of a famous Toni Morrison quote, "The function of freedom is to free someone else." In other words, I make sure that the visions and ideals of Black women and Afrofuturism – reminders of the privilege and possibility in a life of science for someone like me – are always right in front of me.

It is in this halo of hope that I first started having conversations with colleagues about what came to be known as #ShutDownSTEM and #StrikeforBlackLives. These joint calls for a global day of action on 10 June came from a place of grief, anger, fear and, yes, exhaustion. But they also came from a space-time of dreams. When Brian Nord and Brittany Kamai both separately put forward the idea to me that it was time for science to stop business as usual and do more to support the people risking their lives in the streets to proclaim that Black Lives Matter, I immediately agreed. Nord and I didn't have to do much to convince our colleagues in a crew of particle physicists and cosmologists known as Particles for Justice (P4J) when we asked them if they wanted to help.

Five days later, in partnership with a group of astronomers led by Kamai, P4J was publicly calling for 10 June to be unlike any other day in the history of science. On strikeforblacklives.com and shutdownstem.com we posted a statement that said, among other things, "We are calling for every member of the community to commit to taking actions that will change the material circumstances of how Black lives are lived -- to work toward ending the white supremacy that not only snuffs out Black physicist dreams but destroys whole Black lives."

We also stressed that we weren't calling for more workshops or panels on diversity and inclusion, but asking people to focus on community action that would yield real change. The extent to which we were successful varied. There were, of course, the people who responded by holding panels and workshops, and it isn't clear whether these passive experiences translated into any of them taking action. But I also heard stories like the one about people who urged their institution to remove a dean who believed in eugenics – a devastatingly racist mode of scientific thought that remains influential in academia.

They later succeeded in forcing him from the post. This is the power and possibility of scientists working together for race justice. There is even more power in scientists supporting community organising. Let 2021 be your year to get involved, because when we work together, we win. ▮ ›

James Wong is a botanist and science writer. You can follow him @botanygeek

EVERY month in my column, I look into a claim that is ubiquitous in the media, exploring the often surprisingly shaky foundations behind long-held positions we take for granted. This month, though, I wanted to set myself the challenge of examining the evidence behind one of my own closest held beliefs, to see how hard it can be to be objective.

As someone who not only shares his tiny flat with an ever-expanding collection of 500 houseplants, but who also makes a living from writing and presenting about plants, I am perhaps unsurprisingly deeply invested in the idea that being around them improves our mental well-being. However, what does the science actually say about this?

Probably the most common paper cited in lifestyle and gardening magazines as evidence for the beneficial effect of houseplants is a study conducted at a Pennsylvania hospital involving people recovering from gall bladder surgery. Researchers found that those in wards with windows onto a green view experienced a 12.5 per cent shorter hospital stay and needed less pain medication compared with those looking out on a brick wall. Perhaps even more intriguingly, the nurses' notes about the patients' mental well-being revealed that those with a green view were 80 per cent less likely to show signs of emotional distress.

"If you put a bunch of blokes on treadmills, those shown natural views on screens perceive the workout as being less intense"

But what most press stories don't report is that this study was conducted way back in 1984. Examining its design raises other questions. Rather than a gold-standard clinical trial, where relatively large groups of participants are rigorously selected and then meticulously subjected to different interventions, this study was based on simply retrospectively looking at hospital records and involved just 46 patients, spread over a nine-year period, none of whom the researchers ever even met. They are potentially interesting results nonetheless, but hardly something to hang such bold claims on decades later.

In science, the sign of a solid hypothesis is reproducibility. Do the same experiment multiple times and you should expect similar results. So when a 2009 experiment, using double the sample size, found that people recovering from similar minor surgery also reported "significantly more positive physiologic responses evidenced by lower systolic blood pressure, and lower ratings of pain, anxiety, and fatigue" when provided with plants in their rooms, these were some of the first suggestions that this wasn't a one-off. In recent years, a range of similar (although admittedly small) studies on different groups and by different teams have repeatedly reported similar results.

Thankfully, most of us aren't recovering from surgery. Can a view of green plants indoors help the healthy too? Well, a range of exercise studies have demonstrated that if you put a bunch of blokes on treadmills, those shown natural views on screens perceive the workout as being less intense and report having higher feelings of self-worth following the run. Take the exact same view and manipulate the colours to make it red or monochrome, however, and the impact appears to be diminished.

The problem with some of these studies, though, is that the views don't involve living plant material, just screens. Real-life plants add a range of variables that can affect the results, including everything from altering the composition of the air to changing how people navigate through indoor spaces.

Even studies that use actual plants might be highly dependent on the species chosen. With about 400,000 to select from, this could well affect the result. After all, loads of plants have red leaves, for example, and we have already explored how digitally changing plant-filled views from green to red appeared to reduce the therapeutic impact. Could simply painting a room green have an effect similar to, or potentially even greater than, the presence of actual plants? If we were to set up such an experiment, how would we even measure the impact on mental well-being, which is a question plagued by subjectivity?

Therein lies the inherent issue with testing this hypothesis: there are just too many variables. Given this, I am the first to admit that my belief in plants' therapeutic power is based as much on subjective, anecdotal experience as it is on solid scientific data. But I probably speak for all gardeners when I say that this really isn't a deal-breaker for me. When it comes to answering the philosophical question of whether plants make me happy, my own fuzzy experience is just as relevant as any rigorous study. Moral of the story? It turns out it is indeed very hard to be objective. ▮

Annalee Newitz is a science journalist and author. Their website is techsploitation.com

IT'S the time of year when my circadian clock starts yelling at me to make cookies and latkes. Unfortunately, I don't know any recipes for them. I blame my father, an incredible cook who bought every new kitchen gadget he could: fancy

mixers, strange attachments for his food processor, ice cream makers, pasta squishers and even an espresso machine that he plumbed himself so that it would automatically refill with water. The problem is that growing up with a parent like that means delicious meals appear by magic every night. You have very little incentive to learn cooking.

"I weigh the algorithms of online recipes against my recollection of watching my father produce a plump, circular pancake"

My dad didn't pass along any family recipes – and, honestly, I'm not even sure we had any. Although my grandmother loved to cook too, she didn't bequeath the secret of latkes to us. My dad bought a book of Jewish recipes to figure it out, which is perhaps the quintessential second-generation immigrant thing to do in the US. His parents worked so hard to assimilate that they didn't think it was important to teach my dad Yiddish or how to make latkes, knishes, kasha varnishkes, matzo ball soup and all of the other European Jewish dishes that I yearn for in winter.

I didn't start cooking in a serious way until after my father was dead, so I will never know if there was some secret family recipe he never revealed. But there's still one lesson I hold dear from years of watching him cook. A recipe is an algorithm – perhaps one of humanity's oldest consciously produced algorithms – and yet cooking also transcends the power of algorithmic reason.

These days, when I want to cook anything, I start with recipes online. This is the algorithmic part of my process, where I hunt around for variations on the instruction set and parameters. One person likes to add flour to their latkes for structural integrity; another includes matzo meal; yet another insists that it's all about the egg. I don't know exactly which elements will produce my father's results, but I know generally how things should look and smell when a recipe is going the way I like. I weigh the algorithms against my recollection of watching my father produce a plump, circular pancake as opposed to one with a ragged, crispy edge.

When engineers write algorithms, they do something very similar. They will compare the output of an algorithm to output from a real-world process, asking whether, for example, a tornado simulator produces clouds that look natural. Still, cooking requires me to compare recipes to things that are ineffable: a smell, a taste, a memory. Argue with me if you want by saying that we can stick smells into olfactometers and train robots to taste things. That may be true, but the taste of food is profoundly subjective.

If I had a digital file with the flavour of my father's latkes, it's possible that the resulting food wouldn't taste right. Because what I'm trying to make aren't perfect reproductions of a set of chemicals. They're my memories of a small, warm kitchen where onion and potato sizzle in chicken fat, the bite of black pepper on my tongue and a crunch that cannot be quantified. ▮

Graham Lawton is a staff writer at *New Scientist*. You can follow him @grahamlawton

THROUGHOUT this strange, scary but wierdly exhilarating year, an old saying has often popped into my head: "May you live in interesting times." This supposedly ancient Chinese curse – though no such expression actually exists in the Chinese language – is meant ironically. Perhaps it is derived from an actual Chinese saying: "Better to be a dog in times of tranquillity than a human in times of chaos."

It has been chaos, but fascinating all the same, and I don't yearn for tranquillity just yet. I have no desire to see yet more sacrifices made and losses endured, but we aren't out of the woods yet and for somebody in my profession, 2020 has been a vintage year. In January, I was gearing up to write yet more features on environmental science, biodiversity and biomedicine. In February, I was seconded into *New Scientist*'s covid-19 editorial team and plunged into the biggest and fastest-moving science story the world has ever seen.

I have spent the past 10 months frantically reporting, writing and commenting on the pandemic. My background is in biochemistry, so all those years studying genetics, virology, immunology and molecular biology have come in handy. I never expected to need them to report on an epoch-defining historic event.

I have also continued to write my monthly environment column, No planet B. To have such a platform is a privilege and responsibility, and I have tried to use it well. I have had plenty to work with – let's not forget that the pandemic is also an environment story. Covid-19 is the Western world coming face to face with the biodiversity crisis for the first time.

That crisis is at crunch point, but even so, as we head into what will be an unusual Christmas period, I am feeling optimistic. It is increasingly clear that we will get a successful vaccine – I cannot overstate what an immense scientific triumph that will be – and once we have the pandemic under control, there is growing expectation that we will build back better.

As Nobel prizewinning economist Esther Duflo at the Massachusetts Institute of Technology has pointed out, the pandemic is a "dress rehearsal" for the much greater challenge that is climate change. I think the world has performed the dress rehearsal better than expected, and there is now cause for confidence that we can meet other problems ahead.

The defeat and imminent defenestration of that one-man environmental wrecking ball, Donald Trump, also adds to my cautious optimism.

I am no Panglossian – no new dawn is ever as bright as we hope – but my feeling is that 2020-21 will come to be regarded as one of those turning points in history, like 1848, 1918 and 1945, when the old world order was swept away and something new emerged. New doesn't necessarily mean better. But I believe it is possible. Then I will happily go back to being a dog in a time of tranquillity. ▮

Editor's pick

Time to abandon the big bang theory?

28 November, p 34

From Julian Higman, Wantage, Oxfordshire, UK

It was nice to read that what was just a whisper about problems with our leading explanation of the universe is now a shout – that "our best model of the cosmos, a seemingly serenely sailing ship, might be holed beneath the water line". Indeed.

The real question arising from this is: do we use a sticking plaster where we think the hole might be or do we dig deeper to see if there is something more seriously wrong further back? The article largely covers the sticking plaster approach, in other words keep the basic model of the universe and try to adjust it.

I think we need to dig deeper. Doing so may mean discarding our current "best" model to explain the universe, the big bang theory. This may dismay a lot of its aficionados, but it needs to be done.

From Nigel Tuersley, Tisbury, Wiltshire, UK

Could the conundrum about the universe's faster-than-expected expansion be illusory? Since it is red-shifted objects on which we are relying as evidence for this acceleration, could it not be that the space-time in which the matter is embedded is shrinking with distance, producing the same effect through a different route?

Water is my big worry in population debate

14 November, p 34

From Satyajit Roy, New Delhi, India

Of all the resource-related concerns for a growing global population, the availability of fresh water is by far the biggest in my view.

Problems resulting from global warming, the uneven distribution of rainfall, the huge wastage of water and rising sea levels are the main concerns and a red flag. The UN declared that if a third world war happened, it would be over the issue of water.

Some 844 million people lack basic drinking water and each day 800 children under the age of 5 die due to diarrhoea as a result of poor water and lack of access to sanitation, such as handwashing.

There is a water supply crisis even at current population levels. People are struggling to access the quality and quantity they need for drinking, bathing and cooking.

From Peter Brown, Sheriff Hutton, North Yorkshire, UK

In "The great population debate", the key to solving many of the world's problems is summed up for me in the words "people in advanced economies should be rethinking their consumption-fuelled economic models". Somehow, we have to turn around the world's economic system.

Mechanisation, artificial intelligence and technology, together with increases in the global workforce and potential customers, will contribute to extra production, bringing with it increased use of energy and resources, changes in atmospheric composition, pollution from non-recycled products and damage to the natural environment.

We have to find a new way to regulate production and consumption. Whether the answer is to replace capitalism or adapt the market to prioritise a habitable planet, a new system is urgently needed.

From Susannah Matthews, London, UK

You say that those who advocate limiting population must be clear how they intend to do it. No, these aren't the people who hold power. Rather, it is for those who do hold power to be clear how they intend to stop and reverse environmental degradation while the human population continues to balloon.

Limiting population requires globally agreed targets and global economic and social disincentives to exceed these, but also global agreement to cut consumption at the top and improve life chances at the bottom, and an acceptance of more migration.

You set out the barriers to such changes very well: populist governments, vested interests, nationalism, natalism and racism. However, that is no reason to stop thinking about solutions.

How to tackle the thorny issue of vaccine refusal

21 November, p 12

From Andrew Mills, Southampton, UK

As your interview with Heidi Larson suggests, it would seem that persuasion, coercion or appealing to people's better nature is unlikely to have much effect in the uptake of a vaccine against covid-19. So how do we deal with the problem?

Perhaps a system of registration could go some way to convincing refusers to change their minds. A register of those vaccinated would give the operators of aircraft, boats, trains and mass venues such as theatres and sports stadiums the right to refuse people admission or stop them buying a ticket. Checking the register could be quick and simple.

From Geoff Willmetts, Bridgwater, Somerset, UK

Wouldn't it be prudent to issue a secure and easily identifiable badge at the time of vaccination to show who has had it and encourage others to get the injection? It isn't as though it would take long to manufacture them.

Can we address this pandemic waste?

21 November, p 36

From Jonathan Wilkins, Deganwy, Conwy, UK

The arrival of successful vaccines for covid-19 is great news. But if a possible outcome is a shortage of the special glass needed for the vaccine vials, has their recycling potential been considered?

Borosilicate glass can't be recycled in normal waste streams. You mention an estimate that providing enough vaccine to give everyone on the planet one dose would fill 8000 Boeing 747 planes. This amount of non-reusable vials, not to mention the syringes also needed, seems shocking. Is there any way to minimise the waste legacy of this pandemic?

A runaway streetcar is no dilemma for me

31 October, p 23

From Guy Cox, St Albans, New South Wales, Australia

The trolley dilemma always puzzled me. Anyone who has played with a train set as a child knows that accidentally setting the points to the halfway position will derail the train. So, move the lever to this position, the runaway trolley is derailed and stopped, and all the people are safe.

Keep drones away from nesting birds please

14 November, p 28

From Wendy Strahm, Burtigny, Switzerland

Regarding the Aperture photo. Despite what the text says about the birds being calm, drone photography at any nesting site mustn't be allowed. ▮

For the record

▮ **We should have said that birds that moult all their flight feathers from both wings at once may be predisposed to evolving flightlessness (5 December, p 17).**

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Two's company

Photographer
Tobias Baumgaertner

AGAINST a background of city lights, two fairy penguins huddle together to watch the skyline and ocean at the end of the St Kilda Pier in the suburbs of Melbourne, Australia.

Shot by photographer Tobias Baumgaertner, the image captures the pair away from the bustle of their colony. "It was really hard to get a shot, but I got lucky during one beautiful moment," he wrote in the caption to the image, shared on Instagram.

The two penguins would regularly stand together and watch the lights of Melbourne for hours, he says.

St Kilda Pier has a colony of around 1400 fairy penguins (*Eudyptula minor*), which volunteers monitor to make sure the population stays healthy and stable.

Outside Australia, the birds are better known as little penguins because they are the smallest penguin species, growing to an average height of 33 centimetres. They are found mostly on the coastlines of southern Australia and New Zealand.

Although Baumgaertner snapped the shot a year ago, he released it in March this year to reflect the isolation caused by the coronavirus pandemic. The image won the Community Choice Award in *Oceanographic* magazine's Ocean Photography Awards 2020.

Gege Li

Difficult Times

Failing fringe electro band Cosmic String have got a strange new gig, writes **Adrian Tchaikovsky** in this new short story

"There's a gig," says Clawhammer Dougie Jones, or at least his little homunculus trapped in its window on my laptop.

"What gig?" In the window next door, our vocalist Alana Domingo mirrors my utter disbelief. "There aren't any gigs, Doug. The gig economy left the building."

Doug blinks at us, that beatific way he has. Like he's some guru of wisdom about to change your life with a handful of words; like the colossal hit of mescaline he took on that US tour 20 years ago never wore off.

"My people," he tells us, an opening that has never, in the history of music, led to good things. "A paid gig."

And he sends over a figure on the chat channel, and Alana spits out the cheap wine she's swilling and I think about the rent, and the risk.

"I mean..." And the rent has a loud voice, but so does my health. "I don't know if I could even be in a pub's back room now. Not with, y'know, actual crowds." Not that "crowds" is exactly how I'd describe most of our audiences this last decade.

And Doug's damnable smile's gone nowhere. "Pete," he tells me. "Invite only. Select audience. Twenty max. And outdoors. Clover, my people." And, seeing our reluctance eroding in the face of his eternal optimism, "Cosmic String rides again."

A brief history of Cosmic String.

In the seventies, a variety of physicists built on previous models of the universe to come up with a theory describing, to my limited understanding, that the universe might be shot through with constantly vibrating strings, and their vibrational frequency, as a musician like me might understand it, was actually what made all of causation sing.

Now this was explained to me by a then-young guitarist called Doug Jones, whose understanding of the actual science very quickly devolved into all-encompassing uses of the word "quantum", so I never did get my head around it. It seemed very profound when you were high as a kite at three in the morning.

And so, in the nineties, Doug, Alana and me called our fringe electro band Cosmic String on the assumption that we were going to be the universe's next big thing.

That didn't happen. More people have a comprehensive understanding of String Theory than own a copy of the single Cosmic String album. Because yes, every band does its mad concept album eventually, but starting with that was probably a mistake.

"Then a guy's bustling out of the house. It's the actual Lord of the Manor come to greet us in person"

Somehow, though, in a manner just as ineffable as the cosmic strings themselves, we stayed together. Alana does web design on the side, and I write advice columns under the pseudonym Auntie Sheryl, but when Doug calls, somehow we're always free.

Clawhammer Dougie Jones, so called for the frankly uncomfortable way he holds a guitar, was like that before the mescaline. A look on his face like he's not hearing you first-hand, but through an imaginary friend whispering a bad translation into his ear. Goes through life like he's the disguised prince not quite sure why he's still mucking out stables in his late-forties. Somehow never been knifed and dumped in a canal. Not that Alana and I haven't been tempted. But in this year of our entire industry withering on the vine, he's got us our gig.

"Man reached out," he explains earnestly as I take my battered van up literally 2 miles of drive through lush parkland. "Big fan."

Alana's eyes are wide as an owl's, because we know our fans and they generally don't have the money to contribute to a ko-fi account let alone own a stately home. And that is, for real, what we're approaching now. At first I think it's one of those crumbly *Downton Abbey*-style piles that survive on tourism and period dramas, both of which are currently as dead as the live music scene. Closer in, it's new-build, real *Grand Designs* stuff, and that colonnaded front isn't flat but concave, a great angled architectural dish. In front of it, where you'd expect a nice gravel drive and some pot plants, there's a stage being built even now, with the sort of big amps even God would need a mortgage to afford, and a lighting rig. And I slow the van to a crawl and exchange stares with Alana because somehow Doug has come through for us, this once.

Then a guy's bustling out of the house. It's the actual Lord of the Manor come to greet us in person. He's plump, affable, balding with a little Poirot moustache. He greets us by first name. We can call him "Mountjoy" apparently. He's super-enthusiastic. I don't like him. Reminds me of too many promoters and agents who ended up screwing us over. Apparently he's our biggest fan, and that makes zero sense to me. He talks and talks and somehow that sense of about-to-get-screwed-over doesn't go anywhere. But it's not as if we're about to turn around and leave.

Mountjoy has some people take

LUCY JONES

Bio

Adrian Tchaikovsky

Winner of both the Arthur C. Clarke Award and a British Science-Fiction Association Award, Adrian Tchaikovsky's books include the unmissable *Children of Time* series and fantasy series *Shadows of the Apt*.

our bags, and some other people – he's got a lot of people – bring our kit inside. Maybe, before the main event, we could do him the honour of a little set. Just him, just to warm up. He's got a room ready upstairs.

Because Doug won't, I negotiate hard for a sandwich and a sit down first, and we get them. Possibly it's the best sandwich I ever had. And it's served on a silver tray by an actual flunkey. And Alana and I exchange more looks and we ask Doug, basically, what the hell?

"Man loves the music," is all he'll say. "Man gets our vibe."

"Okay, but we're just doing the regular stuff," Alana says, because by unspoken agreement the concept album Shall Remain Buried. And Doug waggles his eyebrows and smiles his smile.

The room Mountjoy takes us to freaks me the hell out because it's full of insects. Well, not actual insects, but there's a big bronze bug on one wall, and a glass case of actual deceased bugs on another, and some bug-related art, and all the same kind of bug. As it happens, it's a bug we're all intimately familiar with because that one year we did the US tour, these bugs were on tour, too, and they were a hell of a lot louder than us. Every set was done to the backdrop of this chorus of CHEE-CHEE-CHEEEER. And the kicker was, these things are almost never about, basically. There's one lot that come out every 17 years and one that does 13 years, and I think the year we toured, both of them coincided and killed off even the tiniest chance that the tour would go well.

But apparently Mountjoy's a fan of them as well as us, and this room is decked out in cicada-themed art, save for a bust of some bald guy at one end.

Doug and I set the gear up. Alana's sorted her mike and is making small talk with our audience of one – and at least that's a crowd size we're used to. The topic gets round to the art, as you might imagine. Mountjoy guides it there, mugging like one of those promoters who knows they're not going to pay up at the end of the night. Except we already got money up front, so it's not that; there's something he knows that we don't, and he's just bursting with how cleverly he's screwing us over.

"This is my ideas room," he tells us, and what nasty crawly ideas he must have. "This is where we meet, my associates and I, your audience. It was here we had the idea to book you, actually."

"These bugs remind you of us, huh?" Alana asks unenthusiastically.

"It's a survival mechanism, you know," he says, waving at the cicadas. "Emerging in prime numbered years. Puts them out of sync with any predators or parasites that might try to match up with them and take advantage of all that bounty. It's like hiding from time. Very clever." He caresses the big bronze bug.

"So, is this Doctor Cicada?" Alana asks, of the bust.

"That?" Mountjoy's self-satisfied smile ratchets up another notch. "That's Enrico Fermi, my dear." And nothing more. Apparently Fermi's self-explanatory.

I google the name later, but half the Wiki entry won't load and by that time the guests are arriving.

Anyway, we play a few of the old bangers for Mountjoy, the proper club stuff people can actually tolerate. Me on keyboards, Doug's guitar, Alana trilling through the jagged, staccato lyrics. Fast electro stuff, loud, aggressive synth, seriously dated. Not what you'd think Mountjoy would like, and indeed he doesn't actually seem to like it much.

"Mr Jones, I was hoping for your other work."

Doug gives me the full cheese of his grin. "You tell that to Pete, man."

Mountjoy's smile is strained. "It really is quite important that you play what you're known for." And from a drawer he brings out the bloody album. The thing that sunk our nascent career 20 years ago and made us the laughing stock of even our tiny corner of the music biz. Cosmic Strong, the sole commercially available recording of Cosmic String, Doug's goddamn concept album. And yes, it's what we're known for, but not in a good way.

Like I said, the mescaline only ›

brought out what was inside. Doug went through his life husbanding a little flame of destiny inside him, and the bad trip brought it into full inferno. Doug was going to reinvent music. And he did. And it was like reinventing the wheel if you decided it would be better square. All these mad time signatures, uncomfortable numbers of beats squeezed into the bar, flights of audio-phantasy that sent freeform jazz musicians crying for their mothers. Alana yipping and barking out weird sounds and words seemingly at random, except none of it was at random. Doug scored everything down to the last beat and it all had to be perfect. We spent months recording it and nobody actually listened to it all the way through.

Except, apparently, Mountjoy.

So we play him our greatest hits, three tracks from the album. It comes back to us, in the same way that a terrible fever dream does. All those awkward shifts in tempo, seven beats to the bar, then 11, then 19. The thundering, irregular bass resounding from the wings of the bronze cicada like an extra set of cymbals. And Doug's face. The look he only ever gets playing these pieces, like he's listening to something angelic and far away, straining for the music of the spheres.

We thought it'd crush him, when the album flopped so hard it broke records. He took it in his stride, a prophet not honoured in his own country. A man whose genius would be recognised in due course. We came to commiserate with him, and he was weirdly elated. "We sent something new out into the world, my people," he told us. "It'll come back to us some day."

Apparently, this is the day.

The weird thing – the thing Doug doesn't see – is that our man Mountjoy doesn't actually like the experimental music either. There's something eager in his face, but he still winces at the discordant bits sane people wince at. He suffers through the performance as though he's been promised a chocolate if he gets to the end. And when we're done, his lavish praise doesn't really seem to have much of the fan in it. Like we're his new skivvies and he's delighted by the shiny spoons without needing to know what sort of cleaner we use.

And I look back at those cicadas and old Fermi and the ideas room and it's almost as if Mountjoy showed it to us just to make sure we didn't get it. We were the hired help, after all. He didn't want us turning up with ideas of our own.

That's the thing with Doug. You tend to assume that vacant grin has a vacant head behind it, and Doug's skull is just crammed with stuff. Just not anything useful most of the time.

"It all had to be perfect. We spent months recording it and nobody listened to it all the way through"

By then the guests are turning up and my old van becomes odd man out in a field of Beemers and Mercs.

They're a varied lot. Some we recognise, even, though not from personal acquaintance. Two are definitely tech moguls, keen on private rocket launches and owning websites that have become common verbs. A couple of TV science bods, next, and an actor best known for belonging to a religion that believes aliens will cleanse your chakras if you pay them enough. Some others we don't know, and it's one of those I find in the cicada room before the set, while Doug and Alana supervise Mountjoy's tech team for the outdoor setup. She's a woman about my age and she looks like a university lecturer, which is exactly what she is.

"This is where you guys do your thing, right?" I say, to break the ice. I wonder if they wear robes and cicada masks while deciding to hire obscure music acts for their parties.

"Doctor Bakirtzis." She sticks out a hand. "Helen." And I respond, "Pete Matelot" and she has no idea who I am. Given she's come for a special command performance of the band I make up a third of, that sends out warning signals.

"I consider myself here as an observer from the other side," she tells me, and I nod wisely. She's up by the bust of Fermi. Apparently, he had a paradox, or that's what Wikipedia says.

"My favoured explanation is that they really are out there," she says, when I bring that up. "The universe is too big for us to be alone in it. Only it's a dangerous universe, Mr Matelot. Especially if we're not alone. Anyone who manages to survive long enough stops shouting out 'Here I am' and finds a way to hide. Tucks themselves out of sight and communicates on channels nobody would think to listen in on. What do you think?"

I think I am out of my depth. I'm only the bloke who plays the keyboard. "So not a fan, then?" I manage, tipping my head towards the stage set-up we can see out the window.

"Ah yes, the band," she says coolly. "Has Mountjoy explained to you what he's trying to achieve here?"

"Doctor," I say, heartfelt, "we are Cosmic String and there is no way in the whole history of the universe that we will ever achieve anything."

"Maybe it's best if you're right." And she seems very serious. And it's not as though I'm unused to being the most clueless man in the room, but still.

And Doug's all manic energy, when I get backstage, outside. Just like when he was working on the

album. Alana gives me a look which says Deal with him, which usually means that he's off his head right before we need to go on. Right now the only thing Doug's high on is Doug.

"The audience, man," he says. His fingers are twitching like spiders on their ninth coffee.

I agree that Mountjoy's private guest list is a bigger house than we've played in years. That's not what he means, though.

"It's like the whole universe, my people. Cosmic strings," Doug says. Alana rolls her eyes, but we're getting Full-on Doug and he's not stopping any time soon. "You never felt like you were calling out to all of creation?" he asks us. "All my life I've heard them singing back, right at the edge of my ears. 'Cept that one time in the States, when they were loud and clear." Meaning the mescaline. "Like nothing else ever sang. Like music never was. But I got it, my peoples. I wrote it down in here," nearly poking his own eye out. "You never thought you had a destiny, man?"

"Just play keyboards, me." I look to Alana. "Mountjoy hear him like this?"

"Mountjoy came in here and fired him up," she says. "All plucking the universal strings and frequencies and time signatures. All about contacting the other. How they're out there. Like him and his posh mates are part of a cult or something."

"The other," I echo. "Like... aliens? He knows in space no one can hear you jam, right?"

"My vision keeps blurring and jumping as though the world's vibrating in 19/8 time"

"Cosmic strings, man," Doug mumbles. "Real big, but real small. Li'l loops of them everywhere. Just need to pluck them right." He mimes his guitar, currently sitting on its rest out on stage. "Universe is your sounding board, they hear you just fine in space."

And then it's time.

As we're going out, I squint at those people out there, the tech giants and the celebrities and the scientists. They all have their nice seats and their nice sandwiches and they don't look like a cult. But there's a dreadful intensity about the way they look at the three of us. They nod to each other and brace themselves, all done up in black tie and gowns as if they're at a reception just waiting for the ambassador. And behind them's the perfect curve of Mountjoy's new-built mansion, the back wall of our amphitheatre that's going to catch and project every sound we bang out.

We start the first awkward, jumpy rhythms that nobody else plays, the difficult times and carefully irregular rhythms. The dreams that Clawhammer Dougie Jones had on tour, where he heard the hidden voice of the universe.

By the second song I find my form and steal glances at what's going on around us. The audience isn't enjoying so much as enduring the music. They're not really looking at us. They're looking past us into that big night sky the curve of the house is throwing all our sound into. My vision keeps blurring and jumping as though the world's vibrating in 19/8 time. There's stuff moving at the edge of my vision, crowding in from a weird axis I never thought about, like height, depth and breadth had a bastard sibling they hid away in the cellar until now.

And Doug's smiling like a martyred saint, as though it's him, and not all of them, who knows what's going on. And out there they're all waiting, the self-appointed elite waiting for the inestimable privilege of first human contact with the other.

The thing is, let's say Mountjoy is right, and there are things out there that speak to each other using a weirdass rhythm and frequency and whatnot that nothing else in the universe operates on. I think of those noisy cicadas, which went to such lengths not to be jumped by their enemies. And if you were some alien which really, really needed to sing to the universe, but at the same time absolutely didn't want any other species to hear you, just how happy would you be if some clapped out 90's electro band began broadcasting on your wavelength from a specially designed amphitheatre that was just maybe interacting with the vibrating strings of the universe.

And if the cosmic strings are all around us, then just maybe so are they.

The crowd's gone still now – I'd say quiet, but Doug's jumpy, skittering compositions are all I can hear. And that's a good thing, I decide. And it's a good thing that whatever everyone's staring at, so aghast, is behind us, because I don't want to have to see it. I crank up the volume on the amps, because right now a part of the universe really is singing back at us to the rhythm of those disjointed time signatures, and it isn't happy that we've crashed its cosmic party.

I see overturned chairs and expensive shoes heading for Beemers and Mercs they're never going to reach. Mountjoy's round face melts like candlewax. A flickering shadows everything there is, like insect wings, and all of it beating to that damnable jumpy time signature. And we keep playing the set, and we'll play it 10 times in a row if we have to, because just maybe that'll be camouflage enough to make them think we're theirs, rather than this reckless humanity that's gone and poked their hidden hornet's nest. And Doug's face is the blissful sky-turned mask of the prophet whose apocalyptic time has finally come. ■

Anamorphic interlude

What you are looking at is a visual illusion created by artist **Lex Wilson** – or at least it will be. Turn over to find out how to create your own illusion

How it works

In one sense, getting this to work could hardly be simpler. Just prop (or stick) the right-hand page of the centrefold against a wall so it is at 90 degrees to the left-hand page, which should be on a flat, horizontal surface. Then step away and adjust your standing position until the distorted image appears perfectly in 3D (see above).

Yet, in another sense, how this works is actually pretty complicated. Like any visual illusion, anamorphic illusions such as this one trick your brain by taking advantage of the way that we stitch together reality from our perceptions.

Your brain can't possibly process all of the visual information it receives, so it takes shortcuts. It constructs an image of what you are looking at based on previous experiences. Most of the time, the expectations match the real, physical world – but not always. When they don't, your brain unconsciously distorts your perception to meet those expectations, making things appear as something they are not.

Anamorphic illusions, from the Greek word for "transformation", have been popular since at least the Renaissance, when artists like Leonardo da Vinci were experimenting with perspective. Perhaps the most famous example is a 16th-century painting called *The Ambassadors* (below) by Hans Holbein the Younger, in which a distorted shape at the bottom of the picture is revealed to be a skull when viewed from an acute angle.

THE NATIONAL GALLERY, LONDON

Make your own... and share it!

In our anamorphic illusion, the *New Scientist* logo floats within a Penrose triangle, which is impossible in the sense that it can't exist as a solid object. But you can create an amazing illusion based on anything you like – provided you can draw it – thanks to artist Lex Wilson. First, visit newscientist.com/christmas-illusion and print two grids. Then simply follow the instructions below. We have even provided another pair of grids, in case you fancy experimenting with something a bit more complicated.

1

Download grids 1 and 2 and print them on A4 paper. Make sure to print at 100 per cent size in print settings.

2

On grid 1, carefully draw your design (example in pink).

3

Using the grid coordinates, transfer your design onto grid 2, making sure to distort the artwork in each cell so that it matches the design in grid 1 (see right).

4

Fold grid 2 along the central dotted line, then stand the paper up as shown. Now step back and admire your work!

5

Don't forget to show off your creations on Twitter and Instagram using #anamorphic and mention @newscientist

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PLAINPICTURE/KAISER; ASSJA/GETTY IMAGES

Festive frolics

Yule love our 29-page holiday features special featuring zebras with machine guns, stardust in the gutter, instant whisky, the mysteries of glacier mice, AI learning to speak whale, battling bots, ancient excrement and much, much more...

Why don't wildebeest have wheels?

There are some adaptations that evolution never seems to produce. Is that because there is a limit to its creativity, asks **Michael Marshall**

"From so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved." That was how Charles Darwin described the incredible diversity of life forms generated by evolution. But he never addressed the big question: if evolution is infinitely innovative, why hasn't it produced animals with wheels? Are there limits to evolution's creativity that mean some things can never evolve? And if not, why haven't things like flying plants arisen or anything resembling a semi-automatic rifle?

Evolution exists because living things vary: each member of a species is subtly different to every other one. Those that are better suited to their environments are more likely to breed and pass on their genes, and so their favourable traits become more common in the population. Given enough time, this slow process can create wonders like gigantic blue whales, cooperative honeybees and towering sequoias. Evolution has produced animals that live more than 10 kilometres under the sea and bacteria that can handle doses of radiation that would kill a person many times over.

Yet some things just don't seem to turn up. Wheeled animals are a classic example – the evolutionary biologist Stephen Jay Gould discussed them in his 1983 book *Hen's Teeth and Horse's Toes* – but there are many others. In a 2015 paper, Geerat Vermeij at the University of California, Davis, identified 32 combinations of traits that evolution has seemingly never produced. For instance, there are no rigid structures like coral reefs in fresh water, no

SYDNEY HANSON

plant-eating snakes and no flying plants.

It is tempting to invent reasons why these can't exist, but Vermeij is reluctant to place such limits on evolution. "I think very few of these are what I would characterise as... forbidden phenotypes," he says – a phenotype being the observable physical properties of a given organism. Given more time, evolution may well produce them.

Vermeij says we should imagine ourselves as evolutionary biologists living in the Ordovician Period, some 450 million years ago. "We couldn't have conceived of some of the things that have actually evolved [since]," he says. "Things like flowers and flying insects. That demonstrates to me that evolution is very much a cumulative process, and what is now possible would not have been at that time."

Jennifer Hoyal Cuthill at the University of Essex in the UK agrees. "Biological evolution is the most unlimited process in the known universe," she says. "Its main striking feature is its ability to produce, as far as we've seen, infinite diversity. We haven't run out of new animals. We have no idea where the edges of this space might be."

Hoyal Cuthill says that many of the seemingly forbidden animals are examples of a kind of selective reasoning. Take the lack of plant-eating snakes. Many groups of animals have switched back and forth between eating meat and eating plants. Giant pandas are one such example: although they depend on bamboo, their ancestors were carnivores and their guts haven't fully adapted to eating plants yet. No known snake has done this so far, which might imply that there is something about having this sort of body that is particularly suited to meat eating – or it might just be a coincidence. Hoyal Cuthill points out that snakes' closest living relatives are lizards, many of which eat plants.

"Projectile weapons have frequently evolved, albeit only in ambush predators"

Vegetarian spiders

There may also be limits to our knowledge. For decades, it was thought that all spiders were primarily carnivorous. Then, in 2009, we discovered that a species called *Bagheera kiplingi* mostly eats plants.

Still, it is possible to go further and imagine much wilder scenarios. A 2007 paper by Timothy Shanahan at Loyola Marymount University in Los Angeles memorably asked: "Why don't zebras have machine guns?" It argued that zebras would benefit from evolving machine guns to repel attacks by lions, but that they can't because evolution has to proceed by intermediate steps, all of which must be advantageous – or, at least, not harmful. A machine gun is only useful when it is complete. As a functionless organ, it would just be hogging vital nutrients.

But there may not be as strong a limit here as it first appears, says Hoyal Cuthill. "Projectile weapons have frequently evolved. Archerfish use water as a projectile weapon. Antlions use sand as a projectile weapon," she says. These animals are all ambush predators, so it may simply be that evolution doesn't favour projectile weapons in prey, because fleeing a predator is normally a better strategy than fighting it. The truth may not be that evolution can't fashion a rapid-fire projectile weapon for zebras, but rather that it doesn't do so because the existing solution – running away – works well enough.

This suggests that evolution hasn't even remotely reached its limits, and that over the next few hundred million years – and assuming humans don't cause a global extinction event – it might lead to animals and plants that are inconceivable to us today.

Vermeij argues that evolution is getting better at producing new things. "Organisms have, on the whole, become more energetic over time," he says. It is known, for instance, ›

Evolution is smarter than you

There are plenty of animals that seem, at first glance, to be evolutionary mistakes; that appear to have evolved obviously disadvantageous traits. Yet on closer inspection, it often turns out that, as the biochemist Leslie Orgel famously said, evolution is cleverer than you are.

Take the Australian night parrot (*Pezoporus occidentalis*). As the name indicates, it is nocturnal, which you might think would mean it can see well in the dark. However, in June 2020, Vera Weisbecker at the University of Queensland, Australia, and her colleagues reported that its eye sockets were smaller than those of other parrots, as were its optic nerves. The study's accompanying press release said the bird "may not be much better at seeing in the dark than other parrots active during the day".

That may initially look like an evolutionary blunder, but Weisbecker's team doesn't claim anything of the kind. The researchers only had access to a skull, so they couldn't examine the bird's actual eyes, which might have adaptations to the dark. "What they suggest, based on the information they do have, is that its visual system is a kind of compromise between sensitivity to low light and also visual acuity," says Jennifer Hoyal Cuthill at the University of Essex, UK. That isn't a mistake – it is evolution balancing two competing problems.

Similarly, there is a popular idea that big spiders like the Goliath birdeater (*Theraphosa blondi*), the largest in the world by mass, will "shatter" or "explode" if they fall even a few feet. This isn't only exaggerated, it is a misunderstanding of how such spiders live.

Species like the Goliath birdeater are indeed vulnerable to falls. "If a large tarantula falls from a height, if it is unlucky enough to land upside down or with great impact, the exoskeleton could break open and the spider could bleed to death quite quickly," says Paula Cushing at the Denver Museum of Nature & Science in Colorado. However, she says that exploding and shattering are misleading descriptions.

More to the point, in practice, these spiders are rarely at risk of falling any distance at all, says Brent Hendrixson at Millsaps College in Jackson, Mississippi. "They're sit-and-wait predators and probably rarely venture to locations that would result in a fatal fall."

that the veins running through the leaves of flowering plants have become more densely packed over millions of years, meaning modern flowering plants can extract more energy from sunlight than their ancestors could 100 million years ago. Similarly, "the average metabolic rates of things like snails and clams and many other organisms have increased over time", says Vermeij.

Energetic expansion

The reason for that is competition, he says. "As organisms become more energetic, they also have more choice, and they have a greater opportunity to modify their environments."

Vermeij says one knock-on effect may be the evolution of general intelligence in multiple animal groups: not just humans and other primates, but cetaceans like dolphins, cephalopods such as octopuses and certain birds including crows and jays. "More brainpower and greater intelligence are themselves products of greater energetic investment, and are again favoured under most circumstances because they give the bearer greater choice," he says. The smartest organisms on Earth may be getting smarter over the ages.

That leads us back to the original question. If evolution is so precocious, why hasn't it created a wheeled animal yet?

Hoyal Cuthill offers a blunt answer. "Wheels are terrible," she says. "The reason so much effort went into the development of the tank is that wheels are atrocious." Sure, they're fine on smooth roads but not so much on badly maintained ones. And in nature, smooth, flat surfaces are rare, so there is no reason for evolution to favour wheels.

The other issue is whether creating a wheel that freely rotates about an axle is beyond evolution, says Vermeij. It is hard to imagine how the wheel might receive nutrients from the rest of the body, as any blood vessels would be torn away. "The wheel might be one of the very few things that may just not be accessible to living things, other than by making a machine as we have done," says Vermeij.

Yet he points out that even if wheels and axles aren't possible, organisms have still found ways to travel using rotational motion. "There are spiders that manage to actively roll down a hill by using their limbs to propel themselves as they form a ball," he says.

Hoyal Cuthill has a final suggestion. "A ball can move rotationally with more degrees of freedom, in more directions, than a wheel on an axle," she says. "Wheels are prone to getting stuck or falling over," she says; balls don't have that problem. So the reason evolution hasn't produced wheeled creatures might simply be that it has other solutions. That's just how natural selection rolls. ■

Michael Marshall is questioning his ancestors' energetic investment

Searching for stardust

There are almost certainly tiny, shiny meteorites hiding on your roof. **Joshua Howgego** went hunting for them

IT WAS a warm summer morning in the countryside near Oslo and Jon Larsen decided to have breakfast outdoors. He carefully wiped down the white plastic table on his patio and went inside to collect his meal. Then, as he sat down to eat, he noticed a tiny black speck on the table. "It was glittering in the sun," he says. "I thought, wow, what is this?"

That was 2009. Fast forward a decade and Larsen has managed to pull off something many thought impossible. He has shown that merely by scouring ordinary urban spaces, you can find your own micrometeorites – tiny specks of extraterrestrial dust that have been floating around since the birth of the solar system, billions of years ago. These days, his collection comprises more than 3000 specimens and he boasts a large fan base of urban space-dust hunters.

I had heard a little about Larsen's work and got the impression that following in his footsteps wouldn't be too difficult. All I needed, it seemed, was some dirt from an undisturbed roof and a microscope. Could I really find my own stardust? I was about to find out.

A meteorite is a chunk of debris left over from the early years of the solar system that has survived passage through our atmosphere and crashed to the ground. They are nearly all chunks that have broken off asteroids orbiting between Mars and Jupiter, and they contain an unblemished record of conditions in the early solar system – information we have used to understand how the planets formed.

Micrometeorites are a lot smaller, obviously. They must be less than 1 millimetre to qualify. But they are also more mysterious. "If you grind up a meteorite you don't get micrometeorites," says Cecile Engrand at Paris-Saclay University in France. Micrometeorites, unlike their bigger cousins, seem to have not been heated at all after they formed at the birth of the solar system and so represent its most primitive matter.

We don't know for sure whether they come from the furthest reaches of the asteroid belt or from comets. But we do know that, while most regular meteorites are bone dry, the majority of micrometeorites contain water and carbon-containing compounds that are the building blocks of life. One hypothesis ›

BIDLZX/GETTY IMAGES

Dust left over from the birth of the solar system is constantly falling to Earth

"Estimates suggest around 100 tonnes of micrometeorites fall to Earth each day"

holds that it was a slow, steady dusting of these particles that helped fill Earth's oceans. "To me, it's a wonder that you can look at something so tiny under a microscope and use it to understand stuff to do with the whole solar system," says Engrand.

Finding space rocks often involves an expedition to a desert, where the meteorites stand out against the plain backdrop. Even there, it isn't easy. Sizeable meteorites are vanishingly rare. Smaller meteorites are more common though, and when you get down to micrometeorite scales, we are talking about a constant sprinkling. Estimates suggest that around 100 tonnes of these particles fall to Earth each day, which works out as roughly two specks of dust per square kilometre per second. That means there is a good chance one has landed on any given roof.

Searching for them has always been considered a futile exercise, largely because of the sheer volume of terrestrial dust you would have to wade through. It is like finding a needle in a whole barn of haystacks. Matthew Genge at Imperial College London studies micrometeorites recovered in remote places, such as Antarctica, where terrestrial dust is barely present. He says hobbyists routinely write to him claiming to have found the stuff, but they pretty much never have.

Larsen wasn't the most obvious candidate to succeed where so many others have failed. He has had an amateur interest in geology his whole life, but he made his living as one of Norway's best-known jazz guitarists (he has recently retired, but Hot Club de Norvège, the band he founded in 1979, is still going strong). Yet he describes himself as obsessive, and after his interest was piqued by the sudden appearance of the speck on the breakfast table, there was no turning back. "I started thinking: there's two truckloads of dust coming in every day and none of it can be found?" he says. "That's very strange."

Book of dust

While touring with his band, Larsen began a curious habit. In each new city, he would collect samples of dust and pick through it under a microscope. The trouble was, he had no idea what he was looking for. The few published pictures of micrometeorites were grainy black-and-white images in scientific papers. These suggested he should look for black spheres about 1-millimetre wide, but there were lots of things that fit that description in the detritus he collected and they couldn't all be from space.

Larsen reasoned that various sorts of earthly dust from industrial processes, the environment and so on ought to be present in different amounts depending on location. Industrial cities might have more bits of dust created from welding, for instance. But cosmic dust ought to appear in the same amounts everywhere. So he began a systematic survey and, over the course of seven years, identified the 75 most common types of terrestrial dust.

Whatever didn't fit into these categories was probably the space dust. He began sending pictures of this stuff to Genge in London. "To begin with, I just wanted him to go away," says Genge. But Larsen was persistent. The particles he was finding were typically rounded and black with a kind of shiny, heavily grooved crust. That made sense because the passage of micrometeorites through the atmosphere often melts the particles and the rushing air moulds their surface into tiny undulations.

Eventually, Genge was persuaded to analyse the chemical composition of the dust and, in 2015, the pair announced that they had indeed

JON LARSEN

A selection of micrometeorites, each less than 1 millimetre in diameter, from the collection of Jon Larsen

found the first urban micrometeorites.

Now it was my turn to find some of this wondrous space dust. I borrowed a ladder and climbed up to reach my roof guttering. Then I used a garden trowel to scrape its contents into plastic sandwich bags. The weather had been fine, so it was mostly dry, dusty stuff and a few clumps of moss that the magpies had broken off the tiles. It wasn't the most glamorous 15 minutes of my life, but somewhere amid the moss, feathers and dirt could be a minuscule cosmic prize.

On the Trail of Stardust, Larsen's guidebook for stardust hunters, explains that the next step is to separate your regular dust from any cosmic stuff. To begin, I emptied my bag of roof muck into a plastic bowl, added water and washing up liquid and then stirred. I picked out the stuff that floated and, once the solids had settled at the bottom, decanted the brown water. After repeating this a few times, I was left with a dish of clean, tiny rocks.

I put these pieces through an old tea strainer to get rid of the larger chunks. Finally, I picked up a powerful magnet I had bought online, covered it in a plastic bag, stirred it around in the dust and transferred the magnetic stuff into a white bowl. This is a crude tactic because not every micrometeorite is magnetic, but it massively reduces the volume of dust you are working with.

The next step is to hunt through your dust grain by grain. I bought a cheap USB microscope and started searching. It is a beguiling world down there. Magnified 60 times, some specks look like pieces of multicoloured popcorn or dark, spiky stars. Others are translucent gems of many colours; red, blue and delicate green.

I knew to look for rounded black beads. But I'll level with you: this stage nearly broke me. I spent at least 7 hours going through the dust. Sometimes, I would find a promising-looking speck only to lose it again. On several evenings, my wife had to explain that there were more important things to do right now, like read our children a bedtime story.

Eventually, I found and photographed seven pieces that looked promising. The only sure way to know if you have discovered a micrometeorite is to analyse its chemistry, but Larsen is such an expert that he can normally tell just by looking. When I sent him my photos, he offered a good-natured chuckle. He couldn't see any convincing signs that these specks came from space.

The beauty of micrometeorites is revealed under the microscope

I had thought that meteorite hunting would be easy and cheap. My magnet, USB microscope and other bits and pieces had collectively cost less than £30, but Larsen told me I would do well to get hold of some lab-grade sieves to isolate grains between 0.2 and 0.4 millimetres in size. This is where the majority of micrometeorites are hiding, he says, so the sieves significantly reduce the time it takes to find them. You also really need a binocular microscope to see the surface texture of the particles, which is the best way to identify those of a cosmic origin.

I am yet to find my own space dust – but I did track down a man who has. I got in touch with Jens Metschurat, a student at Clausthal University of Technology in Germany. He has been interested in hunting micrometeorites since he was a child, but his search stepped up a gear when he came across Larsen's work. In three months using Larsen's methods, Metschurat says he has found eight particles, one of which is more than 0.5 millimetres long – a giant among micrometeorites. So clearly, it can be done.

For his part, Larsen is working on his magnum opus, a 300-page book called *Starhunter*. He is also continuing his searches. What excites him now, he says, is that by sheer volume of discovery, he is starting to find unusual types of micrometeorites. The other day, he came across one that contained a lot of the rare element scandium, and he has found others with carbon-based molecules, the same stuff that forms the basis of all living things.

You might be wondering what happened to the speck that started it all, the one that fell on Larsen's breakfast table. Well, not knowing how best to store microscopic particles, he put it in a matchbox and it got lost. I take a certain comfort from that story. It shows that even the best stardust hunters can come from humble beginnings. ■

"I spent at least 7 hours sifting through a bowl of dust – this nearly broke me"

Joshua Howgego is hoping there might be a binocular microscope under his tree

Ho ho hokum!

If we want our kids to grow up to be savvy, why do we lie to them about Santa Claus, wonders **David Robson**

ROHAN KAPITÁNY was 7 when he started to question the existence of Santa Claus. Every Christmas, like many Australian kids, he had left out an apple and a carrot for the reindeer and a cold beer for the man himself – and every year, he found half-eaten snacks and an empty glass alongside a pile of presents the next day. But Kapitány had started having doubts. With his scepticism growing, he even hatched a plan to check his parents' ATM receipts. "That was the beginning of the end, or the end of the beginning, of my belief in Santa," he says.

Two decades later, Kapitány – now a psychologist at Keele University, UK – is investigating Father Christmas again. This time, he is probing the ways that children tell fact from fiction. He wants to know why some kids are more likely to believe in the supernatural than others, what makes Santa more plausible than other fictional figures and why we lie to our offspring in this way. The answers could have surprising implications for our understanding of young minds, conspiracy theorists and rituals.

As fairy-tale figures go, our modern Santa Claus is a rather recent invention. The real Saint Nicholas was born in the 3rd century AD, but it would take around 900 years for him to be recognised as a patron of children and the magical bearer of gifts. Even then, he was often portrayed as a fearsome figure. It was only in the 19th century that he took on the familiar form of a jolly old man sitting in a sleigh pulled by reindeer.

Beliefs in Santa are incredibly prevalent among children in many Western countries. One study by Jacqueline Woolley at the University of Texas at Austin (UTA) found that more than 80 per cent of 5-year-olds in the US are convinced of his existence. "The characteristics that he supposedly possesses defy everything that children know to be true about the world," says Woolley. "People don't live forever, they don't have reindeer that fly, they can't know what you want without speaking to you. Santa Claus violates all of those things, and yet children still believe in him. So you have to wonder what's going on here."

Some evolutionary scientists see children's beliefs in Santa Claus as a sign of innate credulity. Children evolved to believe what their elders tell them, they argue, because it is safer than learning through trial and error when the consequences could be deadly. "It is easy to see why natural selection – the 'survival of the fittest' – might penalize an experimental and sceptical turn of mind and favour simple credulity in children," wrote Richard Dawkins in his book *Unweaving the Rainbow*.

Yet careful experiments have shown that young children are, in fact, quite sophisticated in deciding who and what they trust. For example, Woolley and her UTA colleague Gabriel Lopez-Mobilia presented groups of 5 to 8-year-olds with fictional animals, such as the ocean-dwelling binbad. They were more likely to believe an animal existed if a zookeeper endorsed it rather than a chef, suggesting that they had already learned to take someone's expertise seriously. Importantly, they also allowed their own knowledge to override expert endorsements. They were less likely to believe in a horse that climbs trees than one that lives in the jungle, for instance.

The rituals we build around Santa may be more for our benefit than for our children's

MARTIN PARR/MAGNUM PHOTOS

Children also want to see evidence before buying into more far-fetched ideas, and are sensitive to implicit clues, such as overhearing two adults talking about a fictional character in an offhand way. One October, Woolley and her colleagues told groups of 3 to 7-year-olds about the Candy Witch, who would leave a toy in return for a pile of sweet treats. Some were simply given a description of the witch. Others also overheard their parents making an apparent phone call to her, asking her to visit, and on Halloween these parents replaced some of their offspring's sweets with toys. Children

given this "evidence" of the Candy Witch's existence were far more likely to believe in her than those who simply had to take their parents' word for it.

This is a surprising degree of scepticism for such young minds. It also hints at the power behind the Santa myth. Parents tell detailed stories about his home at the North Pole and the elves that help him, encourage children to write letters to him and leave snacks for him and his reindeer in the evening that have disappeared by the morning. Some take their children to visit him in shopping centres or even in Lapland. In other words, parents have a variety of rituals designed to provide additional "proof" of Santa's existence. Could these rituals be the key to his credibility?

Kapitány and his colleagues recently put this idea to the test by asking children, aged from 2 to 11, to rate the "realness" of different figures on a scale of 0 to 9. As you might hope, real people and animals – such as celebrities and dinosaurs – were at the top of the pantheon. Santa, the tooth fairy and the Easter bunny, all of whom come with associated rituals, were a close second. They were followed by ghosts and aliens, then finally by fictional characters like Princess Elsa from *Frozen*, which have no associated rituals. "Children are looking to see whether people's behaviour is supportive of their beliefs," says Kapitány. Santa seems to pass that test.

"Children are, in fact, quite sophisticated in deciding who and what they trust"

Check your conspiracy

So much for the credulous young mind. In fact, research by Woolley and her colleagues suggests that children are less likely to believe in supernatural phenomena than adults. Arguably, many of the conspiracy theories flying around the internet are less convincing than the idea of a man flying around Earth delivering presents. Unlike young children, people who buy into such ideas are forgetting to check the expertise of their sources, to use their prior knowledge and to seek other evidence to gauge the reliability of an unlikely scenario.

The big question, though, is why we go out of our way to fool kids about make-believe characters. Woolley says there is no evidence that it harms children in the long term. With Santa, it might even make sense as a way to improve their behaviour. After all, he has god-like omniscience: he knows if you've been bad or good and may punish or reward as appropriate. Kapitány's surveys indicate that many parents use this threat. However, when he surveyed parents in the run-up to last Christmas, they reported that their children were just as naughty and no nicer than at any other time of year.

Given Santa's seeming inability to keep kids in line, Kapitány suspects that these festive rituals are more about familial bonding – not to mention the sheer fun of sharing a story. Parents are often more distressed than their children when the illusion is uncovered, he says. "The magic is for the parents." ▮

David Robson is expecting a lump of coal this Christmas

Wombling, boojums and thunk

Test your knowledge of some of the more arcane terminology used by scientists in our jargon-busting quiz. Can you spot the right answer each time?*

**Some questions have multiple correct answers*

1 Aa
A An isthmus formed when a river meander is cut off, forming an oxbow lake
B A rough volcanic lava flow characterised by jumbled piles of loose, sharp blocks
C A haze of volatile organic chemicals given off by rainforest canopies

2 Boojums
A In physics, geometric patterns that form on the surface of superfluid helium
B In astronomy, Blue Objects Observed Just Undergoing Moderate Starbursts
C In botany, strange cactus-like trees (*Fouquieria columnaris*) found primarily on the Baja California peninsula in Mexico

3 Degeneracy
A When two different genetic sequences code for the same thing
B When two differently arranged quantum systems share the same energy
C When two different plants share the same bed

4 Frass
A Freshly cut grass
B Iron filings
C Insect excrement

5 Jerk
A In physics, the third derivative of displacement with respect to time
B In genomics, a discontinuity in a base sequence that disrupts replication
C In chemistry, a sudden, unexpected reflux through a distillation condenser

6 MACHOs
A Male Androgens Correlated to Hepatic Output, hormones implicated in differing metabolic rates between the sexes
B Massive Astrophysical Compact Halo Objects, a possible identity for dark matter
C Molecular Anionic Compounds with Hydrophobic Oxygen Species, a common ingredient of soaps and face creams

7 Monorchid
A Of a plant, having only one fruiting body
B Of a taxonomic genus, having only one constituting species
C Of a scrotum, having only one testicle

8 Nutation
A Swimming with tucked-in feet to decrease water resistance, as practised by crocodilians and others
B A periodic variation in the direction of a planet's axis of rotation
C The regular shedding of skin, characteristic of many lizards

9 Penguin
A An aquatic bird of the family Spheniscidae, primarily in the Antarctic
B A symmetry-violating process in particle physics in which a quark temporarily changes flavour
C A subroutine in a Google search that penalises sites artificially stuffed with highly searched keywords

MICHAEL HADDAD

10 Piloerection
A A molecular scaffold used to increase catalytic efficiency
B Spontaneous sexual arousal
C Goosebumps

11 Spaghettification
A The braiding of a river's main channel that occurs with high sediment load
B The tangling of neurons in the brain that is a precursor to some forms of neurodegenerative disease
C The stretching of an object by gravity as it falls into a black hole

12 Struthious
A Of or resembling an ostrich
B Causing the contraction of biological cells; astringent
C Of a geometric shape, enclosing a finite volume within an infinite surface area

13 Tappen
A A plug of hardened faeces that seals off a bear's rectum during hibernation
B A viscous resin produced by subarctic pine species that is prized for its antiseptic properties
C The proboscis through which a butterfly extracts nectar from a plant

14 Thunk
A In physics, the fourth derivative of displacement with respect to time
B In psychology, a thought forgotten as soon as it needs to be vocalised
C In computer programming, a subroutine used to feed a calculation into another subroutine

15 Wino
A A gene in fruit flies that, when mutated, causes unusual attraction to ethanol
B A family of three force-carrying particles that is postulated in supersymmetry theory
C An insect related to the pond skater and noted for its skittish movements on water (*Tachygerris inexpectatus*)

16 Wombling
A The act of making useful things from discarded litter, as practised by Elisabeth Beresford's Wombles
B A mathematical method for detecting regions of abrupt change, for example in a genome, named after its inventor, William H. Womble
C Moving along with the belly touching the ground, a method of locomotion favoured by newts and salamanders

17 Ylem
A A historical term for the inert component of air, what we now know as nitrogen
B The primordial matter that filled the universe in the first instant of the big bang
C The proteinaceous component of the cytoplasm, the fluid that fills biological cells

18 CHEMISTRY CORNER:
Which of the following is a genuine name of a chemical molecule?
A Fucitol
B Arsole
C Moronic acid
D Bastardane

19 GEOLOGY CORNER:
Which of the following is a genuine name of a mineral species?
A Fukalite
B Cummingtonite
C Taconite
D Welshite

20 MATHS CORNER
"Given n measurable objects in n-dimensional Euclidean space, it is possible to divide all of them in half with a single (n – 1)-dimensional hyperplane"
This is:
A The chicken nugget theorem
B The jam doughnut theorem
C The ham sandwich theorem
D The turkey twizzler theorem ■

Quiz compiled by *New Scientist* executive editor Richard Webb. He much prefers a bimble to a womble

Answers:
1 B
2 A, B and C
3 A and B
4 C
5 A
6 B
7 C
8 B
9 A, B and C
10 C
11 C
12 A
13 A
14 C
15 B (though there is a fruit fly gene variant that causes unusual attraction to ethanol, called LUSH)
16 B
17 B
18 CHEMISTRY CORNER: A, B, C, D
19 GEOLOGY CORNER: A, B, C, D
20 MATHS CORNER: C. If n = 3 and your three objects are bread, butter and ham, it says that you will always be able to slice a sandwich made from them to share all three things equally

Forbidden fruits

Once a popular ingredient, true currants were ruthlessly eradicated from the US culinary landscape. **Aparna Vidyasagar** has the juicy backstory

IN JUNE 1894, *Harper's Bazaar* ran a page of recipes featuring currants and gooseberries. It proudly noted that "more than forty of the sixty known varieties of the currant are of American origin" including the blackcurrant, "with its medicated taste", the white, "less acid than its ruby sister" and the red, "whose decided flavour renders it pre-eminently valuable as a sauce for meats and game".

Back in the 19th-century, US newspapers and magazines often carried recipes that made use of currants, yet now they have all but disappeared. Meanwhile these delicate fruits remain current in other parts of the world, not least in the UK, where they find use in jams, cordials and various sweet treats such as berry-laden summer puddings and gooseberry fools. And not just that. Even with confectionery brands such as Skittles and Starburst, the purple ones are different flavours on either side of the pond, blackcurrant in the UK and grape in the US. Why?

The answers lie in a ruthless and now largely forgotten war launched by the US government on the currant. While a ceasefire has long since been declared, these unfortunate berries never fully recovered – and so it is likely that the majority of people in the US today have never tasted one.

True currants, in case you are wondering, aren't the same as raisins and sultanas. The popular Zante currants, or raisin currants, that originated in Greece's Ionian islands are actually dried grapes, as are raisins and sultanas. True currants are a berry borne by bushes belonging to the *Ribes* genus, which contains more than 150 species and includes gooseberries. The dainty fruits come in various colours – typically black, red or white – and tend to be tart, with whispers of sweetness.

Currants have grown wild in North America for centuries. Many Indigenous communities used native species for culinary and medicinal purposes, and early colonists introduced more variety. As early as 1629, for example, the Massachusetts Bay colony imported European varieties of blackcurrants and redcurrants for cultivation.

Through the 1800s, these were often used to make jams, jellies, cordials, wine and sweet items like tarts, pies and spiced currants and even festive cocktails (see "Currants past", opposite). Blackcurrants were used in home remedies. By the turn of the 20th century, the US was commercially producing European currants on nearly 50 square kilometres of land, much of it concentrated in the state of New York.

But New York also happened to be home to the eastern white pine (*Pinus strobus*), then the US's primary source of timber. The relatively soft wood of the pine was extremely versatile, used to make everything from matches to furniture, as well as exterior cladding and interior panelling for homes. Demand was high – so high that, by 1900, eastern white pine stocks were severely depleted. It wasn't long before nurseries had to import seedlings from Europe.

"The US launched a ruthless and now largely forgotten war on currants"

Unfortunately, they received a stowaway too, a parasitic fungus named *Cronartium ribicola* that causes a devastating disease known as white pine blister rust.

The spores of this fungus enter through pine needles and spread steadily to the branches and trunk, infecting tissues and creating bulging, spore-filled cankers. Infected branches can be pruned to save a tree, says Melodie Putnam, a plant pathologist at Oregon State University. But once the spores reach the main trunk, the whole tree can be lost. If there is a wound on the tree in which spores can land, "it's like a free lunch", she says. "There's already an opening there for them to cause an infection."

The first credible report of the disease's presence in the US came from New York state in 1909, by which point millions of eastern white pine seedlings had already been imported. At first, officials from the US Department of Agriculture tried to destroy all the diseased planting stock. Then, in 1912, they banned the import of white pines from Europe and Russia. Neither did the job. In just a few years, white pine blister rust had spread across the north-east. By 1921, the disease had overcome the white pine species of the western US. The country was facing an epidemic that threatened to destroy one of its most important industries.

What does any of this have to do with currants, you might ask. Well, it comes down to the fungus's double life. ›

ASSJA/GETTY IMAGES

Currants past

Two festive recipes from the days before the US declared war on currants

CURRANT SHRUB COCKTAIL

Adapted from "Currants and Gooseberries", Harper's Bazaar, *June 1894*

Ingredients:

1 quart (1 litre) red currant juice
¾lb (340g) white sugar
1 quart (1 litre) of "best" brandy or "good" Jamaican rum

Method:

If you are making your own juice, cook the red currants until "the juice runs freely", then squeeze the fruit and strain to remove skins. To the warm juice, add the sugar and stir until dissolved.

Once cool, add in the liquor. Strain, if using fresh currants. Bottle and seal. Simply add water and ice to serve.

MEATY MINCE PIES

Adapted from "Virginia mincemeat", Scientific American, *December 1889*

Ingredients:

2 lbs (907 grams) beef
6 lbs (2.7 kilogram) raisins, sultanas and Zante currants
2 lbs (907 g) beef suet
1 ½ lbs (680 g) candied lemon peel
4 lbs (1.8 kg) apples
2 lbs (907 g) sugar
2 grated nutmegs
¼ oz (7 g) cloves and mace
½ oz (14 g) cinnamon
1 quart (1 litre) currant wine or sherry
1 quart (1 litre) brandy
1 tsp salt
2 lemons and 2 oranges. Juice and rind

Method:

Gently simmer the beef until tender. Let it cool and chop it finely. Chop the apples and beef suet. Mix all the dry ingredients together. Then add the juice and rinds of the oranges and lemons. Place the mixture in a stone jar and pour in the currant wine and brandy. Cover and store in a cool place. Thin out the mixture with currant wine or cider before filling your pies.

CHELMICKY/GETTY IMAGES

WEISSCHR/GETTY IMAGES

Redcurrants (left) are a secondary host for the fungus that causes blister rust (right) in pine trees

Cronartium ribicola needs two alternating hosts to complete its life cycle. Its primary host is one of several species of five-needle pine trees. But the fungal spores that burst out of the cankers on white pines can't directly infect other pines. They must first be carried, sometimes thousands of kilometres, on strong winds to seek out their secondary host: any susceptible species of *Ribes*. More specifically, they target the leaves of the plants. Currant plants act "like a spore-making machine", says Isabel Munck, a plant pathologist with the US Forest Service. "Spores that are made on the *Ribes* are the only ones that can affect white pines."

It follows that if you can get rid of the currant plants, which host *Cronartium ribicola*'s spores, the fungus effectively becomes powerless. And so it was decreed by the US government, with a federal *Ribes* eradication programme that began in earnest in 1916.

The authorities wanted to be swift and aggressive, having been stung by a previous catastrophe. At the end of the 19th century, in a space of just a few decades, the US lost almost all of its population of mature American chestnut trees to another fungal disease, chestnut blight. The country couldn't afford to lose white pines too.

What followed was carnage. Vast swathes of currant shrubs were destroyed in forests, nurseries and home gardens. In 1919 alone, more than 100,000 hectares of currants were cleared in the north-east. During the Great Depression of the 1930s, the Civilian Conservation Corps employed thousands of people to pull up any wild or cultivated currant bushes in the vicinity of white pines, primarily by hand. Eradication efforts ultimately encompassed both east and west coasts as well as the Great Lakes and Rocky mountain regions, and ran through both world wars.

The campaign was indiscriminate. Not all *Ribes* species are equally susceptible to the fungus. The European currants, particularly the blackcurrant, were most vulnerable to blister rust and therefore most dangerous to pines. Yet the eradication programme spared nothing, neither native nor cultivated.

In Wisconsin, to take one example, the heavy-handed federal approach on the lands of the Menominee Tribe was initially met with some resistance "because those [native] plant species are medicinally a part of our culture", says Jeff Grignon, a former forester for the Menominee Reservation. "They were opposed to removal of those species en masse." But the community ultimately complied and Menominee women undertook the bulk of the work. On Menominee lands alone, more than 12 million *Ribes* plants were destroyed between 1921 and 1950, often by scouring the same plots of land three times over.

"By the mid-20th century, you see virtually no recipes with currants"

In the long run, the arduous eradication programme, which sometimes took place on difficult terrain, proved to be unsustainable. The federal programme was dismantled by the late 1960s, but white pine blister rust was never fully stamped out. It is still prevalent in the eastern US, according to Munck, and its range is expanding to new areas in the west of the country. Even while implementing alternative approaches, such as selectively breeding disease-resistant pines, several states retained strict restrictions on currant cultivation, if not barring it entirely.

But the campaign to eradicate currants had a distinct impact on the country's culinary preferences. "Currants went from something that was generally familiar to Americans to something unfamiliar," says food historian Stephen Schmidt. By the mid-20th century, he says, "you certainly see a lot fewer recipes for them. In fact, you see virtually none."

So there you have it. The curious absence of these delicate fruits from the US culinary landscape, and the reason purple Skittles taste different on either side of the pond, can be traced back to the federal government's decades-long campaign to squash the currant. ■

Aparna Vidyasagar is feeling cordial. She tweets @AparnaVid

The moss ball mysteries

Rootless plants that seem to dance across glaciers have puzzled scientists for decades, finds **Stephanie Pain**

FEW have glimpsed them in the wild and you won't see any in captivity. Yet the elusive glacier mouse – small, green and fuzzy – suddenly found itself an A-list celebrity earlier this year when reports of its antics became the antidote to a blizzard of bad news.

You may recall the tales of ice-dancing mice that travel in troupes and move with a synchrony worthy of the corps de ballet. If so, you will know that the mice in question aren't actually mice at all. Purists might call them unattached moss polsters, supraglacial globular moss cushions or just plain moss balls. But when the Icelandic glaciologist Jón Eythórsson first brought them to the world's attention in 1951, he dubbed them *jökla-mýs* (glacier mice) and it stuck. "They genuinely look cute, like a small furry creature – at least from a distance," says Scott Hotaling, a glacier biologist at Washington State University.

Hotaling is one of the scientists who served up the latest instalment in the long-running saga of the glacier mice, which remain a riddle wrapped in a mystery. Those lucky enough to have encountered a colony in one of their remote icy haunts confess that they find them puzzling in many ways, not least their curious movements. Yet thanks to some painstaking sub-zero surveillance, these mossy blobs are slowly giving up their secrets.

Only in recent years have we begun to get the measure of glacier mice. That's partly because they are rare, found only on select glaciers in Alaska, Iceland, Chile and on the Norwegian archipelago of Svalbard, and partly because glacier biologists are rarer still. But where there's one mouse, there are usually many, and as glaciers became a hot topic, the scientists who explored them couldn't help but notice when furry green balls dotted an otherwise white landscape. "Your first impression when you see them is how out of place they look – something so soft in an environment that is so harsh," says Hotaling.

Their presence in locations often considered too cold and barren to support much more than microbes prompted many questions. How do they form, and why only on some glaciers? How do these living plants survive on ice? And, of course, what's with those artfully choreographed migrations?

Eythórsson had noticed that glacier mice usually contain a small stone. More recent investigations suggest they exist only where there are patches of stony debris on the ice, which helps explain their rarity. They seem to form when windblown moss spores from various local species settle on these rocky fragments: mosses are a major component of high-latitude habitats and are quick to colonise newly ice-free areas. However, for mosses to cloak a stone entirely, every surface must be exposed to the sun – and, if it is to stay covered, no moss can remain in contact with the ice for too long or it will die. This means glacier mice must keep turning over. Eythórsson assumed that they roll downslope, helped by the flow ›

MICHAEL MARQUAND/ALAMY

"Glacier mice" usually grow to 10 centimetres, but can be twice as big

The ice pack

Meet the sub-zero menagerie that calls glaciers home

Patagonian dragon

It may be the largest animal living on Patagonia's glaciers, but at 2.5 centimetres long, the stonefly *Andiperla willinki* makes for a rather miniature dragon – and is flightless to boot. Its larvae develop in meltwater pools, while adults roam over the ice seeking food and a mate.

Glacier flea

Desoria saltans – which isn't a flea but a springtail – hops about alpine glaciers, often in huge numbers. It is a tiny creature, just 1.5 to 2.5 millimetres long. And although it prefers a balmier 0°C, the glacier flea can survive temperatures as low as -15°C thanks to antifreeze in its blood.

Ice worm

A relative of earthworms, this is the only annelid adapted to life in ice. North American ice worms *(Mesenchytraeus solifugus)* are thin and up to 3 centimetres long, with dark blue, brown or black pigmentation that absorbs heat and protects them from high levels of UV light. At night, they migrate upwards through the ice crystals to feed on surface algae, retreating when it gets too warm. Hugely successful, they can reach densities of 100 per square metre. A second species lives in Tibet.

Glacial midge

The habitat of the flightless Himalayan glacial midge *(Diamesa kohshima)* is the coldest of any insect. Discovered on the Yala glacier in Nepal in 1984, the midge spends its entire life on ice and remains active at temperatures as low as -16°C. New Zealand's Franz Josef and Fox glaciers are home to midges of another species, *Zelandochlus latipalpis*, confusingly known locally as ice worms.

Glacier finch

Though not strictly an ice-dweller, the South American white-winged diuca finch *(Idiopsar speculifer)* is the only bird known to nest and raise its young on glaciers. The finch's glacier nests were discovered on Peru's Quelccaya ice cap in 2008 at an altitude of 5700 metres.

DARREL A SWIFT

CYRIL RUOSO/NATUREPL

IMAGEBROKER/ALAMY

ACCENT ALASKA.COM/ALAMY

of summer meltwater on the glacier.

Nothing so simple. In 2005, glaciologist Phil Porter at the University of Hertfordshire, UK, and his colleagues studied a dense population on the Falljökull glacier in southern Iceland. Most "mature" mice were ovoid, domed on top and flatter beneath – although many looked as if they had flipped over and were lying belly up. Porter noticed that upright balls were perched on pedestals of ice with tops that sloped in the same direction as the glacier's surface. All the evidence suggested that the moss balls shield the ice beneath them from the summer sun and, as the surrounding ice melts, they are left atop a column of still solid ice – until they slide or topple off their perch back onto the surface of the ice and the whole process starts again.

As moss balls progress downslope, they trap windborne dust and soak up meltwater, encouraging an ever-thicker growth of moss. Mature glacier mice usually measure around 10 centimetres from nose to tail, but the occasional giant can be twice as long. "For mice to form, there must be debris with the

The fluffy green moss balls are only found on a few glaciers

Glacier finch (far left); glacier fleas (middle); and ice worms, which are glacier-residing relatives of the earthworm

right size stones, a source of moss spores, certain temperature characteristics – although we don't know exactly what those are – and a slope so the balls will roll," says Nicholas Midgley at Nottingham Trent University, UK.

In 2010, Midgley travelled to Iceland to study glacier mice movements more closely. He fitted some mice with accelerometers, which measure their speed and orientation, logging data every 30 seconds. Those sitting on the glacier surface don't move, he found, but the ones on pedestals build up to a roll with a slow "creep", rotating a few degrees before they plunge back onto the ice. Typically, the mice toppled every day or two and rotated between 30 and 60 degrees in the process. "Glacier mice rotate often and evenly enough to prevent any part staying in contact with the ice too long," says Midgley. "So now we know how they maintain their covering of moss."

Meanwhile, in the US, Tim Bartholomaus and Sophie Gilbert, both at the University of Idaho, had also caught the glacier mouse bug.

> "They travel in a herd-like fashion, performing a slow-motion ballet"

In the summer of 2009 and the following three summers, they trekked to the Root glacier in Alaska's Wrangell mountains to see how fast the mice travel and where their manoeuvres take them. The pair adopted the "capture-mark-recapture" technique used for tracking small mammals, "capturing" 30 mature glacier mice and marking them with wire bracelets threaded with a unique combination of coloured beads. That first summer, they returned eight times to "recapture" the tagged mice and plot their travels, calculating speed and direction from the locations they recorded.

The mice travelled 2.5 centimetres a day on average. One positively sprinted, with a top speed of 8 centimetres a day, but generally they all moved at about the same pace. The big surprise, though, was that they didn't travel at random, but in a herd-like fashion, performing the strange slow-motion ballet that propelled them into the headlines earlier this year.

Bartholomaus and Gilbert monitored the mice for 54 days. For the first nine days, the whole population travelled south, moving at a sedate 2 centimetres a day. Then, they swerved slightly westwards and kept up a cracking 4 centimetres a day for a week before veering another 45 degrees west and slowing to 3 centimetres a day for the next five days. Finally, they turned another 10 to 15 degrees west and returned to their original pace for a further five days. For the final 28 days they continued on this track, progressively slowing as summer came to an end. The changing speed was linked, at least in part, to the rate at which the glacier was melting, but how to explain the herd-like migration? With Hotaling now on the team, the researchers considered three possibilities: the slope of the glacier surface, wind direction and local patterns of solar radiation. "We ruled out the obvious answers. None explained the patterns of movement, which left us shrugging our shoulders," says Hotaling. "It's most likely a complex mix of all those factors."

Although they failed to crack that puzzle, the team did make an important discovery: glacier mice live a long time. Each summer, Bartholomaus and Gilbert hunted down their marked moss balls. Over the years, they lost a few – two fell into a crevasse and four shed their tags, escaping further scrutiny. On average, 86 per cent of mice survived each year, which translates to a lifespan of more than six years. This matters because there is more to glacier mice than stone and moss: they soak up water like a sponge and accumulate soil and organic debris, providing something very rare on a glacier – a habitat for animals.

Cosy haven

What we know about life inside glacier mice is thanks to Steve Coulson at the Swedish University of Agricultural Sciences in Uppsala. In 2008, he received a parcel of mice from Midgley and set about examining their contents. Each one harboured small soil invertebrates: there were two species of springtails along with large numbers of nematode worms and tardigrades. Coulson believes he might have found mites, rotifers and perhaps even spiders if his extraction methods had gathered in the dead as well as the living. "The mice spent a bit of time in the post, so there might have been other things that were dead on arrival," he says.

For Hotaling, these teeming oases are yet another blow to the idea that glaciers are barren (see "The ice pack", far left). Glacier mice provide warmth, food and water, creating a unique ecosystem supporting self-sustaining communities. "They are little islands of habitat that move around on the ice," he says. "For the animals inside, it's like being in a camper van, equipped with everything you need and buffered from the elements outside." ■

Stephanie Pain likes her ice in cubes, preferably in a glass of gin and tonic

When creepy-crawlies hit the gym

Getting invertebrates to work out in the lab could have surprising benefits for human health, finds **Claire Ainsworth**

RUN run run run THUD run run run run THUD. This is the steady beat of the Power Tower as it subjects a cohort of athletes to extreme fitness training. Each round starts with a vertical sprint up a smooth wall, before a jolt from the machine sends them tumbling to the bottom again. Hour after hour, hundreds are put through their paces. And wow, do they get results: stronger hearts, faster climbs, greater endurance and a metabolism wired to resist stress. Not bad for a small fly you would usually find haunting bananas or floating face down in your glass of Shiraz.

Fruit flies aren't the first thing that springs to mind when you think of fitness training, but they are providing a surprising window on the biology of exercise. They aren't even the strangest invertebrate hitting the gym. That medal goes to a tiny nematode worm called *Caenorhabditis elegans* whose transparent body allows scientists to see the physical consequences of activity in action.

But there's a problem. You can't just plonk these creatures in front of a workout video and tell them to feel the burn. So how do you get a fly to drop and give you 20 or a worm to run a marathon? Like any good personal trainer, you understand your client's motivations and craft your workout accordingly. That's where the Power Tower comes in – along with laser treadmills, electrified swimming pools and other unusual gym equipment. It isn't just the invertebrates that benefit either. This fiendish research is generating unique insights into how exercise affects human health and ageing.

Thanks to a shared evolutionary history, a fruit fly's biology has more in common with our own than you might think, including a tendency to be healthier when active. The benefits of working with them are clear. Cheap to keep and quick to reproduce, they have been the focus of more than a century of intensive study by geneticists who have developed an impressive array of tools to probe their bodies. Motivating flies to run is easy, too: they just want to defy gravity. Home for a fruit fly in a lab is a plastic vial with a cotton wool plug stopping the top. Tap a vial so the flies tumble to the bottom and they scurry up to the plug. Keep tapping it and you can get them to do the equivalent of endurance training, which is exactly what Robert Wessells and his team at Wayne State University in Michigan did when they began this research. Trouble was, they grew tired before the flies did. "We just thought, 'Well, this is pretty tedious'," says Wessells. "So we built a little machine that would raise and drop them with a platform so we could put hundreds of vials on there at the same time." The Power Tower was born.

Now, with four Power Towers on the go, Wessells's team can put thousands of flies through high-intensity endurance training at once. The regime starts with 1.5 hours of uphill running each day, gradually increasing to 2.5 hours. "It would be like a human who ran at very fast times around their neighbourhood for 5 to 10 hours a week," says Wessells. The flies' physiological responses are similar too – at least, they are for males. It turns out that females don't get as much benefit from training. This, the researchers realised, might be a clue to one mystery of human exercise: why some people get a bigger metabolic pay-off than others.

> **"How do you get a fly to drop and give you 20 or a worm to run a marathon?"**

One promising lead is octopamine, a neurotransmitter that male flies produce more of during exercise than females. Wessells and his team found that artificially increasing the levels of octopamine in sedentary flies conferred metabolic benefits like those produced by exercise. Humans have a similar molecule, called noradrenaline, and the researchers have just completed a preliminary study using virtual-reality exercise simulations to try to fool volunteers' brains into producing it. Results were mixed, with only a few people responding to the treatment. "But it does seem like it should be possible to do basically what we did in the fly," says Wessells.

Octopamine helps explain one puzzle: why tissues other than the muscles being exercised also experience metabolic benefits. Another clue comes from sestrins, proteins that humans and other animals produce when under stress. Wessells and his colleagues have shown that flies need to produce a sestrin in their muscles to respond to exercise, and that it works by altering the activity of molecules that control cellular metabolism. Tissues other than muscles also seem to benefit from this sestrin activity, says Wessells, who is now trying to find out why.

The Power Tower was groundbreaking, but it can only get flies to do intensive training. To measure the effects of more gentle exercise, Nicole Riddle and Louis Patrick Watanabe at the University of Alabama at Birmingham have come up with a fruit-fly treadmill that is a dead ringer for a rotisserie – with lasers.

Their machine, the Rotating Exercise Quantification System, is based on another ›

BRETT RYDER

contraption called the TreadWheel, developed by Laura Reed at the University of Alabama and her colleagues. The TreadWheel consists of rotating arms to which the researchers clip vials of flies. As the arms turn, they gradually tip the vials end over end, so the direction of "up" is constantly changing. This encourages the flies to jog to keep up – or they can have a sit down if they aren't really into running. "[Some flies will] run around and do the whole thing for 2 hours," says Riddle. "Then there are other flies that will do it for 10 minutes and go like, 'Well, I'm done. I don't need to do this any more'." She confesses to sharing this lack of enthusiasm for strenuous exercise. "The part that always surprises me is they really aren't that different from us," she says.

Riddle and her team's innovation was adding a monitor with laser beams that lets a computer quantify overall fly activity in the tube by counting how many times the insects cross the beams as the machine rotates. This allowed them to study large numbers of flies. They then scanned the genomes of 161 genetically distinct strains for gene variants linked with an individual's inclination to exercise and response to activity. Riddle and her team found variations in more than 100 genes, many not associated with exercise before. "I think there are definitely things we can learn from the flies that then, hopefully, will translate to something that will work for people," says Riddle.

Swim club

Worms could also teach us a thing or two, especially when it comes to exercise and ageing. *C. elegans* nematodes live for just three weeks (about half the lifespan of fruit flies), so it is easy to see the effects that exercise has on them over their lifetime. To do this, Monica Driscoll at Rutgers University in New Jersey and her colleagues have been chucking worms in at the deep end. An electric field can influence the direction they swim in, a quirk that Driscoll's team tried to exploit to get them to swim laps in a fluid-filled chamber. Unfortunately, the researchers struggled to find the right balance between no laps and fried worms. "So then we switched to: just throw them in the pool," says Driscoll.

"Worms push past tiny, flexible pillars and crawl out of gel as tests of strength"

With no charge to chase, the worms wriggle around, essentially treading water. Those that do this for 90 minutes two or three times a day for the first few days of their lives see marked benefits, including faster crawling and healthier muscles. They also maintain a healthy gut as they age, and being active has a big impact on their little brains. "The animals learn better," says Driscoll. Worms that are genetically engineered to produce the faulty proteins linked with human neurodegenerative conditions such as Alzheimer's disease have neurons that stay healthier for longer if the animals have exercised. This chimes with findings that exercise helps people reduce their risk of getting dementia as they age. The big question is what molecules and mechanisms underlie this protective effect. "We're hoping to use the awesome power of *C. elegans* genetics to understand what is particularly important," says Driscoll.

Another intriguing discovery – again mirroring what has been seen in humans – is that worms that exercise when they are young but then stop retain the benefits into middle age. The biology behind this isn't well understood. One idea is that exposure to low levels of stress – the kind induced by exercise – sets the body's priorities when it comes to preventing and repairing damage, an effect biologists call hormesis. "The idea is that a moderate or small stress, early, ups your defences," says Driscoll. "There's a saying: 'What doesn't kill you makes you stronger'."

Her team is now working with microfluidics engineers to design chips that could house the worms and then automatically push them into the pool, without human intervention. Cameras and other machines would record data on each worm over the entire course of its life. As well as making things easier for the scientists, this kind of set-up would allow them to study differences between individual worms.

So far, worm and fly research has focused on the metabolic effects of exercise, rather than building muscle or losing weight. That could change with new exercise regimes, though. Driscoll gets her worms to push past tiny, flexible pillars or crawl out of a gel to test how strong their muscles are. That isn't so different from pumping iron, although strength training isn't on Driscoll's radar for now. Wessells, meanwhile, is looking into it: he is investigating the possibility of gluing tiny metal weights to his flies' backs, as other scientists studying fly gait have done. Taking a leaf out of NASA's book, he has also tried putting fruit flies into a centrifuge, although he describes the results of his first attempts as "a little bit chaotic".

Still, given the huge potential of exercise research with flies and worms and the determined ingenuity of the scientists who study them, it surely won't be long before a new range of workout equipment arrives at a creepy-crawly gym near you. ■

HERMANN EISENBEISS/SCIENCE PHOTO LIBRARY

Some fruit flies benefit far more from exercise than others – just like us

Claire Ainsworth is buzzing, which is presumably as good as a stint on the treadmill

Social glow

What does gathering around the TV have in common with the campfire habits of our Stone Age ancestors? **Colin Barras** finds out

ERIC HANSON/GETTY IMAGES

LAST year, it was *Frozen*. This year, it might be *Eight Below*. A holiday during the long, cold Michigan winter is a chance for my family to spend some quality time together. And what better way to enjoy our evenings than by watching movies on TV?

Some might call this a waste of time. Anthropologist Christopher Lynn begs to differ. He believes there is a good reason why many of us like gathering around the idiot box. Far from being frivolous, it is a legacy of a behaviour that arose to help humans survive the unforgiving Stone Age world.

It is tempting to see human evolution through the prism of technological breakthroughs that brought tangible material benefits. When our ancestors learned to make projectile weapons, for instance, they could hunt more effectively and secure more reliable sources of meat. Softer aspects of life, such as the ways we socialise, might seem less important to the success of our species. But Lynn, who is based at the University of Alabama, says we socialise not because we like to, but because we need to.

That may seem obvious to anyone who has struggled with isolation during lockdown this year. But Lynn goes further still. He thinks that the pleasure we gain from relaxing around the TV with friends and family might help explain why humanity became so social in the first place. It all began, he says, when our ancestors learned to control fire.

We have known for decades that the use of fire transformed life for early humans. It allowed them to cook food, for example, making it easier to digest. But there is another crucial side to fire: its role as a source of light around which people can gather as dusk turns into full-blown night. One of the few researchers to consider the social importance of firelight is anthropologist Polly Wiessner at the University of Utah. For decades, she has been visiting the Ju/'hoansi, hunter-gatherers who live in southern Africa, to study their way of life. A decade ago, she decided to explore ›

the content of more than 150 Ju/'hoansi conversations she had documented – and she made a remarkable discovery.

During the day, the talk was relatively mundane or practical; about one-third of discussions concerned practical topics such as hunting strategies and technology, for instance, with another third devoted to complaints about group members. Around the campfire at night, however, around 80 per cent of conversations were in the form of stories. Some were funny, others exciting – all were entertaining. Yet they often also contained information about social etiquette and tradition, as well as about geographically distant social contacts who could be visited for help during times of hardship. In other words, listening to these stories had the potential to make life and survival easier. "In the big picture, stories are probably more important than day talk," says Wiessner.

PANTHER MEDIA GMBH/ALAMY

Watching a flickering fire reduces stress and tunes your brain

But there is another way fire might have bound us together as a social species. The archaeological record suggests that campfires appeared perhaps 1.5 million years ago, but there is little evidence that humans actually learned to light fires for at least another million years. If so, then fire was, for much of human prehistory, a resource that had to be gathered from the environment. That can be difficult, says Lynn, so would have encouraged people to cooperate with one another to keep their campfires burning day and night.

He believes that is a big reason why groups containing the most affable and cooperative humans thrived over time. Throw in the idea that these groups took further advantage of fireside cordiality by telling information-laden stories to one another at night, and you arrive at a scenario in which we were evolutionarily selected to find fire comforting rather than frightening, as other animals do, and to enjoy the prospect of cooperating, socialising and storytelling around the flames.

A just-so story, you might think, but Lynn and his team have investigated this further. First, they got volunteers to watch a video of a campfire while having their blood pressure measured. The readings dropped significantly, which is a sign of relaxation, whereas there was no such effect in people who watched a static, upside-down image of the fire. What's more, the largest relaxation effect occurred in the people who were most gregarious, as assessed by a personality questionnaire. So there seems to be a link between fire, relaxation and socialising. "It reinforces the importance of [Wiessner's] findings," says Nathaniel Dominy at Dartmouth College in New Hampshire.

Flickering screens

This got Lynn thinking about the 21st-century implications of our ancient love of stories by firelight. Could it help explain why many of us enjoy gathering around a bright TV screen at night to watch a show with friends? To test this idea, his team recently carried out another experiment. This time, instead of seeing a video of flickering flames, volunteers watched a film. It wasn't an exciting blockbuster, just a dry, anthropological careers advice video. Nevertheless, it, too, reduced people's blood pressure – and, again, the effect was most pronounced in the most gregarious viewers.

Others are intrigued by these findings. "I think there is much to be explored here," says Wiessner. Dominy wonders whether there is something in the nature of flickering firelight itself that stimulates group socialising and storytelling. In 2019, Tetsuhiko Kashima at the University of Tokyo and his colleagues built on Lynn's work by monitoring people's brain activity while they watched a real fire. "They saw this amplification of delta waves, which are brainwaves strongly associated with memory and attentiveness," says Dominy. This might suggest that flickering firelight helps tune the brain so that it is receptive to learning lessons from stories. Dominy hopes to explore further by examining whether the brain activity of groups gazing into a campfire becomes synchronised, boosting the sense of cohesion.

Another interesting phenomenon may occur when we stare at flickering flames. Lynn suspects that their rapid movement and unpredictable flares might generate a "what is it?" reaction that physiologists call an orienting response. Some research suggests that dramatic scene cuts in movies also produce this effect. In both cases, says Lynn, as soon as we remember there is no cause for alarm, we might experience a pleasurable endorphin release. If so, that could help explain why staring at a fire or a TV is deeply comforting.

There is still work to be done, not least to discover whether different types of shows have different physiological effects. Like watching TV, some might call this research a waste of time. Yet Lynn is fascinated by the high value we put on socialising. "It's one of the mysteries we need to focus in on if we really want to understand the evolution of our species." ▮

"Can our ancient love of stories by firelight explain the TV's allure?"

Colin Barras loves the endorphin rush he gets from watching *Frozen*

Taming the bots

The chunks of roaming code that shape much of the internet are getting smarter. Can we bring them to heel, asks **Edd Gent**

THE internet is quite popular. The best estimates suggest that by the end of 2019, some 4.1 billion people were online – over half the world's population. That is hardly news. What's more surprising, perhaps, is that human users are almost outnumbered by non-human ones. Governed by coded instructions, these bots creep around in the background, largely out of sight, browsing websites, clicking links, downloading content and typing text. What are they up to?

We need to know. Although for the most part we still outsmart these free-roaming bots, they are growing more intelligent and destructive, capable of destabilising everything from financial markets to public debate and even our shared sources of knowledge. Only by understanding their secret, complex ecosystem can we hope to tame them.

If you have been online, it is almost impossible for your experience not to have been shaped by bots. These automated chunks of code, preprogrammed to perform a certain task over and over again, account for as much as 39 per cent of activity on the web, says Matthew Prince, CEO of Cloudflare, a firm that helps companies securely manage web traffic. As much as 1 per cent of that comes from Google's army of web crawlers, known as spiders, which scuttle around websites plucking out information like text and links that determine where pages appear in search results. Every search engine, from Bing to Baidu, has its own spider armies too.

Other bots help to maintain order on the web. Monitoring bots are digital meerkats on constant alert, periodically checking websites for bugs, poor performance and outages. Moderator bots live inside social media platforms such as Reddit, Twitch and Discord, automatically hiding or flagging inappropriate content. The same spiders that Google relies on can also scour the web for copyright infringement and stolen content.

Bots play a critical role in cybersecurity, too. Defenders and hackers alike use them to scan for flaws in the code of websites, either to patch up holes or exploit them. "They're like bloodhounds," says Prince. "The bots are almost acting like a scout, running around looking for some new security vulnerability."

But the relative anonymity of bots makes them popular agents for digital crime. One common technique is to use a virus to hijack thousands of computers and run bots from them, like a parasitic fungus using a host to spread its spores. Most commonly, these networks of bots are used for "distributed denial of service" attacks, in which they flood websites and jam up their servers. Scraping bots, meanwhile, flit about like digital magpies looking for shiny objects to hoard, including email addresses to feed into spam bots and valuable web content that can be reused on copycat sites to pull web traffic and make advertising money.

For some big firms, bots are their eyes and ears. E-commerce giants such as Amazon and Walmart are engaged in a never-ending bot war, gathering information on competitors' products and pricing while fending off nosy rivals. "Some of the brightest minds I know are working on trying to figure out how to corral these bots and to manage them," says Patrick Sullivan at Akamai, another company that manages and secures clients' web traffic.

These automated processes can lead to absurd outcomes. In 2011, bots belonging to two competing Amazon booksellers got ›

GRAHAM CARTER

locked in an algorithmic loop when setting the price of an obscure academic tome on fruit flies. One was scraping prices to ensure it was always around 27 per cent more expensive than alternatives, while the other set its price just below those of competitors. The final asking price was a dizzying $23 million.

For most of us, social media is by far the most likely place we will knowingly or otherwise encounter bot activity. Millions of automated accounts post, share and follow, often disguised as human users. Swarms of these bots are wielded by spammers or nefarious actors aiming to stoke division and promote disinformation. During the 2016 US presidential election, Alessandro Bessi and Emilio Ferrara at the University of Southern California found that more than 400,000 bots were politically active on Twitter.

Not all social media bots are malicious. In 2019, Carl Öhman at the University of Oxford and his colleagues found that a bot that posts Islamic prayers from users' accounts is responsible for up to 10 per cent of Arabic language tweets. Alongside the trolls and provocateurs are also benign "art bots" that post cloud pictures or craft satirical tweets, many of which are hugely popular.

"It's so sweet seeing people develop this love for this sort of fictional character," says Nora Reed, a prolific maker of Twitter bots, including one that parodies op-ed titles. Such bots take a finite database of phrases and simple rules for recombining them, but their output can often be surprising. "There's so much room for playfulness and satire," says Reed.

"Two bots got locked in a bidding war on an obscure academic tome on fruit flies"

Now, however, bots are getting radically smarter. Thanks to advances in AI, they no longer need content themselves with doing just the same thing over and over. Social bots can adapt to their environment and learn from their interactions with internet users. Even simple bots can exhibit complex behaviour when their networks get large enough, says Iyad Rahwan at the Max Planck Institute for Human Development in Berlin, who studies human-machine interactions. "If you look at biology, you see many examples of extremely sophisticated collective behaviour that emerges from very simple rules," he says – termite colonies collaborating to build towering cathedral-like structures, for instance. "You can imagine swarms of bots could potentially also synchronise and create collective phenomena online."

Hints as to where this might lead come from financial trading. In 2010, interactions between high-frequency trading bots wiped a trillion dollars off the stock market in a "flash crash", although losses were regained in just 36 minutes. Another example was spotted by Taha Yasseri at University College Dublin, who in 2014 noticed that bots designed to clean up Wikipedia articles were engaging in attritional edit wars stretching over years. Both cases are cautionary tales of how unregulated interactions between automated systems can get out of hand. "We need to understand this jungle," says Yasseri.

Rahwan thinks this growing complexity means we should be using tools and perspectives from ecology and economics to understand the collective behaviour of bots. This means looking beyond their underlying code to consider how their environment shapes them. It also means investigating how a bot's adaptations affect its success or failure, and how human intervention shapes the evolution of bot technology.

Lessons gleaned from these approaches should help develop new tools to detect and understand the impact of bots and guide regulation. More transparency over where bots operate will be important, says Rahwan. That could even involve segregating online areas in which you can be confident that you are dealing only with humans. This might mean having to verify your identity on social media or receive warnings if customer service channels are managed by chatbots.

The clock is already counting down for getting to grips with the world of online bots. Rapid advances mean pretty much anything that humans do online could soon be done by bots, says Rahwan. "The whole ecosystem is just going to be extremely complex." ■

Edd Gent is a human.
No, really, he is.
He tweets @Eddythegent

LARISABLINOVA/GETTY IMAGES

Taste is about more than chemistry – surroundings matter too

A dram without the drama

Can chemists replicate the complex flavours of a vintage whisky overnight? **Chris Simms** investigates

HAPPINESS for me is a few good friends, a selection of unusual whiskies – and definitely no ice. When I lift a glass to my nose, it is a portal to a different world of perception. There could be scents of vanilla, fruit, smoke and even freshly cut grass, all of which act like clues to the story behind the spirit. Sniff carefully, and I might discern the myriad choices the drink's makers made as they carefully crafted it over many years.

Lately, however, I have found myself asking whether the prodigious efforts of distillers are entirely necessary. Ageing spirits in barrels for years is painstaking stuff. Is it possible to make a dram without all that faff? After all, there are people on the whisky scene who claim to be able to produce a delicious version in a single night.

Their secret sauce is flavour chemistry. If you can work out the molecules that produce the complex taste and smell of a great whisky and combine them in the right proportions, they argue, you should be able to create a drink that tastes just as good. But is it really possible to make a convincing whisky within hours in a lab? Together with a group of flavour experts and fellow *New Scientist* staff, I braced my taste buds and put overnight whisky to the test.

The traditional way of making whiskies involves soaking and heating cereal grains to convert their starch into sugars that can be fermented into alcohol. The mixture is then distilled so that the alcohol and other volatile compounds are concentrated, producing a fiery spirit that has a high alcohol content.

Most of the flavour tends to come from what happens next. The spirit is poured into wooden casks and left to mature, sometimes for decades. The molecules in the liquid react with each other, the wood and any residues left in the casks to produce hundreds or even thousands of different substances that can affect the drink's smell and taste. If distillers use casks that once held sherry, for example, they tend to impart flavours of figs and raisins. Some makers go even further, blending different whiskies to marry their profiles.

These complex flavours are what makes whisky – or whiskey, if it is made in the US or Ireland – so popular. In 2019, global sales hit a reported $80 billion. Which is why new players with new ideas want in.

One is Endless West, based in San Francisco. The firm's chemists map the molecular profiles of alcoholic drinks to identify substances responsible for particular flavours and scents. Then they come up with a "recipe" for a tipple they want to create, source the required chemicals and combine them. Molecules called esters, such as the pineapple-tasting ethyl butyrate, could come from fruits. Sugars can come from sugar cane or maize. Whisky lactone, which has a creamy flavour and normally comes from casks, could instead ›

The taste test

One dark Wednesday night, a select group of tasters lined up five small bottles, each labelled only with a letter of the alphabet. Led by Billy Abbott from retailer The Whisky Exchange, we had assembled digitally to sample two highly unusual drinks. The first was Glyph, a spirit made using molecular profiling to taste like whiskey (see main story). The second was Sayers of the Law, a peaty young spirit put in a "reactor" by its Californian creators Lost Spirits to make it taste older. We also tried three traditional Scottish drams – strictly to make it a fair test, you understand.

Sensory science experts Barry Smith at the University of London and Charles Spence at the University of Oxford were part of the panel, as were whisky writer Becky Paskin and a selection of all-too-eager *New Scientist* staff. It didn't take long to work out which drinks hadn't been aged in a conventional manner. Here are some of the things the panel said about them:

Glyph

Our verdict: 4/10

"It's got the smell of a badly made mandarin sorbet."

"That smells so chemically to me that it really is something I'd use to service my bike."

"Artificial sweetener but sherberty like dip dabs."

"Like overstewed tea."

"I would be tempted to buy it."

Sayers of the Law

Our verdict: 6/10

"Soapy, sweet, rubber tyres and something clove-like."

"Kind of like blackcurrant Tunes."

"Very, very intense even though I've watered it down."

"If you've ever chewed on birch bark, it tastes a bit like that."

DEEPOL BY PLAINPICTURE/MEL STUART

Some whisky is left to mature in wooden casks for decades

be sourced from nuts. One of the results of these endeavours is a whiskey called Glyph. Its flavour molecules are mixed up in a neutral-tasting spirit overnight and the drink is ready for bottling in the morning.

Yet a whisky is more than the sum of its parts. If you take a particular molecule, it might smell citrusy on its own. But with other compounds around, your smell receptors might cease to detect that molecule or tell you it has a different scent. No one fully understands how and why the combinations exert such effects. "Odour-mixing chemistry is super difficult," says Barry Smith at the University of London's School of Advanced Study.

A sip of nostalgia

This wouldn't be such a barrier if we knew the identities of every compound that ends up in a traditional dram. But we don't, says Charles Spence at the University of Oxford. "Up to 1200 different compounds could be connected to the drink's flavour. It is unlikely that they could be fully recreated," he says. Some put it more strongly. "That poignant sense of nostalgia as you sip on a whisky that was distilled while you were in school, or even before you were born, simply can't be recreated in a lab," says Becky Paskin, a whisky writer and the founder of the OurWhisky community.

Endless West will only reveal a few of the molecules in its recipe, so I can't know how Glyph stands up in terms of the number of compounds used. The only way to judge it was to do what makes me happy: get some people together and have a drink. I set up a panel to see how it tickled their taste buds (see "All about the taste", left). It had scents of apricot and butter, and tastes of vanilla, caramel and oak. It didn't convince everyone, but most agreed it was better than they had expected.

Those preconceptions turn out to be important. I offered Glyph alongside traditional whiskies and although no one knew which drink was which, our tasters did know they would be encountering an overnight whiskey and most people guessed which it was. "As soon as you know the brand, price or method of creation, it tastes different to you," says Spence. The environment we drank in – our homes in this case – might also have affected the taste. Spence has shown that people think a whisky tastes different if they drink it in a different setting: for example, sitting in a room with more wood in it can make the tipple taste woodier.

Endless West is aware of these issues. People who try Glyph blind say they enjoy it, says Alec Lee, the firm's co-founder and CEO. "We are facing a social problem not just a technical problem. When you aren't drinking Glyph blind, your perception of it drops considerably."

But if we see drinks like Glyph as lacking the human touch, perhaps that needs to change. The world is beginning to turn to chemistry for help in making all sorts of other comestibles, including lab-grown meat with a smaller carbon footprint than the real thing. Lee's firm may operate differently from a Scottish distillery, but its people are still lavishing care on a product. "What we do is also craft," says Lee. "We aren't choosing barrels, but we are choosing molecules." ■

Chris Simms is our spirit guide

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Prehistoric poo

Fossilised faeces are finally revealing their secrets, offering fresh insights into ancient ecosystems. **Graham Lawton** gets the scoop

PAUL BLOW

THE powerful X-rays at the European Synchrotron Radiation Facility in Grenoble, France, have been used to look inside some highbrow stuff: papyri from ancient Egypt, Neolithic cave art, Roman scrolls buried in the eruption of Vesuvius and artefacts from Henry VIII's warship Mary Rose. Then, every now and again, Per Ahlberg rocks up with a load of old crap.

Ahlberg, a palaeontologist at the University of Uppsala in Sweden, really knows his shit. Or, as palaeontologists call it, coprolites. These lumps of fossilised faeces have been known to science for nearly 200 years, but were long regarded as the arse end of palaeontology. "They're not the most glamorous of fossils and they were often overlooked," says Ahlberg. But thanks to Grenoble's X-rays, they are now enjoying a golden age.

Coprolites (from the Greek for "dung stones") first came to prominence in the 1820s, when amateur palaeontologist Mary Anning and University of Oxford geologist William Buckland realised the nodules they kept finding in Lyme Regis, UK, were fossilised faeces. The discovery sparked a brief bout of "copromania" among amateur fossil hunters. However, professional scientists turned their noses up.

In the 1990s, Karen Chin at the University of Colorado, Boulder, revived scientific interest in coprolites with a paper describing a "king-sized" specimen from Canada that she said was probably expelled by a *Tyrannosaurus rex*. It was 44 centimetres long, 16 centimetres wide, 13 centimetres high and crammed full of pulverised bone that may well have come from a young dinosaur, possibly a triceratops.

TERRY DAVIS/GETTY IMAGES

Coprolites often contain material that wouldn't otherwise be preserved

Partially digested

Since then, coprolites have yielded all kinds of amazing finds, including undigested dinosaur meat, the partial skull of what may be the oldest-known mammal, hair, feathers, insect remains and a lot of intestinal parasites; the early turd catches the worm, after all. In 2009, hominin hair was found in a 200,000-year-old hyena coprolite from South Africa, possibly after it feasted on one of our ancestors.

In a way, it isn't surprising that old crap contains so much treasure. Carnivore faeces are especially ripe for fossilisation because they contain lots of minerals from meat and bone. "They're full of phosphates and that helps them to mineralise early on. It crystallises and binds the whole thing together," says Ahlberg. "That protects the contents, including any soft tissue."

Because faeces preserve so well, coprolites often contain material that wouldn't otherwise fossilise, sometimes in exquisite detail. For this reason, the deposits in which they are found are considered a type of Konservat-Lagerstätte, the scientific name for areas that contain exceptionally well-preserved fossils, especially of soft tissues. This has led to coprolites being compared to amber, fossilised tree resin in which ancient animals can become trapped, though coprolites are less likely to end up as the centrepiece of a necklace.

Like amber, coprolites reveal information about the ecosystem they came from, such as who was eating who, and provide a concentrated snapshot of the whole environment. Insectivores, for example, go round snaffling insects from all over the place and then package them up in a neat little bundle for future palaeontologists to comb through. "They give you an insight into a functioning, living ecosystem in a way that very few other data sources allow," says Ahlberg. "They are a phenomenal data source, a sausage-shaped Lagerstätte."

Preservation isn't as good as in amber – after all, the contents have usually been chewed and partially digested. But in other ways, coprolites have the edge. Defecation is a great leveller and coprolites are known from all groups of animals, including insects, reptiles, fish, mammals and birds.

And, unlike amber, which opens only occasional windows on the past, when conditions were just right for tree resin to fossilise, the coprolite fossil record is pretty much unbroken. It also happens to be very

> **"Coprolites are comparable to amber, albeit less likely to end up on a necklace"**

ancient, going back to at least the time when animals first conquered the land in the Devonian period some 400 million years ago.

The trouble is that coprolites have always been slippery customers. To get at the treasure inside, you had to cut them up, taking thin slices to put under an optical microscope or breaking off bits to view in a more powerful electron microscope. You ended up with hard-to-interpret images and there was always the worry that you might have missed the most interesting stuff. Another approach was to dissolve the whole coprolite, but often that destroyed the delicate contents too.

Ideally, you want to see through coprolites without breaking them up. Which is precisely what an imaging technique called propagation phase-contrast synchrotron microtomography (PPC-SRμCT for short) offers. It works by firing powerful, laser-like X-rays through a sample. These diffract according to the density of the medium, which can reveal the internal contents in fine-grained detail. As the sample rotates, the scanner takes multiple images from all angles before software stitches the data together into a three-dimensional representation.

The first two coprolites Ahlberg and his team imaged in this way were from the rich fossil beds of Krasiejów in Poland, which date to the late Triassic period more than 200 million years ago. The work was just a proof of principle, says Ahlberg, but the scans revealed how useful the new technique would be. They showed that the first specimen contained an almost complete fish, plus pieces of scaly skin, bones and crushed bivalve shells. The team concluded that it was excreted by a large lungfish.

The second number two contained numerous fragments of beetle, including wing cases and legs. It was evidently produced by an insectivorous animal that, judging from the size of the coprolite, was larger than most living insectivorous mammals and lizards. The team later identified its probable source as a dinosaur-like reptile called *Silesaurus*.

Ahlberg and his colleagues have since imaged many other coprolites. One was from another dinosaur-like predator called *Smok wawelski* (named after a dragon in Polish folklore) from a different Triassic deposit in Poland. The scans revealed it was a bone crusher like *T. rex* and prone to swallowing its own teeth. The researchers also examined the faeces of a pterosaur, a flying reptile, and confirmed that it was a filter-feeder like modern pelicans. "Now we can get a proper view of what coprolites contain, they become enormously informative," says Ahlberg. Chin agrees: "This opens up a whole new perspective on coprolites."

For now, Ahlberg and his team are the only coprolite researchers using PPC-SRμCT, but he says others are keen to get their hands dirty. Scanning a coprolite only takes a few minutes and you can do a big pile at the same time. "We stack them in tall plastic tubes and scan 25 to 30 at once," says Ahlberg.

Creating the final images and analysing them is much more time-consuming. Ahlberg says he could gather a career's worth of data in an afternoon. And there are so many tantalising coprolites, it is hard to decide which ones to look into first. But whichever ones get the nod, there's treasure to be had. Talk about turning muck into brass. ▮

Graham Lawton is saving his faeces for future palaeontologists

OJIMA

Talk to the animals

Could artificial intelligence help us finally understand our furry and flippered friends, asks **Edd Gent**

RENOWNED LSD proponent John Lilly's attempts to speak with dolphins were certainly inventive. In experiments over decades, he variously plied the animals with his favourite drug, flooded a house to allow a human to live side by side with one and even tried to commune with them telepathically.

His failure has shared the fate of most efforts to do a Dr Dolittle and talk to the animals. The orthodox position is that human language – the sort that allows us to exchange pleasantries about the weather or discuss abstract concepts such as the price of fish – is our sole preserve. If you have ever dreamed of listening to a whale's tales of the deep ocean or asking your dog why it howls at the vacuum cleaner, dream on.

Or, perhaps, wake up to a coming reality. Some researchers think that soon we could finally break through the human-animal language barrier, a belief fuelled not by psychedelic optimism, but by the data-crunching smarts of artificial intelligence. Our relationship with the animal world may never be the same again.

AI is good at language. Today, our email services can complete sentences for us, our browsers automatically translate web pages and voice assistants decode our commands. Earlier this year, research company OpenAI released a system called GPT-3 that can write compelling prose from scratch.

Decoding animal communication is just a logical next step, says Michael Bronstein at Imperial College London. "I think it's the right time, with the right data and with the right expertise, to possibly solve this problem." The latest AIs learn linguistic patterns from huge amounts of human-supplied language data, without any clue how our languages actually work. Essentially, they create a vast, multidimensional "cloud" of words clustered according to how we use them, and this lets them decode new snippets of text.

In 2018, researchers at Facebook realised that if you twist the clouds for two languages in just the right way, you can get words with the same meaning to line up, allowing you to translate. This was a crucial breakthrough, says Bronstein: it suggested we might be able to decipher languages with no pre-existing translations.

Bronstein's pet project is sperm whales. Their large brains, complex clan-based social structures and intricate communication system, comprising sequences of clicks known as codas, make them a promising target for interspecies communication. Bronstein leads the machine-learning team at Project CETI, also known as the Cetacean Translation Initiative, an international collaboration of researchers attempting to decode sperm whale chatter. In a paper published in *Scientific Reports* last year, he and his colleagues analysed around 26,000 recordings to create models that reliably segregated codas into human-defined categories based on the number, rhythm and tempo of clicks, as well as predicting which whale was speaking and its clan.

This is still a long way from deciphering meaning. For that, the project is embarking on what Bronstein calls an "industrial-scale" effort to capture between 400 million and 4 billion clicks a year, deploying underwater robots and buoys loaded with acoustic sensors off the coast of Dominica in the Caribbean. Simultaneously, sensor-laden tags will help identify individual whales, piece together who is talking to who and reconstruct behaviours associated with certain patterns of clicks.

Interspecies internet

Meanwhile, the Earth Species Project plans to apply similar techniques to primates and birds like crows and ravens. Even more ambitiously, an unlikely coalition of animal psychologist Diana Reiss, computer scientist Neil Gershenfeld, rock star Peter Gabriel and internet pioneer Vint Cerf envisages an "interspecies internet" through which animals communicate both with each other and us via interfaces such as animal-friendly video chats or underwater touchscreens.

That might hint at a return to studies along the lines of Lilly's flooded-house experiment with dolphins. But AI isn't a silver bullet, warns Julia Fischer at the German Primate Center in Göttingen, who studies guinea baboon communication. It is great at detecting patterns and can neatly sort whale calls, say, into piles based on their acoustic properties, but often can't tell you what those piles relate to. "It's not a magic wand that gives you an answer to the biological questions or questions of meaning," says Fischer. For that, you need to correlate calls with observations of behaviour – an incredibly challenging task when studying deep-ocean animals like whales, even now that we have high-tech robots and sensors.

AI can easily be led astray as well, says Dan Stowell at Queen Mary University of London, who is using it to build models of birdsong to help study bird development and evolution. Without guidance, it might pick up acoustic properties irrelevant to the animals – a variation in pitch, for instance, when birds might actually be listening out for rhythm or some other feature.

The answer may be to enlist the birds themselves to help. Stowell and his colleagues train zebra finches to hop around to indicate which snippets of song they regard as most similar, then feed this extra information into an AI. "This is really a stepping stone, because we need to know which sound differences are salient to the animals," says Stowell.

Bronstein hopes to get round this same problem by building a sperm whale chatbot that can feed learned patterns of codas back to the animals to see how they react. He says it is uncertain whether we can ever go beyond superficial interaction, particularly with species like whales whose lives are so different from ours. "It might be that it will only be a rough approximation of the true depth and meaning of what they're saying."

Yet while we may never discuss the weather with a whale, even small advances in eliciting meaning from animal language could be revolutionary, says Con Slobodchikoff at Northern Arizona University, an expert on prairie dogs. "Even if they have alien concepts, if we could make at least some of our desires known to them and they could make some of their desires known to us, I think that we would have a completely different world."

Slobodchikoff has founded a start-up called Zoolingua that aims to develop an AI to enable people to communicate with their pet dogs, analysing vocalisations, facial expressions and actions to help diagnose behavioural problems, among other things. Meanwhile, scientists at Georgia Tech in Atlanta have created a system that analyses audio from broiler chickens to detect stress, while researchers at the University of Cambridge have built an algorithm that scours sheep's faces for signs of pain.

If livestock could directly communicate their concerns to us, that might completely reshape animal agriculture, if not potentially render it morally untenable. Interspecies communication in general could force us to re-evaluate assumptions about our supposedly exceptional place in nature.

"Many of the problems we face now, such as the climate crisis or pandemics, follow from seeing ourselves as separated from the other animals," says Eva Meijer, a philosopher who studies interspecies communication. "Learning to listen to them, and viewing ourselves as part of a bigger whole, is a practice that can challenge this and open up new pathways to change."

It is a grand vision that seems worth signing up to – especially if it has the bonus of getting the dog to stop barking at the vacuum cleaner. ■

"AI is good at human language. Animal language is a logical next step"

Edd Gent communicates through a complex, previously undecipherable system of clicks

New Scientist
Newsletter

Fix the Planet

Overwhelmed by climate change?
You're not alone

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

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Adam Vaughan

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

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Can you remember all the biggest science news of 2020? p84

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Picturing the lighter side of life p88

Science of cooking

Transforming Brussels sprouts

Are you a lover or a hater of sprouts? Find out how to change the bitter vegetable into a nutty delight, with **Sam Wong**

Sam Wong is social media editor and self-appointed chief gourmand at *New Scientist*. Follow him @samwong1

What you need

Shredded Brussels sprouts
Onion or shallots
Lemon juice
Parmesan cheese

IN MY family, Brussels sprouts are a much-loved element of Christmas dinner, but for many, they are an annual torture. If you hate them, there are a few science-based tips that may win you over.

The *Brassica* genus, to which sprouts belong, evolved to produce bitter compounds as a defence against herbivores. Just like onions and garlic, they store precursor molecules in their cells. When the plant is damaged, the precursors are released and they interact with myrosinase enzymes in the cells to produce unpleasant-tasting chemicals.

Some cooks recommend plunging chopped sprouts into icy water to lower the activity of these enzymes, but in sprouts, some of the precursor molecules are non-bitter compounds that convert to bitter-tasting products, while others are the opposite. So whatever you do, some of the compounds will always be bitter.

People can be more sensitive to bitter tastes than others, and genetic variations in the TAS2R38 receptor may play a role. But a study in 2011 found the variations aren't linked to the amount of vegetables eaten, so non-genetic factors may play a bigger role.

We can learn to appreciate foods we don't like by pairing them with ones we do. In a 2014 study, a group of young children was given Brussels sprouts with cream cheese every day for two weeks, while another group was given Brussels sprouts alone. On the 15th day, both groups were given sprouts without cheese. Less than a quarter of children in the second group said they liked them, compared with 72 per cent of children who had been trained with cream cheese.

SAM EDWARDS/GETTY IMAGES

A study in 2018, meanwhile, found that the bitter taste of sprouts could be suppressed by drinking red wine at the same time. The researchers thought this was down to the wine's astringency, the dry sensation in the mouth caused by phenolic compounds called tannins, which make proteins in saliva clump together. Interfering with their movement may affect the distribution of bitter chemicals in the mouth. In any case, I need no encouragement to have red wine with my Christmas dinner.

For me, the best ways to cook sprouts are frying and roasting. High heat creates the Maillard reaction, where sugars and amino acids react to produce delicious tastes. When browned, cruciferous vegetables develop wonderfully nutty and savoury flavours that you don't get from boiling.

I like to add caramelised onions or shallots to pan-fried, shredded sprouts, plus a squeeze of lemon juice before serving. This combination livens up the flavour and helps mask bitterness. An umami boost from parmesan cheese goes down a treat too.

As for the odorous after-effects of eating sprouts, that is down to a nasty reaction by our gut bacteria. Unfortunately, there is little that cooking can do about that. ▮

Science magic transforms the festive meal at youtube.com/newscientist

Science of cooking appears every four weeks

In the next magazine

Science of gardening

Cryptic crossword #47 *Set by Wingding*

Scribble zone

For a guide on how to solve *New Scientist*'s cryptic crossword visit:
newscientist.com/cryptic

ACROSS

1 Act idly for animal-loving 16 (8)
6 One getting between grotto and calm resident (7)
11 Sellers' 16 showing unusual passion (11)
12 Entity putting energy into search engine (5)
13 *New Scientist* is into computer science and won't accept no (6)
14 Ask Father Christmas to take off coat for 16 (10)
16 Change title (6)
17 Big cats killed student? Are they positive? (4)
18 Physicist was kind of a pig, they say (4)
21 Instruments have sharp points behind a long head (8)
22 Glands found inside Tesla, nerd announces after U-turn (8)
25 Cybercrime reporter (4)
27 Bit of DNA from odd green men (4)
28 Crime-solving 16 and AI (6)
31 Breaking in new tools using modest voltage (3-7)
32 16 with inner demon adds potassium to jelly mixture (6)
34 Angry terrorists finally get comeuppance (5)
35 Time-travelling 16 encountered bromine in city after setter returned (6,5)
36 Partially missing REM linked to unexplained problem (7)
37 Prepare note to pick up selenium (8)

DOWN

2 Otherwise, Royal Institution's source could be used in perfume (5,4)
3 Within a vegetable, current remained in process of becoming charged (10)
4 Level match with header at the end (4)
5 Financial company with no pests prioritising Europe (8)
6 Reprimand for wearing casual attire (8-4)
7 Take in little of new book with first two parts swapped (6)
8 Russian 16's last letter on virus in the past (7)
9 Awkward nerd sights woman's clothing (10)
10 Olfactory sample from Galileo's microbes (5)
15 Honest physicist dropped one for 16 (12)
19 Stakeholder hangs evil necromancers, primarily, in a frenzy (3,7)
20 Parent took drug with snake, one worn around the neck (7,3)
23 Unnamed article about unknown sumo wrestling (9)
24 Concerning the last person who makes changes (8)
26 Poisonous plant made to show respect with stick, according to Spooner (7)
29 Crop that's repeated on the radio (6)
30 Antelope has *National Geographic* kicked out of the country (5)
33 Uncomfortable sensation for decapitated sorceress (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Answers to this crossword and cryptic crossword #46 are on page 86

Festive puzzles

Colourful beehive
– David Bodycombe

#90

Colour the remaining hexagons red, yellow, blue or green – using at least three of each colour – so that these three rules hold:

1. **Each green shares a border with exactly three reds**
2. **Each blue shares a border with exactly two yellows**
3. **Each yellow shares a border with at least one red, green and blue**

#91

As a bonus, if the leftmost hexagon was NOT red, can you find another pattern that would work?

Major tune – *Alex Bellos*

#92

The major system is a centuries-old technique for memorising numbers in which they are converted into letters and words. Each digit is converted into a particular phonetic sound. For example "tch" represents one digit, and "n" another. Sometimes, the same digit will represent different, but similar, sounds. For example "k" and "g" are represented by the same digit.

Each number below is shown alongside its conversion into the major system.

94146	***a partridge***
84180	***four doves***
07070	***six geese***
125410	***ten lords***

What numbers do the words "major" and "tune" represent, and why are they appropriate here? (It will all add up in the end.)

A version of this puzzle appears in The Language Lover's Puzzle Book *by Alex Bellos (Faber, 2020).*

Battenberg returns
– Andrew Jeffrey

#93

Lady Federica von Battenberg has baked a cake for her daughter Victoria's birthday party. Eight children will be attending in all, so eight slices are needed.

She could, of course, make seven vertical cuts to make eight identical slices. But Victoria has heard it is possible to cut the cake into eight identical slices with only three straight cuts of the knife. In fact, there are at least two different ways to achieve this.

To be clear, not only must each slice be the same shape, they must all have the same amount of pink and yellow sponge and the same amount of marzipan on the outside. Can you find two ways for Lady Federica to achieve this?

Answers to the festive puzzles are on page 86

What happened this year

The pandemic may have stolen many of the headlines of 2020, but this year has been a bumper year for science unrelated to coronavirus research, too. The question is: can you remember it? Find out in our covid-free quiz

1 We kicked off 2020 with the cheery news that the "doomsday" Thwaites glacier in Antarctica is losing about 35 billion tonnes of ice per year. It is currently about the same size as which island?
A Ireland
B Great Britain
C New Guinea
D Java

2 On a lighter note, in June, we published pictures of *Uraba lugens*, a caterpillar that wears its old heads as a hat. How many times can it moult its head?
A 4
B 7
C 9
D 13

3 In September, we reported that astronomers may have spotted the first planet outside the Milky Way. Which galaxy is it in?
A Whirlpool
B Andromeda
C Hoag's Object
D Cygnus A

LEEDS TEACHING HOSPITALS/LEEDS MUSEUMS AND GALLERIES

4 Moving a bit closer to home, this year, NASA announced it had teamed up with Procter & Gamble to create a laundry detergent that works in space. How long do ISS astronauts typically wear their underwear for before changing it, as we reported in November?
A 1 day
B 3 days
C 7 days
D 14 days

5 In February, the newly upgraded Svalbard Global Seed Vault received a deposit of more than 60,000 seeds. Which Native American nation sent seeds to the bank for the first time?
A Navajo Nation
B Chickasaw Nation
C Cherokee Nation
D Choctaw Nation

6 Which animals have been confirmed to socially and physically distance themselves from other colony members when feeling ill, as we reported in April?
A Common vampire bats
B Pistol shrimp
C Naked mole rats
D Sand martins

7 In March, US firm Honeywell announced it was building a quantum computer. Before the announcement, what was the company best known for once making?
A Televisions
B Permanent markers
C Fishing rods
D Thermostats

8 In November, we reported on a squid-like creature that lived 68 million years ago and had a shell that looked like a 1.5-metre-long paper clip. What else was remarkable about the animal?
A Its eyes
B Its arms
C Its suckers
D Its age

9 Speaking of ancient creatures, which part of a dinosaur was formally described from a fossil for the first time in October?
A Brain
B Spleen
C Cloaca
D Gizzard

10 Travelling even further back in time, in May, we learned how meteorite hunting could teach us more about how Earth formed. On which continent have we found almost twice as many meteorites as on every other combined?
A Africa
B Antarctica
C The Arctic
D Asia

11 Whizzing forward a few billion years, we reported in January that researchers had reconstructed the voice of an ancient Egyptian priest called Nesyamun (his mummy is pictured, left), based on his mummified vocal tract. What epithet was written on his coffin?
A True of voice
B Softly spoken
C High-hearted
D Voice of god

CLOCKWISE L-R: NTB SCANPIX/LISE ASERUD VIA REUTERS; SEBASTIAN KENNERKNECHT/MINDEN/NATUREPL.COM; NASA; JAMES MCKAY; MBRSC

"How long do ISS astronauts typically wear underwear for before changing it?"

Clockwise from top left: the Svalbard Global Seed Vault; a white-crowned sparrow; the Thwaites glacier in Antarctica; ancient squid-like creature *Diplomoceras maximum*; and the Mars Reconnaissance Orbiter

12 In July, ORCs were identified for the first time. What does ORC stand for?
A Outer Reabsorption Corona
B Odd Radio Circle
C Orbital Ribbon Coma
D Opaque Rhabdite Cell

13 Which of these nations didn't launch a Mars orbiter in July?
A The US
B The United Arab Emirates
C Russia
D China

14 Hagfish can tie themselves in knots to squeeze through tight spaces. What kind of knots do they tie 45 per cent of the time, as we reported in January?
A Overhand knots
B Bowline knots
C Figure-eight knots
D Trefoil knots

15 In more knot news, we interviewed mathematician Lisa Piccirillo in August, who cracked the 50-year-old Conway knot problem earlier this year. How many crossings does the Conway knot have?
A 9
B 10
C 11
D 12

16 During lockdown, white-crowned sparrows in San Francisco changed their songs, as we reported in September. Which of these changes wasn't observed?
A They sang for longer
B They sang more quietly
C They sang at lower frequencies
D They sang sexier songs

17 Switching our focus to less adaptable creatures, we learned in April that ancient plant-eating cave bears may have gone extinct in Europe because of their overlarge what?
A Teeth
B Kidneys
C Hearts
D Sinuses

18 It was confirmed in May that Pūhāhonu in Hawaii is the largest volcano in the world. What does its name mean?
A Much spreading
B Long mountain
C Turtle rising for breath
D False harbour

19 We explored the mysterious world of Loki's castle in January. What is it?
A A series of lava tubes on Mars
B A field of hydrothermal vents
C A quantum computer
D A transient luminous event (TLE)

20 In September, the largest single photograph ever taken was revealed. What was the picture of?
A A pine cone
B A nautilus shell
C A hell's fire sea anemone
D A Romanesco cauliflower

21 Finally, in November we learned that there have been nearly 100 sightings of which creature in the wild across Great Britain in the past decade?
A Wallabies
B Wombats
C Opossums
D Echidnas ▮

Quiz compiled by Bethan Ackerley.
Answers on page 86

#90 Colourful beehive

The first clue is the most useful. The green hexagons are likely to be in the middle and must "share" the red hexagons efficiently, otherwise you run out of room for the other colours.

#91 Colourful beehive variant

If there is no requirement for any red hexagons to be on the outer border, this packing also works.

#92 Major tune

Tune is 12, the number of days of Christmas. *Major* is 364, which is the total number of gifts given in the carol *The Twelve Days of Christmas*: 1 on the first day, 1+2 on the second, and so on, 1+3+6+10...+78 = 364.

In the major system, each digit becomes a particular phonetic (consonant) sound, and the vowels are added to make memorable words. We can deduce that "s" is 0 while "k" and "g" are both 7. "x" is a k-s sound, so is 70. The "j" in *Major* is the same sound as "dge" in partridge, which is 6. The only consonant sound used in *Major tune* that doesn't appear in the examples is "m", which must be 3. The full key is: 0: s, z; 1: t, d; 2: n; 3: m; 4: r; 5: l; 6: j, sh, ch, tch; 7: c, k, g; 8: f, v; 9: p, b.

#93 Battenberg returns

One way to make eight slices is to cut the cake in half, stack one half on top of the other, cut through the stack, put one stack on the other and repeat:

An alternative is to cut the cake in half, then set it on its end and cut down the diagonals to make eight triangular prisms:

The solution to puzzle #89, Sunday drivers, will appear in the 2 January issue.

Cryptic crossword #47

ACROSS
1 Dolittle, **6** Denizen, **11** Strangelove, **12** Being, **13** Insist, **14** Consultant, **16** Doctor, **17** Ions, **18** Bohr, **21** Althorns, **22** Adrenals, **25** Hack, **27** Gene, **28** Watson, **31** Low-tension, **32** Jekyll, **34** Irate, **35** Emmett Brown, **36** Gremlin, **37** Rehearse

DOWN
2 Orris root, **3** Ionisation, **4** Tier, **5** Economic, **6** Dressing-down, **7** Nibble, **8** Zhivago, **9** Nightdress, **10** Osmic, **15** Frankenstein, **19** Van Helsing, **20** Feather boa, **23** Anonymous, **24** Reformer, **26** Cowbane, **29** Cereal, **30** Eland, **33** Itch

Cryptic crossword #46

ACROSS
7 Wheel, **8** Echidna, **10** Nitrite, **11** Louse, **12** Mandelbrot set, **13** Cabbage leaves, **17** Lilac, **18** Gateman, **20** Galileo, **21** Inert

DOWN
1 Twin, **2** Pectin, **3** Blaise Pascal, **4** Reverb, **5** Odours, **6** Palettes, **9** Heliocentric, **12** Mycology, **14** Boldly, **15** Eggnog, **16** Vamped, **19** Note

Quiz of the year

1 B – Great Britain

2 D – 13

3 A – Whirlpool

4 B – Three days

5 C – Cherokee Nation

6 A – Common vampire bats

7 D – Thermostats

8 D – Its age (it seems to have been 200 years old, but modern cephalopods don't live nearly as long)

9 C – Cloaca

10 B – Antarctica

11 A – True of voice

12 B – Odd Radio Circle

13 C – Russia

14 D – Trefoil knots

15 C - 11

16 A – They sang for longer

17 D – Sinuses

18 C – Turtle rising for breath

19 B – A field of hydrothermal vents

20 D – A Romanesco cauliflower

21 A – Wallabies

How did you do?

17-21 Well, obsessively checking the news is one way to cope with the stress of a pandemic. We bow down to your stellar science knowledge.

11-16 Great work, you have clearly taken time out from making banana bread and sourdough starters to stay up to date during our collective confinement.

5-10 Did all those lockdown Zoom quizzes teach you nothing? We recommend scouring *New Scientist* coverage from the past year to find out what you have missed – and to get inspiration for your next quiz's science round.

0-4 Listen. We get it. There has been a lot of news to keep up with this year. Thankfully, 2021 is the perfect time to get up to speed with all the latest in science and tech. Perhaps a *New Scientist* subscription would help?

CHEMISTRY
LIKE COOKING, ONLY WITH EXPLOSIONS
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42
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I LIKE TO PARTY AND BY PARTY I MEAN READ BOOKS
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$e^{i\pi}+1=0$

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we could measure and quantify security?
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The back pages Feedback *reviews 2020*

Reviews of the year are so passé – in the sense that, if you are reading this magazine linearly, you will already have passed one. If, however, you are (as we sincerely hope) a dedicated back-cover-forwards reader, you have a cornucopia of delights ahead of you. Either way, tarry a while with us as we review the year in our own way and crown the winners of the second annual Feedbys – the much-coveted Feedback awards.

Saw that one coming

The year began, as is traditional, in January. Except for the crew of the good ship *New Scientist*, of course, for whom it began on 21 December 2019 with a preview of this now past year ("New Scientist experts reveal what the biggest science stories will be in 2020"). Neither there, nor in our accompanying leader ("We live in testing times, but there are many reasons to be optimistic"), did we mention an impending global coronavirus pandemic.

For this, our first award, for Seer of the Year, goes to: *New Scientist*. Allowing security to deal with the rowdy collegial protesters at the back of the hall shouting that they pointed out the probability of an oncoming pandemic back in 2017, we are pleased to accept this award on behalf of most of the world.

Don't try this at home

"PANDEMIC" screamed the *New Scientist* cover on 7 March. Well, don't say we didn't warn you. In those early days, seemingly a decade or so ago, social distancing was still a random adjective + gerund combination and the pandemic response in large parts of the world could be summarised as "just give it a good wipe down". A mere two weeks later, reports were flooding in to these pages of efforts to make hand sanitiser from budget vodka, an Australian newspaper that had provided an eight-page toilet paper substitute pull-out, and innovative ways to avoid shaking hands.

Twisteddoodles *for New Scientist*

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

Our next award, for Correction of the Year, comes from this crop. It goes to *The Guardian* newspaper for its amendment of a statement in an article entitled "Coronavirus: Nine reasons to be reassured" that "a solution of ethanol, hydrogen peroxide and bleach will disinfect surfaces". Presumably for those who had in a flash been less than reassured, it was changed to "a solution of ethanol, a solution of hydrogen peroxide or a solution of bleach will disinfect surfaces".

My feet look big in this?

New corona-times, new corona-habits. Many have made hay pushing sometimes questionable innovations to help us through the dark days until a new vaccinated dawn.

The FBI got in early, using the new craze for exercise – something Feedback never personally shared – to push out a fitness app, the downloading of which innocently made almost all of your personal data available to them. Then, of course, there was Gucci, helping us look fabulous in our new, largely virtual lives with a range of new, entirely virtual clothes.

But Feedback's Innovation of the Year award goes to the unnamed cobbler from Cluj, Romania, who produced a pair of extended shoes in European size 75, so as to effectively enforce social distancing.

Don't come near me

Ah yes, social distancing. A review of Feedback's 2020 wouldn't be complete without crowning a Social Distancing Measure of the Year. We mean this literally, in celebration of the various ways you have spotted in which bits of the world have attempted to explain to other bits of the world what 2 metres, or a less spacious 6 feet in pre-revolutionary units, actually means in units of... stuff.

In a truly global celebration of local obsessions, your eagle eyes (see punchline) have given us skis (Colorado), an alligator (Florida), hockey sticks (Toronto), a tapir (Guatemala), a caribou (Yukon) and 10 footballs, six boomerangs, five sea turtles or a kangaroo (all Northern Territory, Australia). Among other things.

But a new entry wins it. We freely admit to having sat on it for a while, as we have been singing it to a seasonally appropriate tune. It comes from the good folks of the Nagshead RSPB nature reserve in Gloucestershire, UK, as sent in by Larry Stoter: "14 and a bit goldcrests, 11 blue tits, 10 robins, 8 and a bit sparrows, 5 green woodpeckers, 3.5 magpies, 2 peregrines" (deep breath) "A-AND ONE WHI-ITE-TAILED EAAA-GLE".

Feedback on you

In a similarly festive spirit, our final prize could go to UK home improvement retailer B&Q for a "genius" storage solution (its word). The listing for the Really Useful wrapping paper storage box on the B&Q website advertises dimensions of height 155 millimetres, length 820 mm, width 255 mm and depth 820 mm.

What of its extension in time, we wonder, a key consumer metric? No matter: we could really do with such a roomy "4D hyperbox", in the description of spotter Richard Hind, to house our extensive piles of correspondence from you.

And so, in fact, our final prize, for People of the Year, goes collectively to you, our dear readers. It has no doubt been a discombobulating time for you too, but your missives have kept a smile on our face(s) at least. We're only sorry we can't print or acknowledge them all: thank you, you truly are what makes Feedback, and this magazine, special. A very Happy New Year to you all, and we hope to see you in 2021. ▮

New Scientist
Newsletter

Launchpad

Voyage across the galaxy and beyond
with our weekly space newsletter

A new era of space travel has officially begun. Let our resident space expert Leah Crane fill you in on all the very latest news on our exploration of the solar system – and beyond.

Every week, she'll send you awe-inspiring pictures, cool facts and all the space stories we publish on newscientist.com, in addition to some stories that you won't be able to read anywhere else.

Leah Crane

Sign up to the Launchpad newsletter and join the conversation about space.
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