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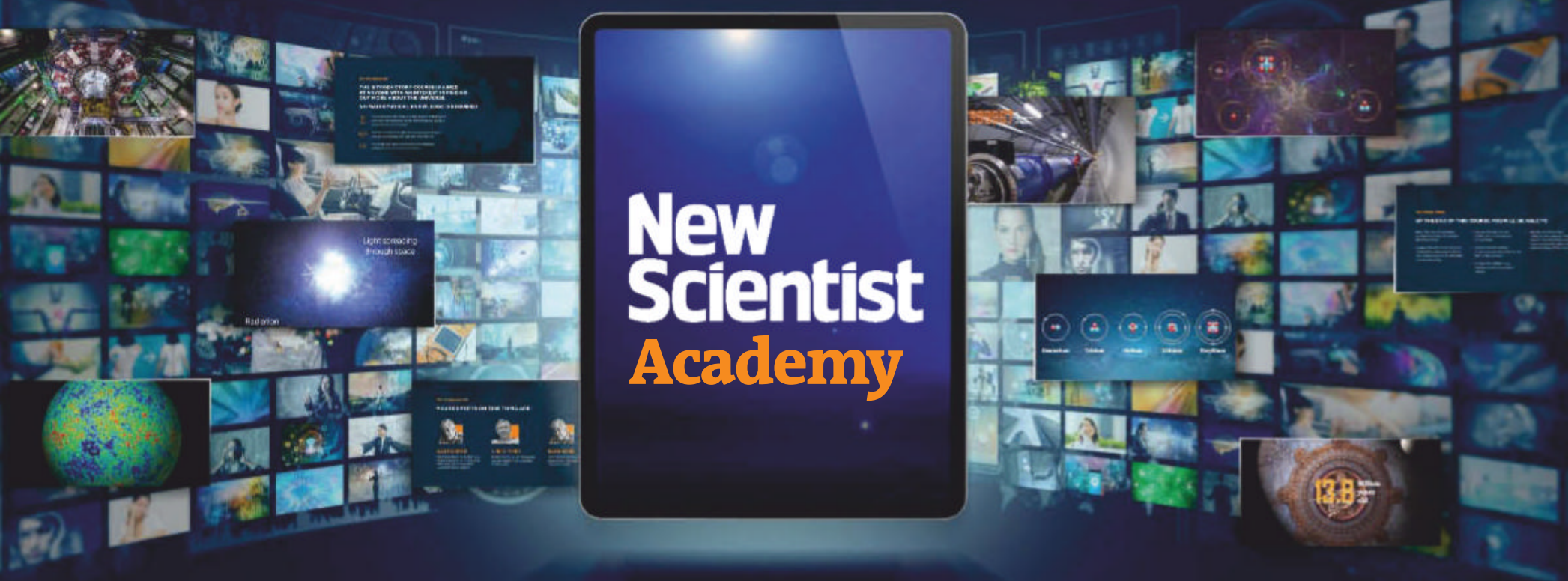

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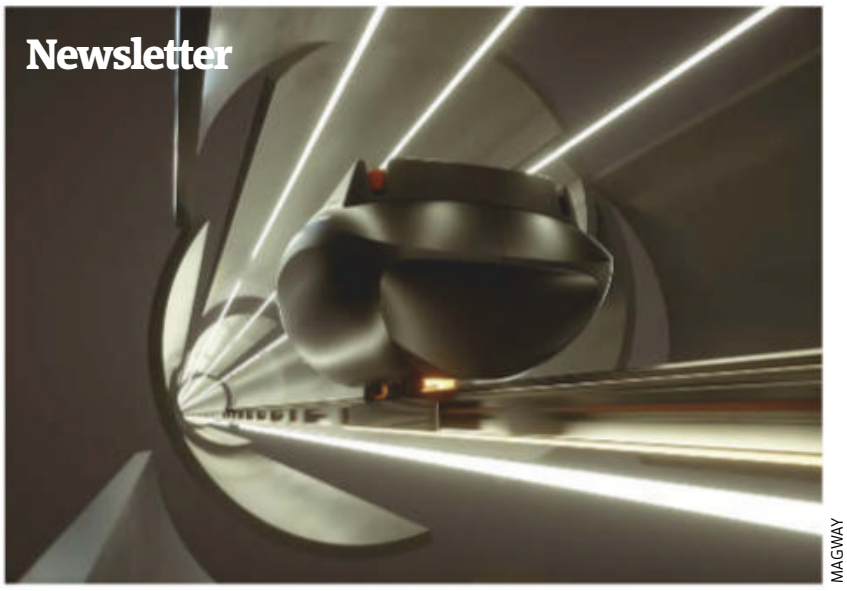

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DANIEL NATUSCH

Night terror This python tried to eat a woman while she slept

Online

Instagram

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Now is not the time

Wearisome it may be, but we need to hold a steady course on covid-19

EARLY on in the pandemic, we heard a lot about behavioural fatigue – the hunch that people would quickly grow tired of restrictions on their lives and throw caution to the wind. It was a factor in the reluctance of the UK government to go into lockdown too quickly, a delay that led to the virus getting out of hand.

We don't hear very much about behavioural fatigue any more. We feel it. The prospect of further restrictions or even "circuit breaker" lockdowns (see page 8) is greeted with dread, and the very real possibility of disobedience.

This isn't the time to let our guard down. Two obvious reasons are that we don't want to overwhelm hospitals or shut schools. But there is another reason to mask up, observe distancing and stick to any extra rules that apply: to prevent the virus from evolving.

Up to now, we have been lucky on this score. SARS-CoV-2 has changed little since it emerged. It is so stable genetically that drugs and vaccines in development ought to work against all variants currently circulating (see page 10).

Yet we cannot take that for granted.

"Unfortunately, herd immunity is bad science and would also expose us to the risk of viral evolution"

The virus does have the capacity to mutate into something worse, but can only do so if it is transmitted from human to human.

Cutting off transmission is therefore vital while we await a vaccine. If and when that vaccine arrives, high levels of uptake are vital for the same reason. Even more so, in fact, as the vaccine will put pressure on the virus to mutate.

Fatigue is also partially responsible for the enthusiastic welcome that the herd immunity strategy, or "letting the virus rip", has received in some circles. It undeniably has a certain freedom-loving appeal. Unfortunately, it is bad science (see page 23), and would also expose us to the risk of viral evolution.

Risk is something we are notoriously bad at assessing. This pandemic has brought new challenges for individuals in balancing the risks to themselves and others, and for governments in balancing the needs of different sectors of society (see page 40). But the behavioural fatigue fiasco showed the danger of basing policy on plausible-sounding hunches. We must not make that mistake again. ▮

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Commercial and events director Adrian Newton

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Email displayads@newscientist.com
Sales director Justin Viljoen
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Recruitment advertising
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CONTACT US

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

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Possible covid-19 vaccines are already in conventional trials

Challenge trials

Intentional infections

A plan to give the coronavirus to volunteers may help us test potential vaccines, if it gets ethical approval, says **Michael Le Page**

RESEARCHERS in the UK have announced plans to infect volunteers with the coronavirus, starting in January. The aim is to establish the minimum infectious dose before testing potential vaccines. The study will be funded by the UK government, but has yet to get final ethical approval.

"The top priority is participants' safety," says Chris Chiu at Imperial College London, whose team will carry out the study. "We have spent many months thinking about the evidence and weighing up the pros and cons."

The coronavirus doses will be created by a company called hVIVO, as the research requires a pure, quantifiable source of the virus, rather than an infection spreading person to person. The doses will contain the same strain that is currently circulating and will not be weakened in any way.

Volunteers will have the virus delivered to their nose in droplets. As soon as they show signs of infection, they will be given the antiviral drug remdesivir. A large trial recently found that remdesivir didn't reduce the death rate from covid-19. However, that trial involved severely ill people who had already been hospitalised, says Chiu. He thinks giving the drug very early on will stop the infection spreading to the lungs. The team will also consider using other drugs, such as antibodies, as more evidence for them becomes available.

Volunteers will be free of known health conditions and aged from 18 to 30. Initially they are likely to be from white ethnic groups because of evidence that black, Asian and minority ethnic people are more likely to get severely ill. The team aims to have volunteers from more diverse backgrounds as soon as it can do so safely.

The study, involving up to 90 participants, will be done at the Royal Free Hospital in London. If any volunteers become seriously ill, the research will be paused to assess if it is safe to continue. However, the team's expectation is that most volunteers won't even develop any symptoms.

Even if no one gets badly sick, this first phase could still take several months if the initial doses prove to be too low, Chiu says. That's because the number of beds at the hospital available for the trial are limited, and volunteers will have to remain quarantined for weeks even if they don't become infected.

This means it could be many more months before the team can start testing potential vaccines by trying to infect volunteers who have been given a vaccine – known as human challenge trials – by which time one or more vaccines might already be available through conventional testing. "We are likely to see results of phase III [vaccine] trials in the next few months," says team member Peter Openshaw at Imperial College London.

"We have spent many months thinking about the evidence and weighing up the pros and cons"

However, many different vaccines will be developed over the next three or four years, and Openshaw says that being able to do human challenge trials will be a valuable way of comparing them. "This will be a way to much more rapidly compare the efficacy and safety of vaccines," says Robert Read at the University of Southampton, UK.

Challenge trials limited to younger people won't reveal if vaccines protect the oldest and most vulnerable, but they can speed up progress by revealing which potential vaccines have no chance of working, says Andrew Catchpole, chief scientist at hVIVO. "What it can do is fast-track vaccines for those groups," he says.

The researchers will set up a website where people can register interest in taking part while the study awaits approval from the UK's Medicines and Healthcare Products Regulatory Agency and the Health Research Authority. Volunteers will be compensated for their time, but Chiu declined to say how much they will get. ▮

Circuit breakers

Lockdown again and again?

Could planned, pre-emptive lockdowns at regular intervals be a way to manage the spread of the coronavirus? **Clare Wilson** investigates

WITH cases of covid-19 rising in most parts of the UK, there is fierce debate over the best way to respond. While some people argue for a "let the virus rip" strategy, others want increasing social restrictions, up to and including full lockdown, as happened in the pandemic's first wave.

But is there another way? One idea gaining ground is that countries should hold regular pre-emptive lockdowns, each lasting about two weeks. They could be timed to coincide with school holidays, minimising disruption to education. In the UK, this would mean having these shutdowns around every two months.

The concept may sound similar to short, sharp, "circuit breaker" lockdowns, which have been advocated by some scientists advising the UK government, including chief scientific adviser Patrick Vallance. Northern Ireland began such a lockdown on 16 October and Wales has announced it will do the same from 23 October.

Yet there is a crucial difference between these strategies: the idea is that pre-emptive lockdowns would happen periodically, even when a country's coronavirus case numbers are relatively low. The advance knowledge of when they are due to happen is supposed to reduce the impact on businesses, while the fact that they are short and have a definite end point could make them more bearable.

It is hard to know exactly what effect this would have on virus prevalence, but it should regularly reset case numbers to a lower level. At best, it could help avoid the longer kind of lockdowns seen in the pandemic's first wave.

This year, there has been growing appreciation of the toll on mental health caused by stopping people mixing with their friends and family. Pre-emptive circuit breakers may lessen this burden slightly. "The specified length of time reduces uncertainty, and it is uncertainty that often promotes anxiety and poor mental well-being," says Charlotte Hilton, a chartered psychologist based in the East Midlands, UK.

> "Pre-emptive lockdowns would happen even when a country's coronavirus case numbers are low"

Businesses like pubs, restaurants and non-essential shops would still have to cope with a loss of income: if two weeks of lockdown were scheduled every two months, they would be closed around a quarter of the time. Yet if they knew when these shutdowns were coming, they may be able to financially plan around them more effectively.

Unfortunately, if a lockdown is suddenly announced, then firms lose out on the advantages of forward planning. As such, it is too late to gain those kinds of benefits from any immediate circuit-breaker lockdowns that may happen this time around.

How can we know if pre-emptive lockdowns would be better than the alternative approach of tightening social restrictions only when cases rise and loosening them when numbers fall? This kind of strategy hasn't been tried anywhere in the world, so we can't yet measure its effects on actual covid-19 cases, mental health or the economy.

But a modelling study by Graham Medley at the London School of Hygiene & Tropical Medicine and his colleagues suggests that a two-week, UK-wide lockdown at the end of October would halve deaths from covid-19 between then and the end of this year. Because health is a devolved matter in the UK, a decision to take such action would have to be made by the respective governments of the four UK nations. When that paper was written, an October lockdown like the one proposed would have been pre-emptive. The work has been put online but isn't yet published.

As coronavirus case numbers are climbing in most parts of the UK, the debate has turned to whether current local restrictions are enough or if the four UK nations need a full, immediate lockdown.

This would be similar to actions taken by Israel last month, which began what was supposed to be a three-week lockdown in response to rapidly rising cases. Although it had to be extended by one week, the country has now started easing restrictions.

In the UK, members of an independent advisory panel called Independent SAGE last week asked for a full and immediate lockdown across the whole of the country lasting two or three weeks, plus several further weeks of slightly less severe restrictions.

Independent SAGE member Christina Pagel at University College London says regular pre-emptive lockdowns wouldn't be needed if the UK used this proposed shutdown to revamp its test-and-trace system. "We do not want to keep closing things. To plan for that is an admission of failure," she says.

Michael Edelstein at the Bar-Ilan University in Ramat Gan, Israel, says planning ahead is vital, but rather than lockdowns happening at set dates, it would be better for countries to have agreed infection thresholds that trigger them. "You don't have time to debate it for weeks." ▮

CHARLES MCQUILLAN/GETTY IMAGES

Northern Ireland entered a short-term lockdown on 16 October

Statistics

Concerns raised about vital UK infections survey

Adam Vaughan

THE UK's largest scheme for tracking the coronavirus is at risk of providing a misleading picture of the epidemic, as a growing share of people invited to take part fail to respond or complete a test.

The UK's Office for National Statistics (ONS) launched its survey in April to estimate how many people are infected with the virus each week. At first, it randomly sampled homes in England, later adding ones in Wales and Northern Ireland.

When the survey began, 51 per cent of English households invited to take part completed at least one test. But that figure is now just 5 per cent, sparking concerns that if tests are only being done by a certain group of people, they may not reflect the wider population and the true state of infections.

The ONS says it weights the results to avoid this, but this may not work, says Sheila Bird at the University of Cambridge. "Reweighting may not deal sufficiently with systematic bias."

For example, if those completing tests are also more observant of guidance, and therefore less likely to be exposed to covid-19, this could underestimate infections.

The scheme has expanded hugely, from inviting 20,000 households initially to nearly 800,000 since 13 July, meaning it may simply be reaching more people who are unwilling to take part. Although the response rate in England is currently 5 per cent, the ONS suggests that shouldn't be considered a final figure, as there is no time limit for how long invited households can take to respond.

A spokesperson for the ONS says: "By randomly testing a large representative sample of the UK population, regardless of whether or not they have symptoms, [the infection survey] continues to offer reliable estimates about the spread of this virus." ▮

Tuberculosis

Pandemic is leading to more TB deaths in India

Nilanjana Bhowmick

THE covid-19 pandemic has collided with an ongoing tuberculosis epidemic in India, leaving many without adequate medical care and stuck at home, where they could infect others.

Globally, the number of new TB cases is set to be around 200,000 to 400,000 higher than usual in 2020, and most of these will be in India, Indonesia, the Philippines and South Africa, according to the World Health Organization (WHO).

In 2019, 445,000 people died from TB in India, according to a recent WHO report. This figure could rise in the coming years. A study led by Finn McQuaid at the London School of Hygiene & Tropical Medicine found there could be an extra 149,448 TB deaths above that baseline level in India between 2020 and 2024 (*European Respiratory Journal*, doi.org/d6ck).

"We are definitely still expecting large numbers of additional cases and deaths from TB in India in particular," says McQuaid. "It's a major concern."

Another study, by Anurag Bhargava at Yenepoya Medical College and Hemant Deepak Shewade of global health organisation The Union, both based in India, estimated there would be nearly 186,000 extra TB cases and almost 88,000 more TB deaths in India this year alone, owing to worsening poverty, undernutrition and under-detection of TB related to the covid-19 pandemic (*Indian Journal of Tuberculosis*, doi.org/gg4rs4).

Undernutrition is a factor in many TB cases. A one unit decrease in average body mass index across the Indian population – 2 to 3 kilograms of weight loss on average – could lead to about a 14 per cent increase in TB incidence, the pair found. "India has inadequate levels of baseline nutrition and the pandemic has worsened the situation," says Bhargava.

SANJAY BAID/EPA-EFE/SHUTTERSTOCK

Artwork for 2019's World Tuberculosis Day at Palampur, India

India launched a national TB control programme in 2017 with the aim of eradicating the disease by 2025. Key to this effort is accurate monitoring, but under-detection of TB is a problem. Even before the covid-19 pandemic hit, there were more than 1 million TB cases missing from India's official statistics, according to a 2016 analysis of drug sales data.

88,000

Estimated number of extra TB deaths in India this year

The situation worsened this year when the government diverted public health resources from TB to the covid-19 response, including community health workers who are key to door-to-door screening.

The result was a 60 per cent drop in notifications of new TB cases in the first six months of 2020, according to India's national TB report. Other reports have pointed to a fall of around 80 per cent in daily notifications during the nation's lockdown period.

Treatment has also been lacking. A survey launched in March by the Global Coalition of TB Activists and other tuberculosis researchers found that 36 per cent of TB patients in India reported their health facilities to be closed.

In India, there are currently 354 million people who are infected with the TB bacteria but don't have symptoms or feel ill. Disruption in door-to-door screening and monitoring by community health workers could let their infection become active. For those with active TB, disruption in care could allow their infection to become drug resistant. India has an estimated 124,000 drug-resistant TB cases.

"Progression from infection to active disease is a serious concern now," says Bhargava. "We will have to find a balance between covid response and caring for other serious diseases." ▮

Virology

The evolving coronavirus

The coronavirus has mutated very little, but as more people are treated or vaccinated it could face pressure to evolve, finds **Graham Lawton**

"FORTUNATE" isn't a word that often comes up in relation to the coronavirus pandemic, but in one respect it is true. In the nine months that the virus behind covid-19 has been circulating widely, it has hardly mutated at all.

"We are fortunate that the virus is not mutating fast," says Sudhir Kumar at Temple University in Pennsylvania. A rapidly mutating virus could evolve into different, possibly more virulent, strains. "So it's good to have a low diversity" among the viruses currently circulating, he says. However, this could be the calm before the storm.

"As we start to get standardised drug deployment, resistant mutations will likely arise"

A recent analysis of more than 18,000 genomes of the new coronavirus, formally called SARS-CoV-2, sampled from around the world found very low levels of genetic diversity. The study, led by Morgane Rolland at the Walter Reed Army Institute of Research in Maryland, concluded that these viruses are so similar that a single vaccine should protect against them all (*PNAS*, doi.org/fdkz).

There are three main reasons for this. First, even though SARS-CoV-2 is an RNA virus, which generally have the fastest mutation rate of any biological entity, coronaviruses change relatively slowly because their genome-copying machinery has a proofreading function.

Second, when mutations have appeared, they are almost all biologically harmful or neutral to the virus, and so haven't persisted.

And third, the virus hasn't needed to evolve in order to be successful. Not yet, anyway. This is what makes some virologists nervous as we move into the next phase of the pandemic.

SPUTNIK/SCIENCE PHOTO LIBRARY

A person with covid-19 connected to a ventilator in Tver Regional Clinical Hospital, Russia

2

Known covid-19 reinfections from genetically distinct viruses

As a rule, evolutionary adaptation happens due to "selection pressure", which is when an organism's environment changes to favour certain variants over others.

Right now, SARS-CoV-2 is under very weak selection pressure. There are still plenty of humans to infect who have no "immune memory" to fight the virus; there are very few drugs to evade; and there is no vaccine. But as these benign conditions become harsher for the virus, selection pressure will ramp up and we can expect to see it evolve in response, perhaps in ways that make it even more dangerous.

According to an epidemiological model developed by a team led by Chadi Saad-Roy at Princeton University, the evolution of the virus will have a substantial effect on how the pandemic pans out over the next five years, ranging from sustained outbreaks to near-elimination (*Science*, doi.org/fdqc).

Change is coming

Predicting what will actually happen is impossible. "I don't think anyone can do that," says Oscar MacLean at the University of Glasgow in the UK.

"There is no strong evidence that the virus is evolving

adaptively," says Sergei Pond, also at Temple University. "It is boring genetically, with relatively little diversity and divergence, and we haven't exposed it to much selective pressure."

One thing we can be sure about is that the virus will change. "It is changing at a slow pace compared to many other viruses, but at a brisk pace compared to the human genome," says Kumar.

"There will be more interesting mutations as time goes by, especially as vaccines and treatments are introduced," says Rolland, who continues to monitor the virus's evolution.

Successful therapies could cause the virus to evolve resistance, for example. "As we start to get standardised drug deployment applied to every infection, then resistant mutations will quite likely arise," says MacLean. The same applies to the spread of natural immunity and vaccines, he says.

The selection pressure doesn't force the virus to mutate. But if a mutation conferring resistance to a drug happens to arise in a virus that is inside somebody being treated with that drug, then the mutant could proliferate and go on to infect another person, and then spread far and wide. This is known as "escape".

While this scenario is unlikely to happen in any one person, there are so many cases of covid-19 around the world that it isn't an impossibility.

Because of this danger, it may be wise to hold back some drugs to use as a last resort, says MacLean, or to administer two different drugs at once to exploit the fact that two resistance mutations are extremely unlikely to arise simultaneously.

SARS-CoV-2 also has another mutational trick up its sleeve: recombination. If a cell is simultaneously infected by two SARS-CoV-2 viruses with slightly different genomes, the RNA-copying enzyme can mash them together to make a hybrid. In this way, mutations can be brought together, which is another source of genetic variation that selection pressure could act on.

"We do expect them to recombine," says MacLean. "Coronaviruses recombine so often in bats."

Viral surveillance

There are already signs of new strains of the virus emerging. There have been several confirmed cases of reinfection, and in at least two of these, the second infection was with a genetically distinct virus. But whether these genetic differences enabled the viruses to dodge the host's immune memory hasn't been established, says Rolland.

Selection pressure and subsequent escape due to a vaccine is unlikely, she says. It has never been observed before. There is a case of an experimental HIV vaccine inducing genetic changes in that virus, says Rolland, but HIV has a much higher mutation rate than SARS-CoV-2.

Related viruses can also be a guide. The original SARS virus that caused the 2002-2003 epidemic acquired two big genetic changes early on in the outbreak. These mutants came to dominate, suggesting they were adaptations.

"Could SARS-CoV-2 adapt in the same way? Yes," says Nathan Grubaugh at Yale School of Medicine. However, he emphasises that mutation doesn't necessarily mean a virus will become more virulent or deadly. Mutations often do the opposite.

But we can't rely on this happening with SARS-CoV-2, says MacLean. "I think people are jumping the gun assuming that mutations will reduce the severity of infection. I really don't think that is a valid assumption," he says.

Viral diseases do become less virulent over time in a population, but that is partly due to people becoming immune. While killing hosts is bad for a virus's survival, being aggressive could be a useful trait, says MacLean, and therefore selection pressure can stop it becoming less aggressive.

What we must do, says Kumar, is limit opportunities for the virus to acquire mutations that could be advantageous to it when selection pressure is applied.

New mutations can arise during an infection, but evolution mainly acts on genetic differences already existing in the virus population. Right now, there are few of those says Kumar, and we can keep it that way by limiting transmission.

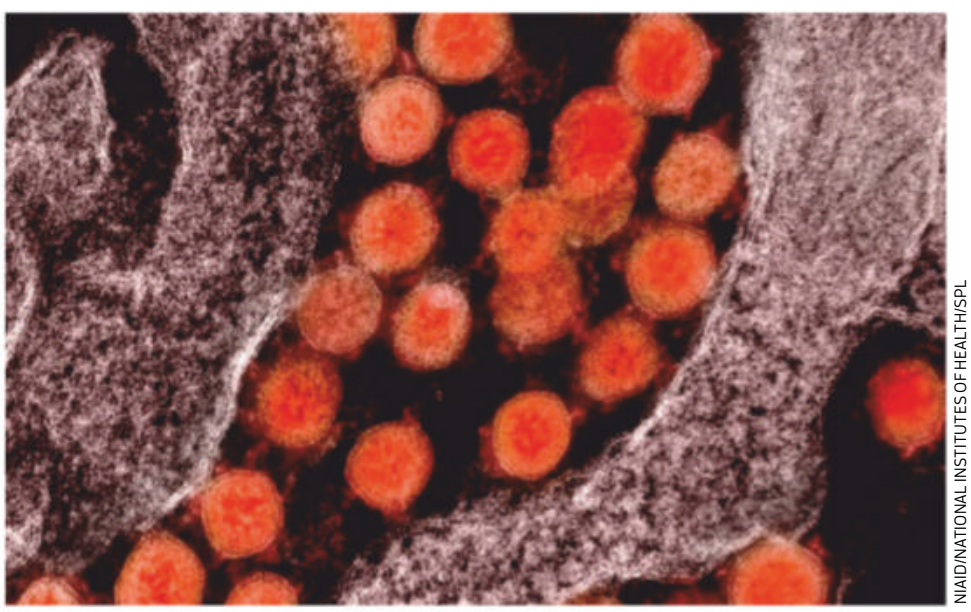
The virus can only evolve if it infects another person. If it isn't being transmitted as frequently as it used to be, any potential evolution of new strains will decrease.

"If everybody wears a mask and everybody gets vaccinated, the virus can't evolve"

But just in case, virologists are keeping the virus under surveillance to watch for mutations of interest. One project at Temple University monitors newly sequenced viral genomes. If it spots a mutation that has arisen independently twice, it assumes it may be being selected for and flags it up for other labs to check for enhanced virulence.

Another emerging approach is to grow the virus in cell culture, challenge it with drugs or an immune response and observe how it reacts at the genetic level. A project to do that is getting under way, but its leaders told *New Scientist* that it was too early to share any details.

For Kumar, the message from evolutionary biology is clear: "The future is hard to predict, but if everybody wears a mask, and if everybody gets vaccinated, the virus can't evolve. Then the chance of escape is less. That is what we are hoping for." ▮



SARS-CoV-2 particles (orange) isolated from a person with covid-19

NIAID/NATIONAL INSTITUTES OF HEALTH/SPL

Conservation

Ape escape

Ropes helped gibbons at risk of jumping to extinction

Clare Wilson

WITH a population that fell to just 25 individuals a few years ago, every Hainan gibbon counts. So when a 2014 landslide on China's Hainan Island forced the last surviving members of the world's most endangered primate species to make death-defying leaps across a gap in the forest canopy, conservationists were concerned.

"It was scary to watch – my heart just popped out of my throat," says Bosco Chan at the Kadoorie Farm & Botanic Garden in Hong Kong.

The researchers lent a hand by stringing ropes between the trees (pictured). The plan worked. Most of the gibbons (*Nomascus hainanus*) learned to use the ropes to cross the 15-metre gap. Some even balanced on them like tightrope walkers.

Chan says rope bridges are now proving useful in helping other primates cross gaps between fragmented habitats (*Scientific Reports*, doi.org/fdnm). ▮

KADOORIE FARM AND BOTANIC GARDEN

Animals

Snake with tracking device attacks woman

IT WAS 2.30 am when Lea-Ann Mears woke to the pain of a 4-metre-long scrub python sinking its teeth into her posterior.

Mears knew the python was near her home in northern Queensland, Australia – in fact, reptile biologist Daniel Natusch had called the previous day to warn her to lock doors and close windows. Natusch, based at Macquarie University in Sydney, had been tracking the snake, which had been implanted with a radiotelemetry device, for the previous five weeks as part of a study to understand more about the pythons' use of land.

"They could kill the children," says Natusch. "So I said, 'Look, it's never going to happen, but lock the kids' doors and windows at night.'" Mears had a toddler and a 3-year-old in the house.

Mears did lock her children's bedroom, but because the weather where she lives is uncomfortably warm even at night, she left the front door open to let in a draught before retiring for the night.

After the snake attacked, Mears managed to turn on the light. "The snake was still latched onto my butt," she says. "I had to reach down and put my hand in its mouth and yank its teeth through the flesh to get it off."

She managed to lock the python inside her kitchen. Natusch arrived quickly and watched the house while Mears went to hospital to deal with her minor injuries. Later, Natusch took the snake 100 metres away and set it free.

Natusch notes that the incident raises the question of why a 5-kilogram snake would even attempt to eat a 64-kilogram woman it could never hope to swallow. He tracked down a few more examples of this happening through news clippings, suggesting Mears's experience wasn't unique.

"It's a bloody tough life out there in the bush. These snakes need to take chances"

Natusch suspects that the pythons target such large prey partly due to a harsh environment in which they can go months or even years without eating. At night in the dark, this particular snake may have just seen an exposed leg and underestimated the size of its prey (*Austral Ecology*, DOI: 10.1111/aec.12956).

The same snake came back 10 months later and tried to eat one of Mears's 25-kilogram dogs. It was in the process of strangling the dog when Mears freed her pet.

"My theory is it's a bloody tough life out there in the bush," says Natusch. "These snakes need to take chances." ▮

Joshua Rapp Learn

Fertility

Hints that daughters of older mothers may be less fertile

Michael Le Page

A STUDY of women born in the Netherlands in the 19th century adds to the evidence that the daughters of older mothers may be slightly less fertile.

Many animal studies have found that females born to older mothers have worse health and fewer offspring on average. This could be because eggs accumulate mutations as they age.

Some studies suggest the same is true of people, but in modern populations factors such as education and wealth have a big effect on the average number of children women have.

To try to get around this, Ingrid van Dijk at Lund University in Sweden and her colleagues used data on births, deaths and marriages in the Dutch province of Zeeland during the 19th century. They looked at more than 7000 mothers, who collectively gave birth to nearly 10,000 daughters between 1812 and 1874, and who also had a total of just over 73,000 grandchildren.

They found that with every year's increase in the mother's age, there was a 0.3 per cent decrease in the number of children each daughter had. The effect is small but statistically robust, the team says (bioRxiv, doi.org/fdzc).

"I think that there are some advantages to using historical populations for this type of study," says Olga Basso at McGill University in Canada. "Women were expected to marry and have children, and most did." This suggests childlessness was rarely voluntary, as it can be today, she says.

However, with so many factors at play – including, for instance, the age of fathers – it isn't clear that the lower number of children being born to daughters with older mothers in Zeeland is due solely to a biologic effect of maternal age, says Basso. ▮

Human evolution

Did climate change wipe out early human species?

Donna Lu

SUDDEN climatic changes may have been a significant driver of the extinction of early human species.

Pasquale Raia at the University of Naples Federico II in Italy and his colleagues have used climate modelling and fossil records to determine the effect that climate change had on the survival of the species in our *Homo* genus.

The researchers used a database of 2754 archaeological records of the remains of several species that lived over the past 2.5 million years, including *Homo habilis*, *Homo ergaster*, *Homo erectus*, *Homo heidelbergensis*, *Homo neanderthalensis* and *Homo sapiens*.

They cross-referenced these records with a climate emulator, which modelled temperature, rainfall and other weather data over the past 5 million years. The aim was to determine the climatic niche for each species – a range of conditions including temperature and precipitation that are optimal for survival – and how widely distributed the niche area was through time.

The team found that *H. erectus*, *H. heidelbergensis* and *H. neanderthalensis* all lost a significant portion of their climatic niche area just before they became extinct.

"Species are good at surviving when they have a large area at their disposal to live in," says Raia. But when liveable areas decrease and the result is small patches that are geographically isolated from each other,

2754

The number of archaeological records examined in the study

species enter what is known as an extinction vortex.

The reductions in liveable area resulted from sudden climatic changes, the team found. *H. erectus*, for example, went extinct during the last glacial period, which began about 115,000 years ago. The researchers suggest this was the coldest period the species had ever experienced.

The team found that for the Neanderthals, competition with *H. sapiens* was also a factor, but that even without the presence of our species the effect of climate change alone may have been enough to lead to extinction. Even species with the ability to control their local environment – with fire, for example – were susceptible to the effects of climate change, says Raia (*One Earth*, doi.org/fdnq).

But gaps in data may compromise the certainty of the conclusion that climate change was the primary extinction driver, say other researchers.

Aside from Neanderthals, there is very little fossil evidence for the other species studied, says Bernard Wood at George Washington University in Washington DC.

"Individuals belonging to these [species] lived at times, and in places, not sampled by the existing fossil record," he says. "And the first appearance date of a [species] almost certainly underestimates when it appeared, and its last appearance date almost certainly underestimates when it became extinct."

As species approach extinction, regardless of the cause, their range necessarily declines, says Corey Bradshaw at Flinders University in Australia. If a species' range was already in decline, that could give the false impression that the climate niche area was also declining, he says.

"No species that we know of has ever gone extinct from a single mechanism. It's always a combination," says Bradshaw. For example, in the case of many large animals in the last glacial period, it seems human hunting and climate change both contributed to extinction. ▮

LANMAS/ALAMY

Was *Homo ergaster* driven extinct by climate change?

Materials science

Superconductors are hot again

A material with zero electrical resistance could spark an energy revolution

Leah Crane

ACHIEVING room temperature superconductivity, a major goal in materials science for decades, may finally have been cracked, with the potential to revolutionise the way we use electricity.

An enormous amount of the energy we produce is wasted because of electrical resistance, which generates heat. But in a superconducting material, electrical current can flow with zero resistance, meaning these losses don't occur.

This property has made such materials sought-after, but until now getting them to work has required very low temperatures and extremely high pressures.

Under pressure

"If you had a room-temperature superconductor that you could deploy at atmospheric pressure, you could imagine a whole host of large-scale applications," says M. Brian Maple at the University of California, San Diego.

Ranga Dias at the University of Rochester, New York, and his colleagues have gone part of the way to addressing those requirements. The team made a superconductor by crushing carbon, sulphur and hydrogen between two diamonds at a pressure about 70 per cent of that found at the centre of Earth and at a temperature of around 15°C.

That is the highest temperature at which superconductivity has ever been measured, and the first such material that can reasonably be said to have this property at room temperature (*Nature*, doi.org/ghfp4w).

The new approach was partially inspired by the idea that solid metallic hydrogen is expected to be superconductive, but it is incredibly difficult to make because it requires extraordinary pressure. The researchers found that adding carbon and sulphur to hydrogen makes it behave as if it is at a higher pressure than it is.

"Say you are in a room and you have four walls. One way you can compress yourself is to bring the walls closer and closer, but you can also keep the same size of room and add 10 people into the room, you'll still feel squeezed," says Dias. In this experiment, adding carbon and sulphur to the hydrogen is like adding more people to the room: it acts to chemically pre-compress the hydrogen.

Once Dias and his team found that the electrical resistance of their material went to zero at 15°C, they did other tests to confirm that it really was superconductive, such as making sure it blocked magnetic fields.

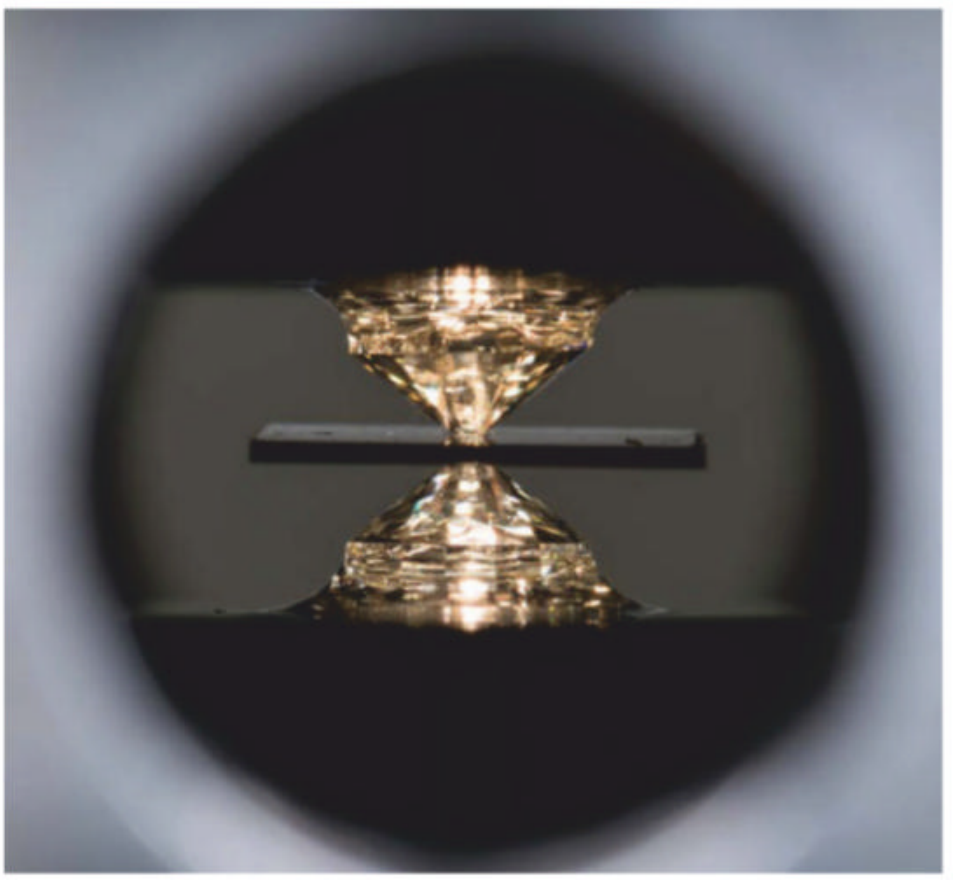
"These are very thorough experiments, they basically nailed it down. When you look at the data, it's stunning," says Shanti Deemyad at the University of Utah.

15°C

Temperature at which the new material operates – a record high

70%

of the pressure found at the centre of Earth is required to produce the superconductor



ADAM FENSTER

Two diamonds were used to crush a mix of three elements

"This is going to shake the field."

Questions still remain, though. For example, despite knowing that the superconducting material is made of carbon, sulphur and hydrogen, we don't know how those elements are bonded. "It's not uncommon in this type of research to have an experiment without knowing the structure," says Eva Zurek at the State University of New York at Buffalo. More theoretical work will be needed to match the material's behaviour with models of various compounds to figure out exactly what it is, she says.

Maple also cautions that there may be formidable challenges ahead. It is possible these could be so great that you might not be able to get a superconductor that can perform well enough for many hoped-for applications, he says.

Dias and his team are working to produce their material at lower pressures. "Take diamond: it is a high-pressure form of carbon, but nowadays you can grow it in a lab with chemical deposition," says Dias. "It used to require high pressure, but now we can grow it. We may be able to do something similar with superconductors."

The fact that this compound has three elements in it, whereas other superconductors have tended to only contain one or two, makes it more adjustable, which Dias says will help in the effort to make it work at lower pressures.

If that can be achieved, this material could be used in applications ranging from quantum computing to building better MRI machines to drastically reducing energy waste from electricity transmission. "If we could make superconducting wires that we didn't have to cool, we could in principle replace the whole power grid," says Zurek. "That would be a real revolution."

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US election

Trump's scientific legacy

Whatever the outcome of the US presidential election, Donald Trump is likely to have a lasting impact on the nation's health and environment. **Chelsea Whyte** reports

AS US President Donald Trump prepares to face the ballot box in the hopes of winning a second term, his handling of the coronavirus pandemic will be at the forefront of voters' minds. But Trump's impact on health, space and environment policy during his time in office also warrants examining.

In the past four years, Trump has promised to reverse environmental regulations and climate change policy, to repeal and replace his predecessor Barack Obama's landmark healthcare policy and to revive the fortunes of NASA. Has he succeeded?

EVAN VUCCI/AP/SHUTTERSTOCK

A green undoing

One promise Trump has kept is the removal of the US from the landmark 2015 Paris Agreement on climate change, in which nearly all nations agreed goals to reduce carbon emissions in an attempt to keep global warming below 2°C above pre-industrial levels.

During a campaign speech in May 2016, Trump said: "We're going to cancel the Paris climate agreement and stop all payments of US tax dollars to UN global warming programmes." He followed through once in office, announcing in June 2017 that the US would exit the agreement, though Congress continued to fund such UN programmes.

Environmental campaigners were dismayed. As the US is the second largest carbon emitter behind China, combating global warming can only be done with it on side. "The alternative is the end of the world as we know it," says Kassie Siegel at the Center for Biological Diversity Action Fund in Washington DC. "We've known this for a long time, we've known what the science demands."

"The Paris climate accord shackles economies and has done nothing to reduce greenhouse gas emissions," says Judd Deere, deputy press secretary for the White House.

The US won't officially exit the Paris Agreement until 4 November, the day after the US election, due to the rules of withdrawal in the accord. Siegel thinks rejoining could happen quickly under another president, but other environmental policy changes may be harder to reverse.

580km

Length of wall constructed on the US-Mexico border

The Trump administration has rolled back dozens of regulations, such as endangered species protections, limits on greenhouse gas emissions and emissions standards for power plants and vehicles. "There's a whole suite of things intended to ram through as much fossil fuel production as possible," says Siegel.

These include weakening regulations put in place under the Obama administration's Clean Power Plan (CPP). Its Trump-era replacement, the Affordable Clean Energy rule, scraps federal emissions standards and gives responsibility for setting those standards to state governments. This effectively takes the legs out from the US Environmental Protection Agency, which is responsible for policing infractions but is now unable to set common standards.

The CPP called for a reduction in greenhouse gas emissions from the power sector by 32 per cent between 2005 and 2030, and would have relied on states moving away from using coal power plants. Its elimination makes it easier to keep coal plants operating for longer.

Fossil fuel industries have also benefited from deregulation in other ways. The Trump administration poked holes in a rule that requires coal power plants to cut their emissions of toxic mercury. Oil and gas companies, meanwhile, no longer have to report and repair methane leaks. Methane is a particularly important greenhouse gas in the short term because it has a greater warming effect than carbon dioxide. "The oil and gas sector is a massive source of methane, and it's technically feasible and extremely cheap and easy to stop those leaks," says Siegel.

Donald Trump signs an executive order on energy and infrastructure

Trump has repeatedly claimed that the US has the cleanest air and water in the world, which isn't true. In fact, efforts to reduce pollution have been weakened under his leadership. For example, Obama-era emissions standards for vehicles that required a 5 per cent decrease in carbon emissions each year have now been downgraded to 1.5 per cent, while

Obama's expansion of federal protection for streams and wetlands has been reversed, with long-term consequences.

"The impact that will occur because headwaters and intermittent streams in the wetlands are going to be less protected will take a while to actually show up," says Durelle Scott at Virginia Tech. Degraded ecosystems, contaminants in the water and poorer health for people and animals could take five to 10 years to appear, he says.

Trump's signature campaign promise to build a border wall between the US and Mexico has also taken a toll on natural resources. "The Trump administration is extracting hundreds of millions of gallons of water from desert aquifers to mix concrete for the 10-foot-deep barriers at the border," says Laiken Jordahl at the Center for Biological Diversity Action Fund, who works in the border region in Arizona.

US Customs and Border Protection says 580 kilometres of border wall have been erected. While the president's detractors often point out that much of this is replacement wall, the new, taller barriers have a much greater impact on wildlife, says Jordahl. It has affected 93 plant and animal species that are endangered, threatened or identified as warranting protection, he says.

An obscured crisis

The Obama-era law Trump has targeted most vehemently is the Affordable Care Act (ACA), also known as Obamacare, which resulted in 20 million more people having healthcare insurance. It is still in place, but the president has been chipping away at it bit by bit since the day of his inauguration.

On 20 January 2017, he signed an executive order stating his intent to seek its "prompt repeal" and allowing US agencies to eliminate portions of the law that placed an economic burden on patients, insurers, drug-makers, doctors and states. The resulting slash in funding for programmes helping people get healthcare through the ACA led to an estimated 400,000 fewer people getting coverage the following year.

In an effort to make good on the rest of Trump's promise, Republicans in the US Congress spent much of 2017 attempting to repeal the law, going on a rollercoaster ride of proposed and ultimately failed bills. By October 2017, Trump had taken matters into his own hands. He signed an executive order to permit less robust health insurance plans under the ACA, such as short-term plans that can expire when someone is in the middle of treatment.

In December 2017, as part of a tax bill signed by Trump, a key part of the ACA was reversed. The individual mandate, which required most people in the US to have health insurance or pay a fine, was revoked. This requirement kept younger, healthy people insured alongside older people and those with health conditions, lowering costs, as younger and healthier people pay in but require less treatment.

SUSAN E. DEGGINGER/ALAMY

The border wall threatens birds in Whitewater Draw Wildlife Area, Arizona

In the ensuing years, the number of uninsured people in the US has gone up. According to Census Bureau data, 25.6 million people were uninsured in 2017, a figure that rose to 27.5 million in 2018. More recent figures show that in the first three years of Trump's tenure, up to the end of 2019, the number of uninsured people in the US rose 2.3 million.

Because many people in the US have health insurance through their employer, the covid-19 crisis has also led to a marked decrease in healthcare coverage. The months between February and May saw the largest ever increase in the number of uninsured adults – a jump of 39 per cent, or 5.4 million people – according to a study by The National Center for Coverage Innovation in Washington DC.

Trump has repeatedly promised to produce a healthcare plan that would replace the ACA, but he hasn't delivered. In May 2018, he said his plan would come out in four weeks. In June 2019, he said it would be released within two months. During the pandemic, he has mentioned on several occasions that he is on the verge of revealing a new healthcare plan. It has yet to materialise.

The focus on the pandemic has obscured an existing US health crisis: the large number of deaths due to opioid overdoses. When he was campaigning for office in 2016, Trump said he would tackle this, and while his administration has taken steps to do so, it hasn't been able to stem the tide.

In the 12 months preceding February 2020, drug overdose deaths in the US hit an all-time high of more than 72,000, with more than two-thirds of that due to opioids. This is an increase from about 65,000 overdose deaths ›

Nuclear meltdown

The New Strategic Arms Reduction Treaty (New START) – signed in 2010 by Russia and the US – was a signature policy of Barack Obama's administration, limiting each country to 1550 deployed nuclear weapons. It is set to expire in February 2021, two weeks after the next US presidential inauguration, and Trump has so far declined to sign a five-year extension.

This wouldn't be the first arms control treaty Trump has pulled out of. He withdrew the US from Obama's 2015 nuclear deal with Iran and the Intermediate-range Nuclear Forces treaty with Russia, which banned ground-launched cruise missiles.

The Trump administration has argued that China should be included in a future arms control treaty that would replace New START, but has recently dropped that condition in negotiations with Russia. That still hasn't paved an easy road. On 14 October, US officials signalled that a deal was near, while the Russian deputy foreign minister announced that this wasn't the case. A failure to reach agreement could see New START limits slip away, setting the stage for a nuclear arms race.

in 2017, according to the US Centers for Disease Control and Prevention. It is also a reversal of a short-term trend that showed drug overdose deaths declining slightly in 2018, mainly due to a reduction in prescription opioid deaths. A rise in overdose deaths from illegal drugs has reversed that progress. In 2020, overdose deaths are spiking again, according to the American Medical Association.

In 2017, the Trump administration declared the opioid crisis a public health emergency, though the US Government Accountability Office found that this has had a minimal impact. The administration expedited a survey on prescription drug trends and waived some red tape for research on treatment.

In 2019, Trump announced that the federal government would set aside $1.8 billion for treatment and prevention. States have used the money to treat overdoses and fund recovery programmes.

More funding may be needed, especially now. "The covid-19 pandemic has exacerbated an already difficult situation by reducing access to life-saving treatment, harm reduction, and recovery support services, while increased stress and isolation might increase the risk of addiction and substance use disorders," wrote Leana Wen at George Washington University in Washington DC and Nakisa Sadeghi at the University of North Carolina at Chapel Hill in *The Lancet*.

Shoot for the moon

Obama's space policy was muddled. He cancelled a George W. Bush-era programme to send astronauts to the moon in favour of focusing on Mars, via a human mission to an asteroid that had lukewarm support.

Under Trump, NASA has the moon firmly in its sights. "This time, we will not only plant our flag and leave our footprint, we will establish a foundation for an eventual mission to Mars and perhaps, someday, to many worlds beyond," Trump announced in 2017, on the 45th anniversary of the Apollo 17 lunar landing.

In 2019, vice president Mike Pence set an ambitious timeline, directing NASA to return to the moon by 2024. "The goal of 2024 put some energy into the system and it's been aggressive and helped things move faster than they would have," says Mary Lynne Dittmar at the Coalition for Deep Space Exploration.

Whether Trump's space policy can actually deliver remains to be seen. NASA's Artemis programme aims to put a man and a woman on the moon in four years, and Dittmar says that's a challenging goal. "I've never seen human space flight come in on time by anybody, by any nation," she says.

TOM WILLIAMS/CQ-ROLL CALL, INC VIA GETTY IMAGES

People in Washington DC protest in support of the Affordable Care Act (ACA)

But NASA is moving forward quickly. "This time, we are not going alone, but with commercial and international partners. To meet these goals, this president has called for historic increases in NASA's budget," says Will Boyington of the National Space Council.

On 13 October, eight countries signed up to the US-proposed Artemis Accords, which sets out rules for lunar mining and standards for sending both robots and people to the moon's surface. The hope is to avoid potential future disputes over the use of materials extracted from the moon, although China and Russia – both major players in space flight – haven't signed up.

"NASA's Artemis programme aims to put a man and a woman on the moon in four years"

Beyond NASA, in 2019 Trump directed the creation of the US Space Force, which was touted as a new branch of the military. "It's like the army and the navy, but for space, because we're spending a lot of money on space," he said. In reality, it is more of a bureaucratic shuffle of existing space command away from the air force, army and navy branches that housed them before.

The Trump administration also set out to develop standards around space traffic management, cybersecurity issues for satellites and launch regulations. "Some of these will be implemented by the end of the first presidential term. There's been more focus on trying to address some of these structural problems than I remember in the past 20 years," says Dittmar. ▮

The tech cold war

Donald Trump has overseen increasing conflict between the US and China over technology. One of the most high-profile battles has been about the video-sharing app TikTok, owned by Chinese firm ByteDance.

Throughout 2020, Trump raised concerns about the potential for China's government to use the app to gather data on people in the US. There is no evidence that the app gathers data other than what is collected by other social media apps, and TikTok says it hasn't received requests from the Chinese government to access data.

Still, in September, Trump said he would ban the app along with WeChat, owned by Chinese company Tencent. The two services are used by 100 million people in the US. To avoid the ban, TikTok has made an agreement with US companies Oracle and Walmart to share ownership of the app. The deal must be completed by mid-November or the ban may still go through.

Must
~~Nice to~~ have this holiday season

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

And that's just the stuff we know about.

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Wildlife

Iconic elephant population on the brink of extinction

IVORY COAST, named for its elephants, had one of the largest populations of the animals in West Africa. But now they are in rapid decline.

Sery Gonedelé Bi at the University Félix Houphouët-Boigny in Abidjan, Ivory Coast, and his team surveyed 25 protected forest areas across the country between 2011 and 2017. They also analysed media reports and records of conflict between humans and elephants.

From this, the researchers estimate that there are 225 forest elephants left in Ivory Coast, a fall of 86 per cent since a 1994 survey. Estimates suggest that about a century ago, the forest elephants there numbered between 3000 and 5000, says Gonedelé Bi.

Based on dung counts, the team confirmed the presence of elephants in only four of the 25 protected forest areas they checked. Habitat degradation is a likely driver of the decline.

The team found that of the 360,000 hectares the 25 protected forests cover, 71 per cent of this has been cleared, mostly for growing cocoa, says Gonedelé Bi. More than half of the areas have been totally lost to farms and settlements (*PLoS One*, doi.org/fdm6).

Previous analysis has shown that an estimated 265,000 hectares of forest are cleared in Ivory Coast every year, the highest deforestation rate in sub-Saharan Africa.

The researchers believe that without immediate action to safeguard still-existing populations, such as ranger patrols and law enforcement, forest elephants will go extinct in Ivory Coast. **Donna Lu**

Technology

Sun-powered box pulls water from air

A DEVICE that can extract water from almost dry air using heat from sunlight could help provide a sustainable source of water in remote areas that lack electricity.

Alina LaPotin at the Massachusetts Institute of Technology and her colleagues developed the apparatus. It contains a material called a zeolite, which takes up water vapour from the air at night. During the day, heat from the sun hits a solar collector and drives the release of the water from the material so it is suitable for use.

Because the zeolite is very porous and has a large internal surface area, it can adsorb the tiny quantities of water held in almost dry air, says LaPotin. Modelling based on initial tests of her team's device predicts it could produce water from air with a relative humidity as low as 20 per cent – levels seen in deserts. Existing atmospheric water harvesting devices, such as fog harvesting and dewing systems, only work at relative humidity levels of at least 50 per cent.

Fog harvesting also has the disadvantage of being limited to areas with fog, and dewing systems need to consume a lot of energy to power refrigeration systems that cool air below its dew point, she says.

The box-shaped solar device is made of acrylic, aluminium and copper, and weighs about 7 kilograms. During tests, it was able to produce 0.77 litres of water each day for every square metre of solar collector (*Joule*, doi.org/fdnj).

LaPotin says her team is investigating ways to increase the amount of water that can be adsorbed by the material inside the device, to increase its efficiency further. "New materials are being developed which have a higher uptake," she says. **Layal Liverpool**

Evolution

Odd penis shape helps thwart rivals

COMPLEX penis bones capable of removing a rival's semen could be a way for males to ensure their paternity with a long-term mate.

The baculum bone, found in the penis of most mammals, sets the shape of the penis tip and varies widely in form across species, says Charlotte Brassey at Manchester Metropolitan University, UK. We are one of a few primate species to have evolved this bone away.

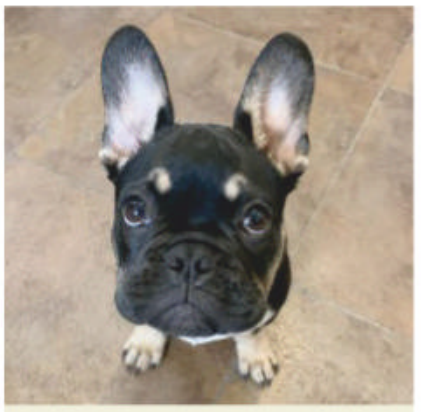
COURTESY OF CHARLOTTE BRASSEY

Brassey's team used X-rays to compare the bacula of 82 species, including dogs, wolves and otters, and concluded that the bone shape may have a role in "post-copulatory sexual competition".

When females mate with more than one male during the same fertility cycle, the sperm of those males compete to fertilise the few available eggs. The design of the penis tip could displace sperm already in the reproductive tract, clearing the way for the new male (*Proceedings of the Royal Society B*, doi.org/fdnf). The honey badger's baculum (pictured) even looks like an ice cream scoop, says Brassey. It really seems "designed to scoop out other sperm".

The most complex bacula were found in animals that are socially monogamous, meaning they tend to pair for an extended period. However, many such females mate outside their "couple", so the bone shapes may have evolved for males to ensure paternity, says Brassey. **Christa Lesté-Lasserre**

Really brief



RYAN WILLS

Pugs more likely to have eye problems

An analysis of UK veterinary records shows that pugs and bulldogs are more likely than dogs with longer snouts to develop painful eye inflammation. This may be because these dogs have shallow eye sockets, meaning their eyes are prone to drying out and injury (*Scientific Reports*, doi.org/fdnd).

Turn farms to forest to store carbon

Converting 30 per cent of farmland in some tropical regions to its original state, such as forest, would create a carbon sink large enough to store half of the carbon dioxide emitted since the Industrial Revolution, according to a study. It would also help reduce animal extinctions (*Nature*, doi.org/ghfp4x).

Minimum alcohol price can cut deaths

Introducing a minimum price for alcohol in Canada would cut the number of hospital admissions related to alcohol consumption while also reducing deaths attributed to drinking, researchers conclude. Other countries might see similar benefits (*Journal of Studies on Alcohol and Drugs*, doi.org/fdng).

Zoology

Water bears glow to survive a blast of UV

A TINY tardigrade can survive intense ultraviolet radiation for an hour by glowing.

Tardigrades, also known as water bears, are about 1 millimetre long. They are famous for being able to withstand conditions that would kill most organisms, such as being completely dried out.

While studying moss, Sandeep Eswarappa at the Indian Institute of Science in Bangalore and his colleagues found what may turn out to be a new species of tardigrade. It seems to like places that are bathed in sunlight. For now, they have named it the *Paramacrobiotus* BLR strain.

The researchers exposed these animals to a germicidal ultraviolet lamp. A control animal, a worm called *Caenorhabditis elegans*, died in 5 minutes, but *Paramacrobiotus* BLR survived for an hour. While wondering how the tardigrades might survive , they left a tube of them near a UV source and noticed the tube started glowing.

Further experiments revealed that the tardigrades contain a fluorescent chemical. "It is absorbing the UV light and emitting harmless visible light in the blue range," says Eswarappa.

The researchers were able to transfer this chemical to another tardigrade, *Hypsibius exemplaris*, and to *C. elegans*, both sensitive to ultraviolet. This protected them from UV for 15 minutes (*Biology Letters*, doi.org/fdnn).

The team hasn't yet identified exactly what the chemical is, but once it is known, Eswarappa hopes to make more of it and explore whether it might be used in sunscreen. **Michael Marshall**

Solar system

SHUTTERSTOCK/KEATON MCQ

Magnetic moon helped shield early Earth from solar threat

OUR planet's moon may have kept the atmosphere here safe from a more active sun 4 billion years ago, thanks to a magnetic field that has long since disappeared.

While the moon has no magnetic field of note today, recent evidence from rocks brought back by the Apollo missions show that between 4.2 and 3.4 billion years ago, when the moon was more than twice as close to Earth as it is now, it did have a magnetic field that was at least as strong as Earth's is today.

James Green at NASA and his team used this discovery to model the impact of the moon's field. They found that it should have combined with Earth's field to create a protective magnetosphere, possibly for hundreds of millions of years (*Science Advances*, DOI: 10.1126/sciadv.abc0865).

The combined field would solve a problem with the young Earth. We believe the sun was more active then, ejecting up to 100 times more solar particles than now. This should have removed Earth's atmosphere, making prospects for life bleak. But instead, life flourished. "We now know it had help, and that help came from the moon," says Green. The finding may have implications in the hunt for life beyond our solar system. Jonathan O'Callaghan

Animal behaviour

Ants are pretty good architects

ANTS that construct turrets for their nests choose what to build them with in an architecturally sound way, even when given unfamiliar materials.

South American leafcutter ants (*Acromyrmex fracticornis*) carry plant clippings underground to use them to cultivate fungus for food. To promote fungal growth, they build thatch-like turrets that keep rainwater out, but that create the correct humidity level for their "crop".

In their natural environment, the ants select thick wooden sticks for the turret base. They use light grass for the top, which promotes higher humidity inside the structure. They then plaster the interior with clay, with the whole process taking three days.

To test how the ants use materials, Daniela Römer at the University of Würzburg, Germany, and her colleagues replaced their usual choice of twigs and fresh grass with slivers of processed smooth wood and dry grass.

They found that the ants still made the same architectural decisions with these materials, selecting for thickness at the base and lighter vegetation at the top (*Royal Society Open Science*, doi.org/fdnp). **CL-L**

Signal Boost

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

Working for peace through education with refugees and internally displaced communities in Myanmar

Myanmar is enduring the longest running civil war in the world. Dating back to the 1940s, the war has had a devastating impact on the education and life chances of generations of young people in the country.

Mobile Educational Partnerships (MEP) is an award-winning educational charity, built by British and Burmese teachers to offer hope to communities affected by conflict, poverty and neglect.

MEP has developed a unique and innovative model of teacher training. Our mobile units work with local refugee and migrant teachers and children in some of the most difficult to reach, poorly resourced schools in Myanmar. We work at a grassroots level forming meaningful partnerships with local teachers and impact the learning of thousands of children every year.

Importantly, the MEP ethos is not to impose training or a specific teaching ideology; instead, we work alongside teachers, building relationships, blending the best from East and West to find solutions for learning in the most challenging of surroundings.

Regular in-class support is crucial; working with small groups MEP develops core skills, and then provides individual mentoring to develop teachers' confidence and enhance classroom practice. We also help teachers improve their English and support them through internationally accredited Cambridge English courses, enhancing their career prospects.

Our strength is in our size – we can be mobile, flexible and extend our reach into the most remote and sometimes dangerous parts of Myanmar. The help MEP gives is part of a bigger movement in Myanmar, working for peace and changing attitudes through education.

We expect a lot from our trainers including personal commitment, a willingness to adapt to isolation and sometimes hardship, but in return they get an experience that will stay with them for life, knowing they have made a difference to the futures of some of the country's most disadvantaged young people.

MEP has no public funding and is solely dependent on donations. While all charities are suffering during the pandemic, 2020 has seen MEP's funding sources diminish dramatically.

Want to help?

If you would like to donate, please visit mobileeducationpartnerships.org or to find out how to support us in other ways; go to 'Get Involved!' on our website

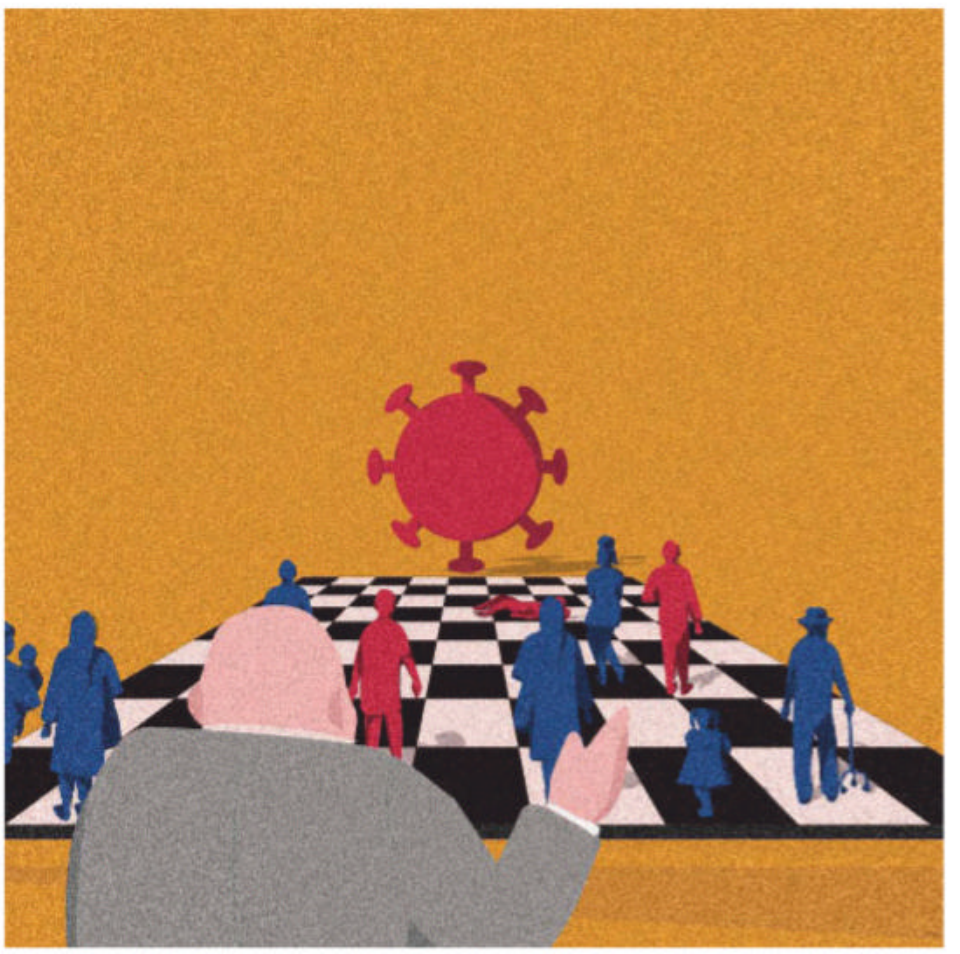
Views

Comment

Absurd about the herd

Assuming that herd immunity will result from letting most people get covid-19 is unscientific and irresponsible, says **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist*



MICHELLE D'URBANO

AS I write this, my 19-year-old son is self-isolating in his university room with symptoms of covid-19, awaiting test results. He is quite poorly, though overwhelmingly likely to make a full recovery. But I worry that he will be one of the few young adults who get seriously ill or even die, or end up with long-term health problems.

To some, however, his illness is welcome; in fact, they wish it on all of his peers. According to the signatories of an open letter called the Great Barrington Declaration, lockdown measures are doing more harm than good and we should open up society and let the virus rip.

OK, that is a bit of an exaggeration. The declaration – named after the US town where it was signed – advocates a strategy called "focused protection" under which the most vulnerable people shield and everybody else "should immediately be allowed to resume life as normal". This will then allow herd immunity to build up.

The declaration publicly exposed a scientific disagreement that has been simmering for months. On one side are mainstream scientists who reluctantly see restrictions on freedom as the only way to keep a lid on the pandemic while we wait for vaccines; on the other, the libertarians who see the damage done to economies and individual lives as too high a price.

The mainstream media lapped up the disagreement narrative, but completely missed the fundamental problem with the declaration: its extremely dubious claims about herd immunity. This is central to the strategy, but the document badly fluffs the science.

Herd immunity is conceptually simple. If enough people become immune to an infectious agent, the entire herd is protected because infectious people rarely encounter a non-immune person, and so transmission fizzles out.

The level of individual immunity required to attain herd immunity against a virus depends on how infectious it is, as measured by R, the average number of people that each infectious person infects. The classic example is measles, which has an R number of around 15 and a herd immunity threshold of 95 per cent. The numbers for the coronavirus SARS-CoV-2 are about 3.5 and 60 to 70 per cent.

Herd immunity has only ever been attained by vaccination. But the declaration advocates naturally acquired immunity. In other words, letting between two-thirds and three-quarters of the population catch the virus.

There are a number of issues with this, not least collateral damage. Even if the death rate is under 1 per cent, letting the virus run free will hospitalise and kill millions.

But there is another crucial scientific detail that the declaration – along with most discussions of herd immunity – misses. We can't take it for granted that widespread individual immunity will automatically create herd immunity.

Herd immunity can only be built if the immune response totally prevents individuals from picking up and transmitting the virus. That sometimes happens, but often doesn't. A lot of the time, an immune response stops us from falling ill if we reacquire the virus, but doesn't prevent onward transmission. The same is true of vaccines.

We don't yet know whether natural immunity to SARS-CoV-2 (or the experimental vaccines) will halt transmission. Until we do, assuming that herd immunity will automatically appear is unscientific and, frankly, irresponsible.

There are many other reasons to be sceptical of the declaration. It doesn't even mention the debilitating, lasting effects of "long covid", for example. But they are of secondary significance to the fundamental hole at its heart: the mystifying and dangerous failure to properly grasp the concept of herd immunity. Get well soon, son. ▮

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

Annalee's week

What I'm reading
Henry Nash Smith's classic Virgin Land, *a cutting analysis of the US myth of manifest destiny.*

What I'm watching
The delightful Julie and the Phantoms, *about a teen in a rock band who has ghosts haunting her garage.*

What I'm working on
I just started an email newsletter on Substack *called* The Hypothesis. *You should subscribe!*

This column appears monthly. Up next week: James Wong

This changes everything

Why do we still have email? By rights, email should now be obsolete, yet it has outlived the computers where it was born with dogged determination, says **Annalee Newitz**

I WISH my doorbell would stop emailing me every few hours about how its camera isn't working. I also wish a certain person would stop sending long-winded, hostile proclamations to one of my favourite email lists. My two wishes bookend the long history of email problems, from irritating listservs 40 years ago to automated notices from inanimate objects today. It is one of the internet's oldest apps – from the days before we used the word "app" even – and despite its drawbacks, most of us still use it every day.

Typically, the apps we download in 2020 have been available for mere days or months. We are used to the pang of regret when really useful software suddenly winks out of existence. How has email remained a constant for nearly 50 years? Yes, it is helpful that email is based on an ancient communications medium that stretches back to some of the first examples of written language. But that isn't the full story.

First, email managed to survive massive upheavals in the way we use computers. In the early 1970s, when email was born, it was almost exclusively a tool for researchers, university students and engineers. You would send, receive and store your email on a work computer. With the rise of personal computers in the 1980s and 90s, email became something you kept on your own private machines or disks – almost like storing old letters in a shoebox. Now, we have come full circle. Most of us store our personal mail in the cloud, which is essentially like storing it on somebody else's work computer.

It is extremely rare to see apps make the leap from one platform to another like email did. They tend to die in the journey from web to mobile, or from one game system to another. Sure, there are Sega Dreamcast games that we can play on emulators, but that isn't the same. And don't even get me started on what happened to some of my favourite web animations when Flash went to the rainbow bridge.

As well as weathering dramatic tech changes, email dealt with another major hurdle: spam.

"In the age of cloud mail, it is rare to see quaint old subject lines touting 'V1@g*r$@!' to get around word filters"

MARIIA RESHETNIAK/GETTY IMAGES/ISTOCKPHOTO

In the 1990s and early 2000s, people's inboxes were clogged with so much junk that it was impossible to find the stuff you wanted. You had to install another program – a spam filter – just to use your email program. But in the age of cloud mail, anti-spam systems have become so good that it is rare to see one of those quaint old subject lines touting "V1@g*r$@!" or "pron" to get around word filters.

As anyone who has dealt with the bizarro world of social media knows, it is enormously difficult to filter out unwanted messages. Props to email providers for figuring out how to separate the ham from the spam. Indeed, this is another way email offers a lesson to app makers who want their wares to last more than a decade. Tech critic Sarah Jeong talks about this in her book *The Internet of Garbage*. She argues that spam filters can provide a model for how companies like Twitter and Facebook should deal with abuse, propaganda and all the other horrifying stuff that we never asked to see in our feeds.

And yet, despite its heroic triumph over tech obsolescence and spam, email isn't exactly alluring. We use it mostly for official correspondence, automated reminders (hello, doorbell!) and shopping receipts, along with the occasional bit of personal news. Though email communication is practically instantaneous, it feels slow. Why email when you could text?

Perhaps that is the point. Email isn't a brand-new way to socialise, nor is it juiced up with memes and hot takes. But we are still opening Gmail or Hotmail or Zaphodmail every day because it works and everybody has it. Under the hood, email uses a protocol that keeps trying to send data, over and over, hoping that it can outlast network problems. It doesn't give up. And somehow, by trying really earnestly, it has outlived the computers where it was born and the spammers who tried to defeat it. ▮

Introducing ATEM Mini

The compact television studio that lets you create training videos and live streams!

Blackmagic Design is a leader in video for the medical industry, and now you can create your own streaming videos with ATEM Mini. Simply connect up to 4 HDMI cameras, computers or even technical equipment. Then push the buttons on the panel to switch video sources just like a professional broadcaster! You can even add titles, picture in picture overlays and mix audio! Then live stream to Zoom, Skype or YouTube!

Create Training and Educational Videos

ATEM Mini's includes everything you need. All the buttons are positioned on the front panel so it's very easy to learn. There are 4 HDMI video inputs for connecting cameras and computers, plus a USB output that looks like a webcam so you can connect to Zoom or Skype. ATEM Software Control for Mac and PC is also included, which allows access to more advanced "broadcast" features!

Use Professional Video Effects

ATEM Mini is really a professional broadcast switcher used by television stations. This means it has professional effects such as a DVE for picture in picture effects commonly used for commentating over a computer slide show. There are titles for presenter names, wipe effects for transitioning between sources and a green screen keyer for replacing backgrounds with graphics!

Live Stream Training and Conferences

The ATEM Mini Pro model has a built in hardware streaming engine for live streaming via its ethernet connection. This means you can live stream to YouTube, Facebook and Twitch in much better quality and with perfectly smooth motion. You can even connect a hard disk or flash storage to the USB connection and record your stream for upload later!

Monitor all Video Inputs!

With so many cameras, computers and effects, things can get busy fast! The ATEM Mini Pro model features a "multiview" that lets you see all cameras, titles and program, plus streaming and recording status all on a single TV or monitor. There are even tally indicators to show when a camera is on air! Only ATEM Mini is a true professional television studio in a small compact design!

ATEM Mini.....**US$295***
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ATEM Mini for use in training, conferencing and teaching purposes only.

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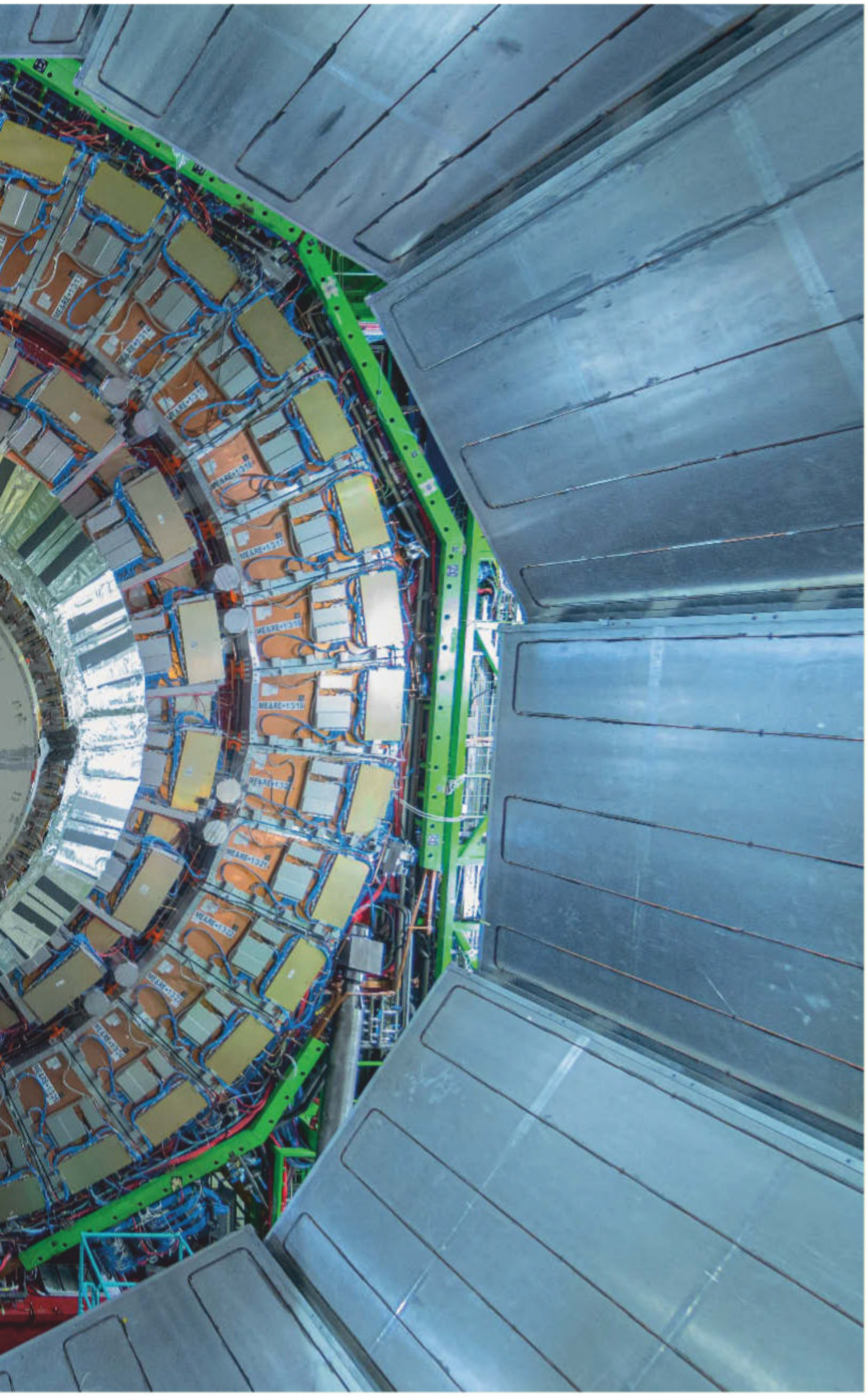


Hunting muons

Photographer Noemi Caraban Gonzalez/CERN

THIS amazing instrument may be the world's heaviest camera-like device. But instead of photons of light, it records something far more exotic: muons, produced by the collisions of billions of subatomic particles.

Weighing in at 14,000 tonnes, the Compact Muon Solenoid (CMS) detector is one of four big experiments at the Large Hadron Collider, based at the CERN particle physics laboratory near Geneva, Switzerland. The LHC is the most powerful particle accelerator in existence and can push protons close to the speed of light.

The CMS sits at one of the LHC's collision points, and it builds a picture of the particles produced when protons collide. It specialises in muons, negatively charged particles similar to electrons but more than 200 times heavier.

The solenoid magnet at its core bends charged particles, helping the CMS detect their charge and momentum. Muons are very shy of interacting with matter, so they pass undetected through most of the CMS. They are caught by components around the detector's edge, providing extra information that allows the complex particle interactions occurring as protons collide to be reconstructed.

One of the particles that these collisions produce is the Higgs boson, the particle that gives all other fundamental particles mass and which has a characteristic decay into four muons.

In September, CERN finished installing the CMS's outermost layer of muon detectors, letting it pick up muons that scatter at an angle of 10 degrees. CERN plans to add hundreds of new detectors to expand the range of muons it can detect.

Gege Li

Editor's pick

On balance, life on two legs is complicated

10 October, p 34

From Katherine Conroy, Manchester, UK

Caroline Williams highlighted the complex mechanisms involved in staying upright. As an ear, nose and throat doctor with experience in treating balance disorders, I do feel this subject is underappreciated.

In particular, I am aware of the link between balance and mental health Williams described, especially anxiety. I recall an audiologist demonstrating a moving platform posturography test to me, used to quantify balance. The subject is strapped into a box that tilts, and their centre of gravity is measured. The audiologist demonstrated that, upon tilting, a relaxed subject can adjust their centre of gravity much quicker than a tense one, greatly reducing the risk of falling.

In fact, this connection has been used by a team in Japan for a paper published in June suggesting that cognitive behavioural therapy can significantly improve chronic subjective dizziness symptoms in patients with anxiety conditions.

From Geoffrey Withington, Bridge, Kent, UK

I cured my problem with loss of balance by accident. Williams is correct on at least two counts: movement is the key and swimming doesn't help. During a period when I couldn't swim, I went back to jogging. Almost straight away, I experienced a feeling of euphoria when I stopped running and walked for a while.

This was a definite physical sensation. I could feel myself being in a state of perfect balance. I can only assume the constant pounding equalised some fluid or other in my ears. A friend had a similar experience.

From Rupert Fawdry, Leighton Buzzard, Bedfordshire, UK

In 1947, as a boy aged 6 on a slow voyage in a tiny cargo boat, moving our home from Cyprus to Aden, I was taught to go down stairs "navy fashion". Now a frail 80-year-old, as my balancing powers deteriorate, I would suggest that this advice significantly reduces my workload risk to the health service.

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

It has been realised that the main technique for balancing a bicycle consists of many micro adjustments of the steering. This is much easier when travelling quickly and almost impossible when going very slowly.

Might the equivalent process for correcting gait while on our feet be easier while running? If so, I think that humans originally "gorilla-knuckle-walked", but then learned to run before they "human-walked".

Don't forget the threat from false negatives

26 September, p 8

From Carmel McNaught, Melbourne, Australia

You highlighted the issues associated with false positives in coronavirus testing regimes. However, false negatives are a much scarier proposition. With a false negative result, infected people can merrily go out into the community spreading the virus. They would believe they are safe and possibly relax mask wearing, social distancing and other protective measures.

Could 'innocent' Venusian slime wipe out life here?

Letters, 10 October

From Enzo Casagrande, Rogerstone, Monmouthshire, UK

Yannis Gourtsoyannis and Anjaneya Bapat rightly point out the risk of bringing potential pathogens back from Venus. If these organisms, supposing they exist, are harmless in the disease sense there could still be a danger.

Having evolved independently on Venus, it is highly probable they would have very different chemistry to life on Earth. Should these organisms find conditions here to their liking, they might reproduce unhindered. Imagine, for instance, a thin film of Venusian slime innocently covering everything and slowly smothering all life on Earth.

In the search for ET, the silence says it all

3 October, p 36

From Eric Wynter, Taunton, Somerset, UK

Complex life couldn't arise anywhere without an equivalent to the "mitochondrial event", the symbiosis between an early single-celled eukaryote and a bacterium to create a more sophisticated organism, as Dan Falk suggests in his look at the chance of finding intelligent life beyond Earth. If Venus has life, this will suggest alien life is more common than we dared to hope. But the lack of signals from advanced civilisations implies complexity, and certainly sentience, are much rarer. It may indeed be a long search for ET.

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

The evolution of mitochondria is the obvious chief example of symbiosis in the rise of more complex life, but it isn't the only one. Such events aren't of "mind-boggling improbability".

Evolutionary theorist Lynn Margulis proposed that cilia and flagella arose from organisms taking thin spirochaete bacteria on board as endosymbionts. That is controversial, but the origin of chloroplasts as endosymbionts isn't, and that seems to have happened at least three times.

Without wildlife, the future may be like this

Letters, 10 October

From Ametrine Lavender, Hebden Bridge, West Yorkshire, UK

Geoff Harding suggests that plummeting wildlife populations may mean humans having to deliberately take on some of their functions, like artificial fertilisation of plant species.

This brought to mind Maja Lunde's book *The History of Bees*, which is set against a fictional past, near present and future for bees and humans. The future story line, set in China in 2098, is about workers whose job, from around the age of 8, is to hand pollinate trees, since bees have died out.

Maybe nuclear isn't so bad after all

10 October, p 14

From Philip Belben, Radstock, Somerset, UK

You report work showing improvement in greenhouse gas emissions in countries embracing renewables, but not nuclear-powered nations. However, it could simply be that in the latter, the improvement had already taken place. Renewables are fairly new. Nuclear, by contrast, is a fair bit older. Countries with it have mostly had it for decades.

For the record

The image with our "Doctor's diary" article (10 October, p 10) showed people queuing for flu vaccines at Hamstreet surgery in Kent, UK, prior to the coronavirus pandemic – hence the absence of face masks and social distancing.

Video game *Wasteland 3*, which we reviewed (10 October, p 32), doesn't feature aliens, unlike *XCOM*. Both have turn-based combat, though.

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, 25 Bedford Street, London WC2E 9ES will be delayed

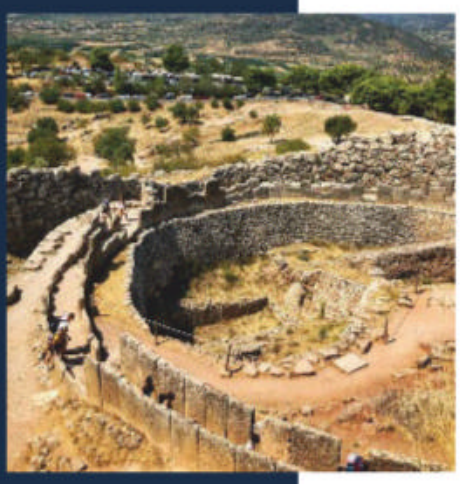
New Scientist Discovery Tours

Thinking about exploring the world again?

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

Whether you're ready to book or just want to carry on dreaming for a little longer, we hope you enjoy browsing some of the new tours we've created for 2021.

Visit newscientist.com/tours for detailed itineraries and how to book



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Big data's first election victory

During the cold war, big data was secretly used to help elect President Kennedy, finds **Vijaysree Venkatraman**. Now it is used to rig elections via social media

Books

If Then: How the Simulmatics Corporation invented the future
Jill Lepore
W. W. Norton

The Hype Machine: How social media disrupts our elections, our economy, and our health – and how we must adapt
Sinan Aral
Penguin Random House

IN SEPTEMBER 2016, Alexander Nix, CEO of Cambridge Analytica, told an audience in New York about the power of big data in global elections. Know the personality of the people you target, and "you can nuance your messaging to resonate more effectively" with them, he said.

That London-based political consultancy was behind the Brexit Leave campaign. And it offered the Trump team a model to predict the personality of individual voters in the 2016 US election.

Another shiny product of 21st-century data science? No. As early as 1960, a US firm used prediction analytics to help elect a president. In *If Then*, Harvard historian Jill Lepore tells that riveting story.

In 1959, Simulmatics was set up in New York. It was to lay the foundations of a world in which algorithms attempt to forecast and influence our every move by simulating our very selves.

Simulmatics founder Ed Greenfield brought in behavioural scientists, technologists, pollsters and statisticians. The idea: collect enough data on enough people, feed it into a machine and everything will be predictable. Minds will be simulated, acts anticipated, and even driven, by targeted messages.

STAN WAYMAN/THE LIFE PICTURE COLLECTION VIA GETTY IMAGES

John F. Kennedy campaigning in Mayville, Wisconsin, in March 1960

The scientists compiled data from election returns and public opinion surveys going back to 1952. Then they built a computer simulation of the 1960 election on which to test scenarios about an endlessly customisable population. Using the if/then formula of computer language Fortran, they could model any move a candidate might make and track voter response down to the tiniest segment of the electorate.

Dubbed the "People Machine", this simulation predicted that to win, John F. Kennedy needed the black vote. He took a strong position on civil rights. It also advised him to confront religious prejudice and win minority support by being upfront about his own Catholicism.

Today, Kennedy's victory might look like a forgone conclusion, but his telegenic personality and charisma alone didn't carry the race. His team denied getting help from any "electronic brain", but Simulmatics's reports are in the archives at the John F. Kennedy Presidential Library and Museum, Lepore writes.

After the elections, Simulmatics took on new projects, but was limited by 1960s technology. In 1970, it declared bankruptcy. It lives on in science fiction novel *Simulacron-3* and film adaptation *World on a Wire,* itself a forerunner of 1999 cult classic *The Matrix*.

By the 21st century, information about individuals was abundant, accessible and easier to process with faster computers. Social media connected millions, then billions – all exchanging messages guided by algorithms designed to inform, entertain and manipulate.

Its sheer power helped those early dreams to grow and prosper in unimaginable ways. In *The Hype Machine,* Sinan Aral at the Massachusetts Institute of Technology examines the science behind this disruptive power. He outlines his own research into Twitter, which has shown how fake news penetrates further and faster than accurate information. The more shocking, salacious and emotionally arousing (especially fake political news), the more we are moved to spread it.

"Fake news penetrates further and faster than accurate information on Twitter"

In 2014, Russia's Internet Research Agency set up accounts on platforms including Facebook and Twitter to sway US voters with fake news. This was "one of the most comprehensive weaponizations of misinformation the world has ever seen", says Aral.

But it still had to target the right misinformation at the right voters. Cambridge Analytica's model, built using Facebook data, helped to predict voter personality. Russian fake news

targeted voters in swing states with customised messages. Supporters of Black Lives Matter, for example, saw memes that encouraged them not to vote, while other messaging persuaded right-leaning voters to turn out.

Did Russian interference really flip the US election against Hillary Clinton in 2016? We need more research, says Aral. As for the upcoming 2020 US election, last month, Facebook took down a small network of fake accounts linked to Russian operatives. This was no surprise. Intelligence officials had warned that Russia has adopted less detectable tactics. And Facebook founder Mark Zuckerberg's recent blog on the company's election-related policies has left Aral thinking the company has not done enough to make the 2020 elections safe.

To stave off the threat of digital manipulation, we need to understand it and legislate to neutralise it, writes Aral. The US lacks even a basic federal law to protect consumer data. The question of how to maintain privacy while feeding more data to machines emerged in the 1960s with the People Machine, but a big opportunity to do something was missed, says Lepore.

If Then and *The Hype Machine* are both eminently relevant now. Lepore's page-turner about a forgotten chapter of US history resonates today, and Aral's nuanced, slower read offers hope that we can re-engineer social media to better serve society.

The books' biggest service, however, is to make us rethink our attitudes to big data and social media. This can only be good: after all, it is still humans who cast the votes, not machines. ▮

Vijaysree Venkatraman is a science journalist based in Boston

Hunting Pepe?

The real story of super-meme Pepe the Frog makes a surprising new film, finds **Elle Hunt**

Documentary

Feels Good Man

Arthur Jones

Ready Fictions, streaming; BBC 4 Storyville, 26 October

OVER 25 years of the internet, memes have evolved from a one-note online sight gag – a dancing baby, say, or a cat with an irreverent caption in Impact font – to a muscular means of communication, capable of nuance and complex irony.

Yet no meme has had as strange and storied a journey as Pepe the Frog. The laid-back amphibian from cartoonist Matt Furie's cult hit *Boy's Club* was wrested from that context to become the face of anarchic bulletin board 4chan. The beatific Pepe of Furie's comic, with his catchphrase "Feels good, man", became sorrowful ("Feels bad, man") and then, unexpectedly, fascist.

***Feels Good Man*, Arthur Jones's debut documentary, follows Pepe from the web to Donald Trump's White House as a smirking alt-right symbol, and Furie's battle to reclaim him.**

As 4chan's meme culture spilled over into the mainstream internet, with pop stars Katy Perry and Nicki Minaj sharing Pepe memes, the community set out to ward off appropriation by "normies" by making Pepe as shocking as possible.

During the contentious 2016 US elections, Pepe became so associated with racism, anti-Semitism and other forms of bigotry that both Hillary Clinton and the Anti-Defamation League defined him as a hate symbol – much to 4chan's glee at being taken so literally.

Yet in among the juvenile provocation (4chan's founder was a 15-year-old boy), there was a strand of sincerity. Pepe, like Trump, was being embraced by a fringe but growing far-right movement that masked its intent with irony online.

Furie's attempt to capitalise on his creation's ubiquity came too late: there is a scene in *Feels Good Man* where he looks over thousands of dollars' worth of Pepe merchandise that can't even be donated, lest it end up with white nationalists.

At the film's heart is Furie's relationship to his creation as it is repurposed as a hate symbol, collectible art, occultist iconography and even as a cryptocurrency by an implacable internet. Against that, Furie stands as a quirky, quietly principled figure, resolutely trying to "save Pepe". However, as the film's coda reveals, the frog's emergence at Hong Kong's pro-democracy protests last year shows the hunt for its meaning continues. ▮

Elle Hunt is a freelance writer based in London

FEELS GOOD MAN

Pepe the Frog has had many incarnations, from beatific to fascistic

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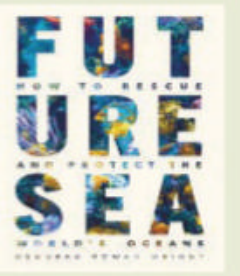
Science Friday, a weekly talk show and podcast from US public radio stations, offers 2 hours of essential listening about science, nature, medicine and technology. It also broadcasts live from the Ig Nobel awards.



Read

Future Sea sets out marine policy researcher Deborah Rowan-Wright's ideas about how to end destructive industrial activities at sea and enable ocean wildlife to return and thrive. Luckily, she includes steps that anyone, from children to political leaders, can take.

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The War on Wildlife is a new podcast featuring birdwatcher Charlie Moores and conservation film-maker Ruth Peacey. Episode 1 follows the start of the UK shooting season and the release of 50 million pheasants and partridges.

The film column

What memories are not made of *Black Box* is an intelligent, intriguing and melancholy science fiction film that plays with identity, fate and death, as the survivor of a car wreck with no memory must take extreme steps to get his life back, says **Simon Ings**

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

COURTESY OF AMAZON STUDIOS

Nolan (Mamoudou Athie) turns to Lillian (Phylicia Rashad) for help

NOLAN is trying to put his life back together after a car accident robbed him of his wife and his memory. His daughter Ava has to steer him about, though she is barely old enough for school. She encourages him to reapply for his old job. She sets the satnav for the supermarket. Three times now, Nolan (Mamoudou Athie) has forgotten to pick Ava (Amanda Christine) up from school. It is more than possible that he sometimes forgets her existence altogether. Child services hover.

In desperation, Nolan signs up for an experimental procedure promising to put him back in touch with his memories. It is a device – the "black box" of the title – comprising a VR headset, a computer that looks (and, given the budget, probably is) 20 years old and blarney. The rubric is so arbitrary and playful (in your subconscious you'll find a safe room; in the room, you'll find a watch; press the crown to play a memory; wind forward to move onto the next), I wondered about that name: Nolan.

Is *Black Box* an homage to Christopher Nolan's *Inception*?

That I had time for such idle musings tells you what is wrong with this movie. It is wordy. It explains itself far too much. Unlike Christopher Nolan, first-time feature director Emmanuel Osei-Kuffour is altogether too hung up on being understood.

"Should our current circumstances define us? Should memories ever matter more than our current reality?"

Nor (if I am right about the nod to *Inception*) is it fair to expect much by way of homage. Nolan's last budget, for *Tenet*, ran to $205 million. Osei-Kuffour's didn't. He is the latest director making films for Blumhouse Productions, a company that gives small amounts of money to young directors, along with artistic control, and hopes for the best.

A shaky sounding proposition, for sure. Yet *Paranormal Activity*, a 2007 movie from Blumhouse, was made for $15,000 and has earned nearly $200 million.

Black Box is unlikely to perform such feats in these covid-19 times. But Amazon Prime's latest sci-fi streamer is still a sincere and watchable piece of work about identity, fate and death.

Nolan's trouble is that he flatlined after the accident, and no matter how miraculous his recovery, no matter how hard he tries, he can't seem to bring his life back to life. Even when he starts having genuine memories of his own, they are the wrong ones.

Even more terrifying is Lillian, the clinician running the "black box" experiment. Anyone who associates actor Phylicia Rashad primarily with her role on *The Cosby Show* is in for a shock.

All that said, *Black Box* is out to make audiences think more than squeal. Should our current circumstances define us? Should our memories ever matter more than our current reality? And what might we owe people who remember us better than we remember ourselves?

Athie delivers a wonderfully affecting performance as Nolan, especially around Ava, the little girl he can't accept as his. As Nolan's "wrong" memories begin to kick in, Athie has some subtle fun playing multiple personalities.

Film-maker David Cronenberg once said that his favourite actors were the ones he could see were actually thinking. Athie is one of these. And *Black Box*, were it not quite so safe, might bear comparison to an early Cronenberg outing. As well as genuine melancholy, there is an intelligence to the film, and a puzzle worth unpicking. Osei-Kuffour is a director to watch. ▮

Film

Black Box
Emmanuel Osei-Kuffour
Amazon Prime

Simon also recommends...

Films

Brainstorm
Douglas Trumbull
"The door to the mind is open" screamed the poster for this technologically prescient 1983 sci-fi shocker about the relationship between VR and death. The mind in question is played by the peerless Christopher Walken, so buckle up...

Seconds
John Frankenheimer
An unhappy middle-aged banker buys a false identity and a gorgeous new body (Rock Hudson's, in fact) in a paranoid masterpiece about missed life chances and medical false promises.

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The great viral team-up

Viruses are no lone wolves. They have social lives and work together in ways we ignore at our peril, finds **Graham Lawton**

IF YOUR social life has suffered during the coronavirus pandemic, you may not want to know that the virus has a social life too. And it is probably better than yours right now.

It may seem odd to say that viruses fraternise when they arguably aren't even alive, but virologists are discovering just how rich this aspect of their existence is. Far from being lone operators, viruses cooperate and compete with one another; they can be altruists, freeloaders or cheats. These discoveries are rewriting the virus rule book and suggesting novel ways to tackle viral diseases, and that includes the newest one, covid-19, caused by SARS-CoV-2. Understanding these complex and sometimes strange interactions could be the key to getting our own lives back to normal.

The classical view of a viral infection doesn't create much opportunity for social interaction. A single virus particle, or virion, encounters a target cell and breaks and enters. Once inside, it disassembles like a cat burglar unpacking tools and then executes its potentially deadly genetic program.

This program is designed to do one thing: build an army of virus clones to move on to the next victim. To this end, the virus requisitions the cell's protein and genome production facilities, churning out millions of copies of its constituent parts. These viral genomes and proteins assemble into virus particles and, once they reach a critical mass, disgorge out of the host cell, killing it in the process. The infection cycle then begins anew.

This view isn't wrong, but is vastly simplified. Viral attacks are rarely solo missions. "The virion has been traditionally viewed as the minimal viral infectious unit," says Rafael Sanjuán at the University of Valencia in Spain. "However, single virions often fail to establish productive infections."

In truth, virions usually hunt in packs, and can infect cells en masse, alongside other species of virus. And this creates hitherto underappreciated opportunities for virus-virus interactions. The microbiologists who study such interactions in the new field of sociovirology say they can be understood using the same concepts developed to describe those between animals, plants and, more recently, bacteria.

Social evolution theory, which seeks to explain these interactions, grew out of attempts to incorporate complex animal behaviours such as cooperation and competition into evolutionary theory. One especially thorny problem was altruism, such as cooperative breeding systems, in which some individuals forgo the opportunity to reproduce in order to help rear others' offspring. Why make such a costly sacrifice? The answer turned out to be self-interest. Individuals will make sacrifices, but only for close relatives, and hence help to usher genes that are effectively their own into the next generation. As the great evolutionary biologist J. B. S. Haldane put it: "I would lay down my life for two brothers or eight cousins." This is known as kin selection.

Classical virologists did have some inkling that viruses interact with one another. They knew, for example, about superinfection exclusion: how, once a cell has been infected, other viruses are often blocked from entering it. But most weren't schooled in social evolution and were unaware that there were ready-made concepts to explain such things. And in any case, the "single infectious virion" dogma didn't require much in the way of social skills. True, the infected cell would end up full of viruses, but as they were all clones of the original invader there was little opportunity for complex relations to arise. ›

RONALD KURNIAWAN

Recent discoveries have changed all that. Around 20 years ago, social evolution was extended to bacteria, which made microbiologists more aware of it. Then it became apparent that viruses, too, were subject to its rules.

"An important realisation was that superinfection exclusion is a fundamentally social trait," says Samuel Díaz-Muñoz, an evolutionary virologist at the University of California, Davis. "That is because the virus has had to evolve a way to contend with other viruses around it."

And contending with other viruses turned out to go way beyond shutting them out. For example, even when a host organism is infected by a single virus, it can end up harbouring a vast array of different viral genomes. Viruses have very high mutation rates; those with genetic material made from RNA have the highest error rate of any known biological entity. Newly minted genomes aren't always proofread and mutations in their genetic code can accumulate at an alarmingly high rate. A single host organism can thus harbour thousands of different variants of the "same" virus, creating ample opportunities for competition and cooperation between them to evolve.

Another key discovery was that viruses often get together to hunt. They form a variety of "collective infectious units", which can be as simple as an aggregation of identical viruses, or as complex as a bubble-like vesicle crammed full of many virions of two or more unrelated viruses. Viruses interact within the unit, and can also coinfect the same cell, again setting up the conditions for complex interactions. These coinfections turn out to be extremely common. "Coinfection is the default condition of humans," says Díaz-Muñoz. "We always have several viruses in our cells."

A lot of the early work on sociovirology was done with a class of viruses called bacteriophages, or phages for short. These look a bit like minuscule planetary landing craft that alight on the surface of bacteria and inject their genetic material into them. The doomed bacterium then becomes a phage production plant.

Phages were once seen as the quintessential solo assassins. But in 1999, colleagues of Sanjuán in Valencia made a surprise discovery about a phage called phi 6, which is among the most extensively studied viruses on Earth. They found that if bacteria were simultaneously infected with two slightly different genetic variants, the infection was initially more successful, but becomes less so over time. Exactly why wasn't clear, but the researchers realised that the decline in fitness could be described using a mathematical approach called game theory to explain interactions, specifically a classic thought experiment known as the prisoners' dilemma.

"Cooperation has been seen in many viruses, including flu, measles and hepatitis B"

In this scenario, two partners in crime are

told that if they alone confess and snitch on the other, they will get a shortish sentence and their partner a long one. If they both confess and snitch, they will both get intermediate sentences. If they both stay shtum, they will both get an even shorter sentence. The best collective outcome is to say nothing, but neither can risk it in case their partner snitches. So they both confess and produce a less-than-optimal outcome. The phages appeared to be playing a version of this game. They initially kept quiet, but then one discovered the benefits of snitching and the other followed suit. In other words, they were interacting (anti)socially.

In another key discovery, phages infecting a bacterial colony were discovered to be sending molecular messages out of the cells they were in. When there were more viruses, the levels of signalling molecules increased and this communicated the overall level of infection, and hence whether it was time to burst out or lay low for a while. This is the phage equivalent of quorum sensing, a common cooperation strategy in bacteria.

Focus soon moved from phages to the viruses that infect mammals, including humans. One of the earliest discoveries that these viruses also cooperate came in 2005. Marco Vignuzzi, then at the University of California, San Francisco, engineered poliovirus – an RNA virus with a very high mutation rate – to replicate its genome with greater precision. He found that this "improved" virus was actually much worse at infecting cells. Exactly what was going on wasn't clear, but Vignuzzi proposed that poliovirus mutants somehow worked together to boost collective success.

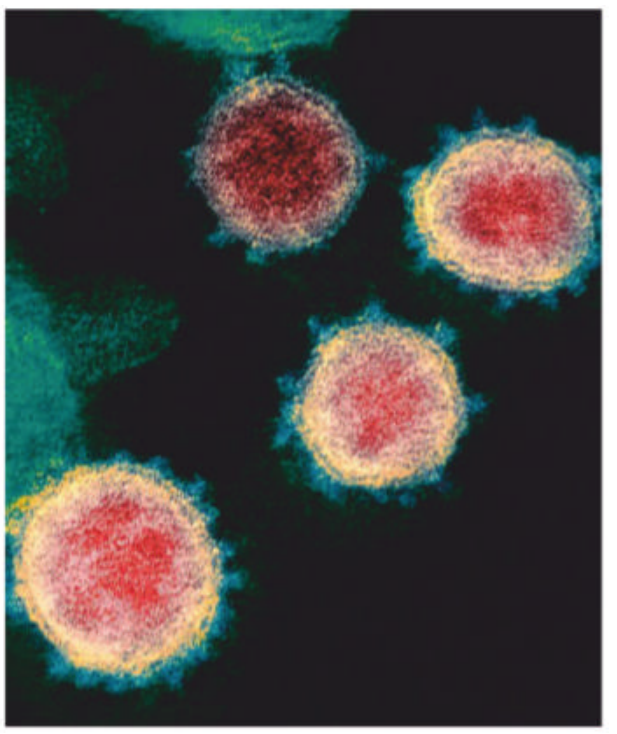
Of course, "working together" doesn't imply intentionality, says Asher Leeks, a sociovirologist at the University of Oxford. It just so happens that swarms of mutants are better at passing on their genes, so this has been selected for by evolution.

Since then, cooperation has been documented in many other viruses, including measles, flu and hepatitis B. In 2016, a team at the University of Washington in Seattle found that an H3N2 influenza virus was more successful when two genetic variants coinfected the same cell. One variant is highly efficient at entering cells, the other is efficient at exiting. Neither is very successful on its own, but when they work together they are dynamite.

Further work has also suggested other ways viruses cooperate. Mutants might produce slightly different versions of a viral protein, some of which are slightly more successful under certain circumstances. It is unlikely that a single virus will acquire all of these beneficial mutations, but no matter. Viral proteins and genomes mingle inside the cell and become "public goods", another key concept from social evolution theory. By dipping into this pooled resource, a perfectly adapted virus will probably assemble and lead the charge out of the host cell.

Viruses have even been observed performing the ultimate social interaction: altruism. The hepatitis C virus, for example, maintains an army of mutants, some of which strongly attract the attention of the immune system and allow others to fly under the radar. These decoy mutants aren't successful individually, but they evolved to take one for the team.

Last year, Sanjuán's team discovered another form of viral altruism. It showed that an RNA virus called VSV, or vesicular stomatitis virus, can suppress the immune system of its host – usually a horse, cow or pig, but occasionally a human – by producing a molecule that inhibits antiviral interferons, substances released by cells that alert neighbours to viral attack. Engaging in this sort of chemical warfare is an expensive investment for the virus and it has a detrimental effect on its reproductive fitness early on in an infection, but it paves the way for future success by keeping nearby cells susceptible.



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There are signs that the SARS-CoV-2 virus forms collective units to infect us

Farewell freeloaders

The team then introduced a mutant VSV that doesn't suppress interferon, and can therefore freeload on viruses that do. As expected, this mutant took advantage and outcompeted the non-mutant, but its cheating eventually caught up with it and it was nailed by the interferon system. Over the longer term, viruses that made the initial sacrifice are much more successful than the freeloaders.

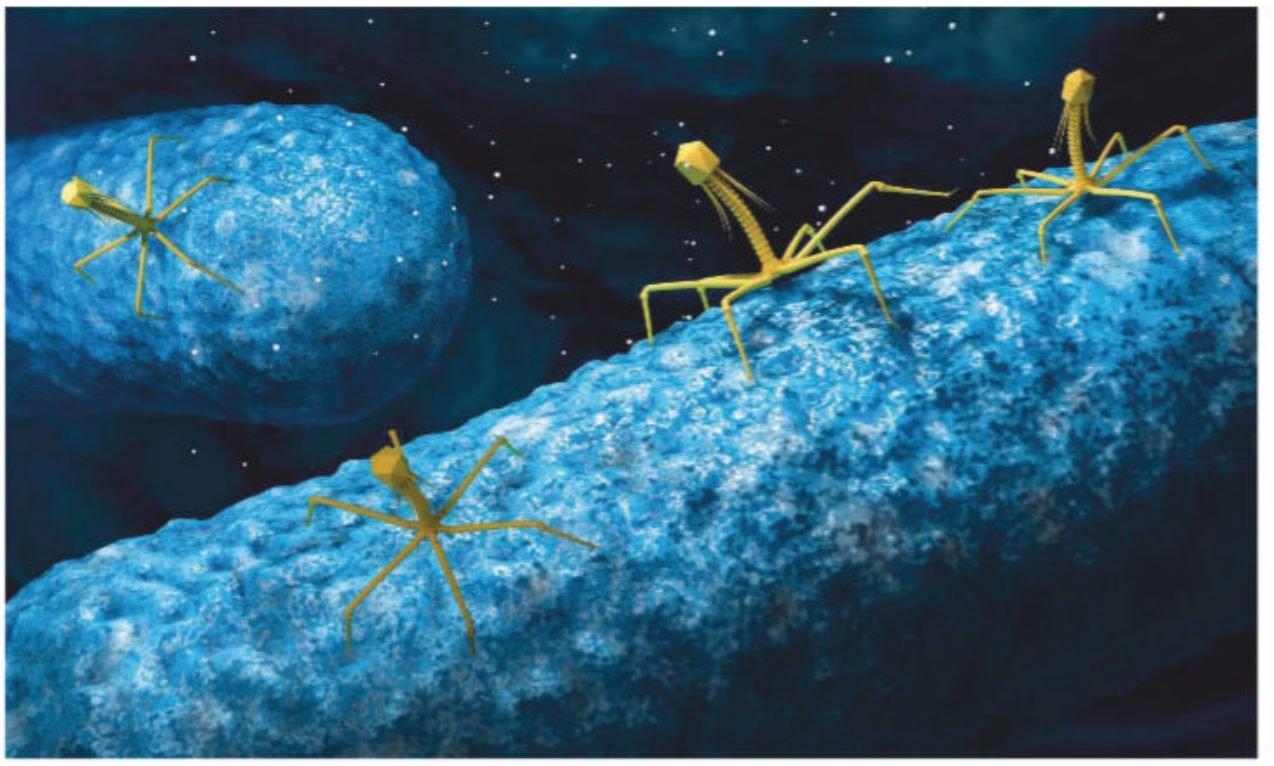
If at this point you are thinking, "OMG, they're ganging up on us", here is some comforting news. Social interactions can also be a real drag for viruses.

The creation of public goods opens the door to cheating or freeloading. As we have seen, this can be overridden by altruism, but that is a rare exception. More often than not, viruses fall victim to the classic "tragedy of the commons", where everyone hoovers up public goods as fast as possible until they are all gone and everybody loses.

In a cell that is coinfected with two unrelated viruses, for example, both types may compete for a genome-replicating enzyme produced by one of them. Selection pressure will then favour freeloader genomes that can utilise the enzyme, but don't make any themselves, at which point there isn't enough to go around and the infection can grind to a halt.

Freeloader genomes are a major problem for viruses, especially RNA ones. "Cheating is common in the viral world," says Leeks.

RNA viruses are such sloppy copiers of their genomes that they churn out all sorts of useless junk – half-finished ones, ones with ›



CHRISTOPH BURGSTEDT/ALAMY

Phage viruses are like mini planetary landing craft alighting on bacteria

crucial bits missing or mere fragments. These are known as defective interfering genomes (DIGs), and for good reason. They consume public goods such as enzymes without contributing any themselves, and even though they are assembled into virions and are ejected from the host cell in search of pastures new, they can't establish an infection on their own.

Being significantly shorter than complete genomes, defective interfering genomes are copied at much higher rates – up to 80 times faster, says Leeks. That means they hog the replication enzymes and end up vastly outnumbering complete viruses.

At this point the virus is itself being parasitised, to the extent that – in tissue culture at least – an infection can spontaneously fizzle out. This is such a problem for viruses in general that virologists are attempting to exploit it as an anti-virus strategy. "If we can engineer or isolate defective interfering genomes, maybe they would be an effective therapy," says Díaz-Muñoz.

So, what of SARS-CoV-2? For now, its social life remains largely unexplored as virologists focus on more pressing questions.

From what we know about coronaviruses, it seems likely that important social interactions are occurring, with possible consequences for the future of the pandemic. "I have no doubt that there will be sociovirological aspects," says Díaz-Muñoz.

For starters, SARS-CoV-2 is an RNA virus, which raises the spectre of a hyperfast mutation rate. But fortunately, it is a very unusual RNA virus, which proofreads new copies of its genome, so doesn't generate swarms of mutants. "The genome is exceptionally stable for an RNA virus," says Díaz-Muñoz.

Nonetheless, it still generates oodles of defective genomes. That is because the enzyme it uses to replicate its genome is highly promiscuous and frequently jumps from one part of the RNA template to another, so produces multiple incomplete fragments. It isn't yet known whether these are interfering genomes that cheat and hog public goods, but if they do, it offers a new target for drug development via artificial DIGs. The group in Valencia recently began research into this possibility.

"We can be infected with SARS-CoV-2 and viruses that cause colds at the same time"

There are also signs that SARS-CoV-2 forms collective units, and that it takes more than a single virus to sicken a human. The current estimate of the number of viruses required – called the infectious dose – is quite imprecise, ranging from tens to tens of thousands. A clearer understanding of this could help us to stay out of harm's way. "The infectious dose is one of the most critical pieces of data that we don't have that could inform public health," says Díaz-Muñoz.

There is also good evidence for coinfection. "We know that humans can have SARS-CoV-2 and other viruses – basically all your suspects for the common cold," says Díaz-Muñoz. That includes rhinoviruses, influenza viruses, parainfluenza viruses, respiratory syncytial virus and four other coronaviruses in general circulation.

The effect of SARS-CoV-2 coinfection in the human body isn't yet known, says Díaz-Muñoz. It may be why different people react so differently to the virus, from being asymptomatic to dying from it and a range of outcomes in between.

But coinfection does open the door to more danger. Because the enzyme that makes copies of the viral genome has a tendency to jump about mid-task, it can stitch together genomes from two different coronaviruses that coinfect the same cell. This is probably what gave rise to SARS-CoV-2 in the first place, says Díaz-Muñoz: a mash-up of two different bat coronaviruses. And it could happen again, in a person coinfected with SARS-CoV-2 and common cold coronaviruses.

It sounds scary; yet another new coronavirus to contend with. But in fact a hybrid might be less virulent than SARS-CoV-2 and could ultimately outcompete it.

"There's a tendency to think that any new mutation leads to catastrophe," says Díaz-Muñoz. "But 'we're all going to die' is from the movies. It may actually confer a more mild progression of the disease, and that may be evolutionarily advantageous to SARS-CoV-2. It could spread more easily and go on to infect huge proportions of the human population."

That would be a huge improvement to the virus's social life – and ours. ▮

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

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The problem with risk

Coping with the covid-19 pandemic requires us to constantly calculate risk – both personally and across societies. That doesn't come easy to most of us, finds **Dan Jones**

THE covid-19 pandemic recently passed the milestone of a million deaths, and infections continue to rise. For months to come, perhaps years, we will have to keep a balance between minimising the deaths and harms caused by the coronavirus and carrying on with life to maintain our economic livelihoods and mental well-being.

"Getting through this pandemic is essentially an exercise in risk management," says Allison Schrager, an economist at the Manhattan Institute in New York. To do this well, we have to rely on the information we get from public health experts, the media and governments. We want to know how dangerous the virus is to us, and to friends or loved ones made perhaps more vulnerable by age or other factors. We want to know the risks stemming from the current surge in infection rates, so we understand whether measures such as renewed lockdowns are proportionate.

Risk communication is a tricky business even at the best of times, but in many countries, the covid-19 pandemic has brought a deluge of scary-sounding statistics and graphs about infection rates and rising death tolls. David Spiegelhalter, chair of the Winton Centre for Risk and Evidence Communication at the University of Cambridge, has called it "number theatre".

So how do we take the drama out of the theatre and come to a measured assessment of the uncertainties we face? There are no easy answers, but by understanding how our brains deal with risk and the pitfalls in the way numbers concerning risk are often presented to us, we can go some way to easing the mental burden – through the pandemic and beyond.

Despite nearly non-stop media coverage since the start of the year, the covid-19 pandemic remains an unfamiliar threat for most of us. This is where the difficulties with assessing its risks start. "We're comfortable with risks we take every day, but new and dramatic ones throw us," says Schrager.

That's especially true when single events cause harm to lots of people in a short period, like plane crashes, terrorist attacks and natural disasters. Images of such events fire up parts of the brain evolved to evaluate risk and make us take notice. "One region, the amygdala, responds to the degree to which things are risky, while the ventromedial prefrontal cortex allows us to weigh the costs and benefits of different options so that we can decide what, on balance, is the best thing to do," says Joseph Kable, a neuroscientist at the University of Pennsylvania.

The trouble is that these evolved responses can cloud rational thinking when threats are new and dramatic. Risk researcher Gerd Gigerenzer at the University of Potsdam, Germany, calls these threats with an emotional impact that skews how dangerous we think they are "dread risks". "Even though they cause fewer deaths than risks we happily live with, dread risks capture the attention of the media, stoke anxiety in us and make us fear some things excessively," he says.

"The emotional impact skews how dangerous 'dread risks' seem to us"

That fear can change our behaviour in ways that actually increase our risk of injury or death. In 2004, Gigerenzer infamously found that after the 9/11 attacks, when lots of people were terrified of flying, many took the more dangerous option of driving. "As a result, an estimated extra 1600 Americans lost their lives on the roads," he says.

Similarly, people now are avoiding visits to hospitals because they are so scared of getting covid-19. According to the World Stroke Organization, in the first months of the pandemic, across 100 countries studied, hospital admissions for stroke symptoms dropped by an average of 60 per cent compared with the same period in 2019. There were similar declines for heart attack admissions in the US and UK. One study in England and Wales found that, between March and the end of June, missing out on essential care led to 2085 more deaths from heart disease and stroke than would be expected normally, or 17 extra deaths a day.

The dread risk of covid-19 differs from events like 9/11 because it is primarily driven by numbers, rather than visceral images. Images of people suffering or dying from the virus have been conspicuous in their ›

ANDREA DE SANTIS

1 in 106

Lifetime risk of dying in a motor vehicle crash in the US

Source: National Safety Council

1 in 9821

Lifetime risk of dying in an air or space transport accident in the US

Source: National Safety Council

10x

The risk of passing on the coronavirus inside a home is 10 times higher than that of passing it on in hospital, and 100 times higher than infecting others on public transport

Source: School of Public Health, Southern Medical University, China

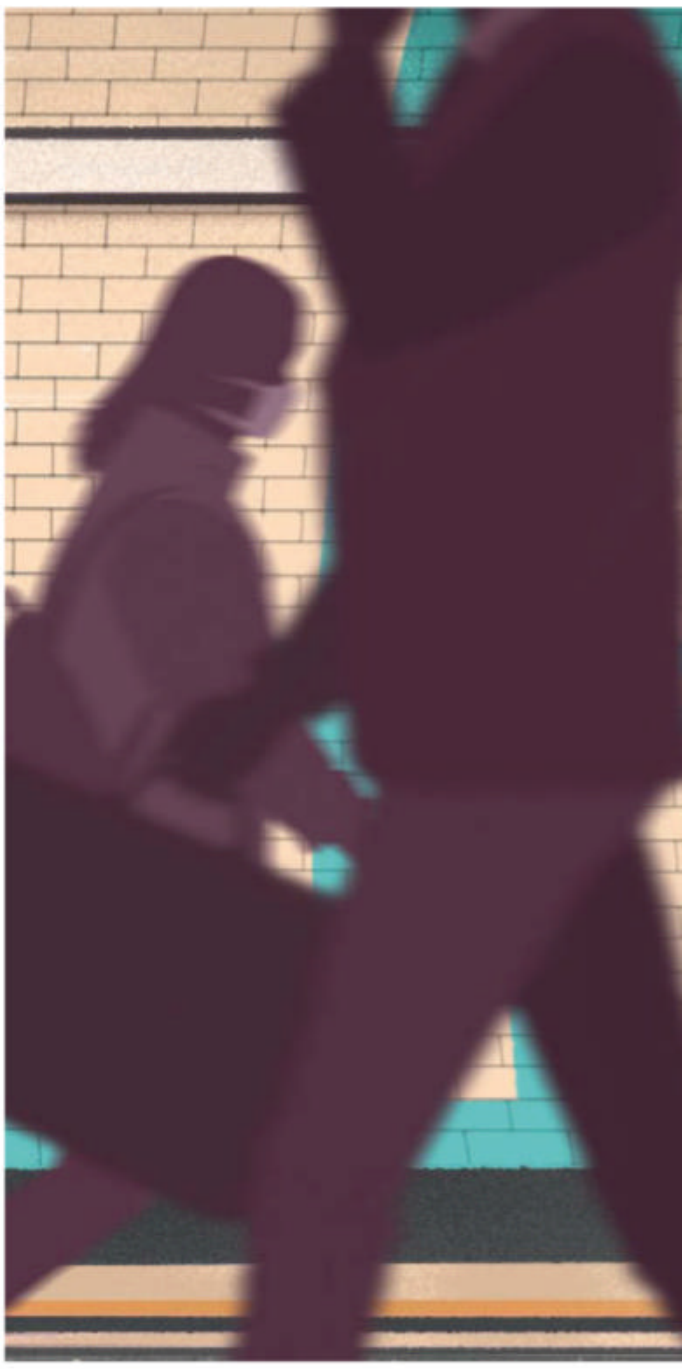
absence, because of the need to isolate patients. But numbers alone can be sufficient to induce dread, particularly when we don't have a firm handle on what they really mean.

That points to a second problem beyond our evolved fear responses that makes risk assessment tricky. "Most people have no training in statistical thinking," says Gigerenzer. Even numbers associated with everyday risks can throw us. What does a weather forecast telling us there is, say, a 30 per cent chance of rain tomorrow signify? "Some think it means it will rain 30 per cent of the time, others that it will rain in 30 per cent of the region the forecasts covers, and still others that three out of 10 meteorologists would predict rain," says Gigerenzer – not what it actually means, that there is a 30 per cent chance of there being any rain at all.

That's a relatively harmless example, but similar ambiguities or missing context can mislead us with health risks too. For instance, when in the mid-1990s the UK Committee on Safety of Medicines warned that some contraceptive pills doubled the risk of potentially deadly blood clots, or thrombosis, that prompted many women to stop taking them. A spate of unwanted pregnancies led to an extra 13,000 abortions the following year.

The thrombosis risk sounded alarming, but in absolute terms it meant that 2 in 7000 women who took a third-generation contraceptive pill experienced thrombosis, compared with 1 in 7000 for women on the second-generation pill. The initial risk was low and so the relative doubling of risk meant the absolute risk was also low.

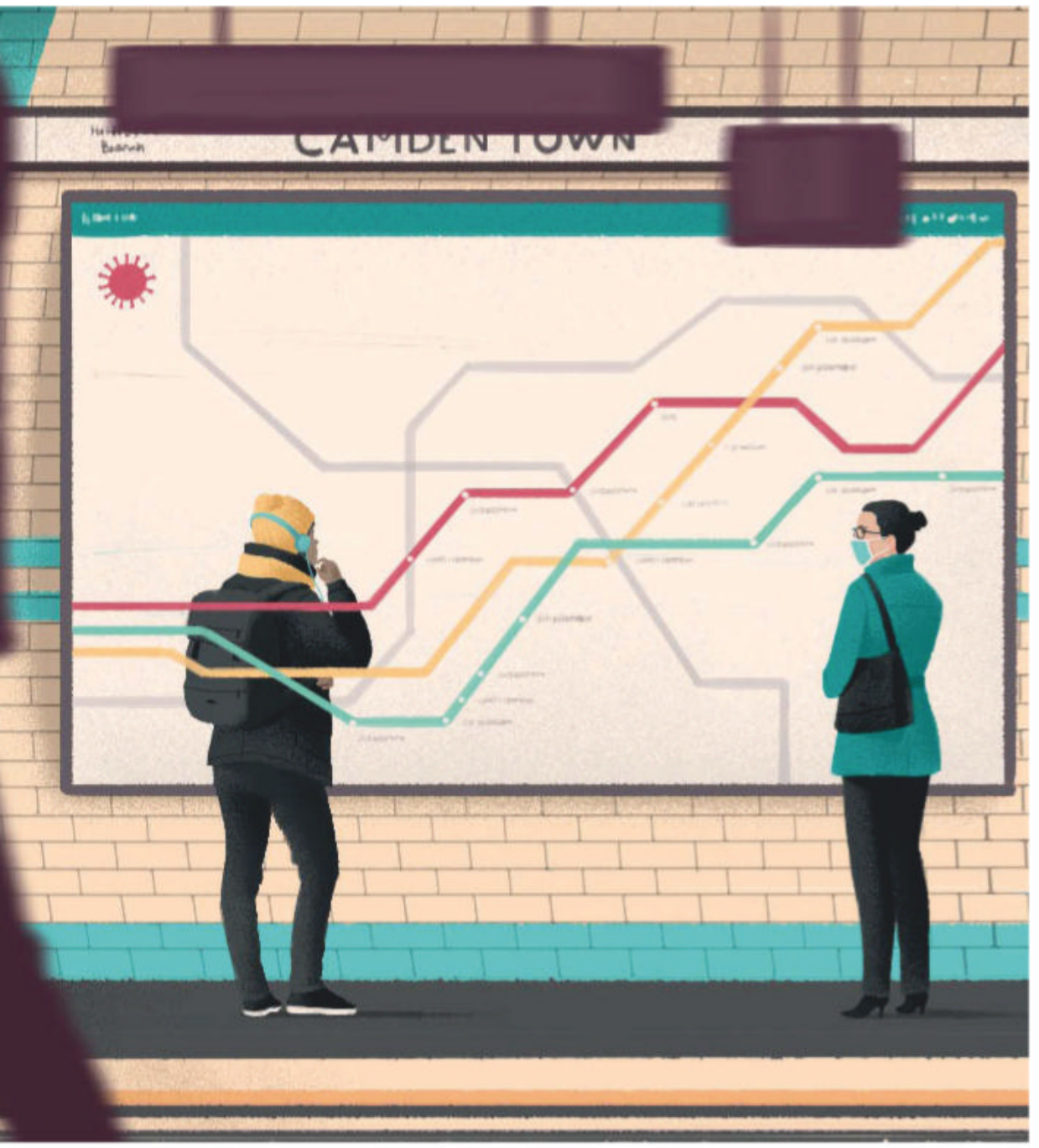
We often need both kinds of information to put a given risk or benefit in perspective. But even supposed experts can get confused about them – something we have seen during the covid-19 pandemic as well. In August, Stephen Hahn, head of the US Food and Drug Administration, made headlines when he said that blood plasma taken from people who had recovered from covid-19 would, when given to those infected, save 35 lives for every 100 people treated. In reality, a poorly designed study had found that the plasma treatment reduced covid-19 fatalities from



around 14 per cent to 9 per cent – a relative risk reduction of 35 per cent, but an absolute risk reduction of just 5 per cent, meaning the treatment would save five out of every 100 covid-19 patients.

For those of us trying to navigate the choppy waters of coronavirus risk, simply being aware of the difference between relative and absolute risk, and knowing which one a given number represents, is already a big step in understanding its true relevance. But even then, trying to pin down the risks around covid-19 can be a befuddling exercise. New information is emerging all the time. The risk that covid-19 poses for each of us – either in absolute or relative terms – depends on how old you are and whether you have any pre-existing health conditions.

"The link between age and the chances of covid-19 being fatal for you are astonishing," says Spiegelhalter. "An 80-year-old is



1000 times more likely to die from it than a 20-year-old." Estimates from a team at Imperial College London have put the chance of dying from covid-19 if you catch it when you are aged between 10 and 20 at 0.006 per cent, or six deaths for every 100,000 people of that age infected. By the time you are in the 40-49 age bracket, the risk goes up to 15 in 10,000 and if you are over 80 years old, it is almost 1 in 10.

"An 80-year-old is 1000 times more likely to die from covid-19 than a 20-year-old"

Risk profusion

As so often, the significance of these numbers is difficult to assess without additional context. To attempt to give it, in the US the lifetime risk of dying in a motor vehicle crash is 1 in 106, according to estimates compiled by the National Safety Council, a US non-profit organisation. The lifetime risk of dying of heart disease is 1 in 6.

To more meaningfully compare how covid-19 increases your chances of dying compared with life's other risks, however, Spiegelhalter suggests we should size it up against the risk of dying in the following year, our annual death risk. This rises exponentially from the age of about 10, doubling every eight years or so. Getting covid-19 doubles your normal annual risk of dying – still very low if you are young, but higher the older you get.

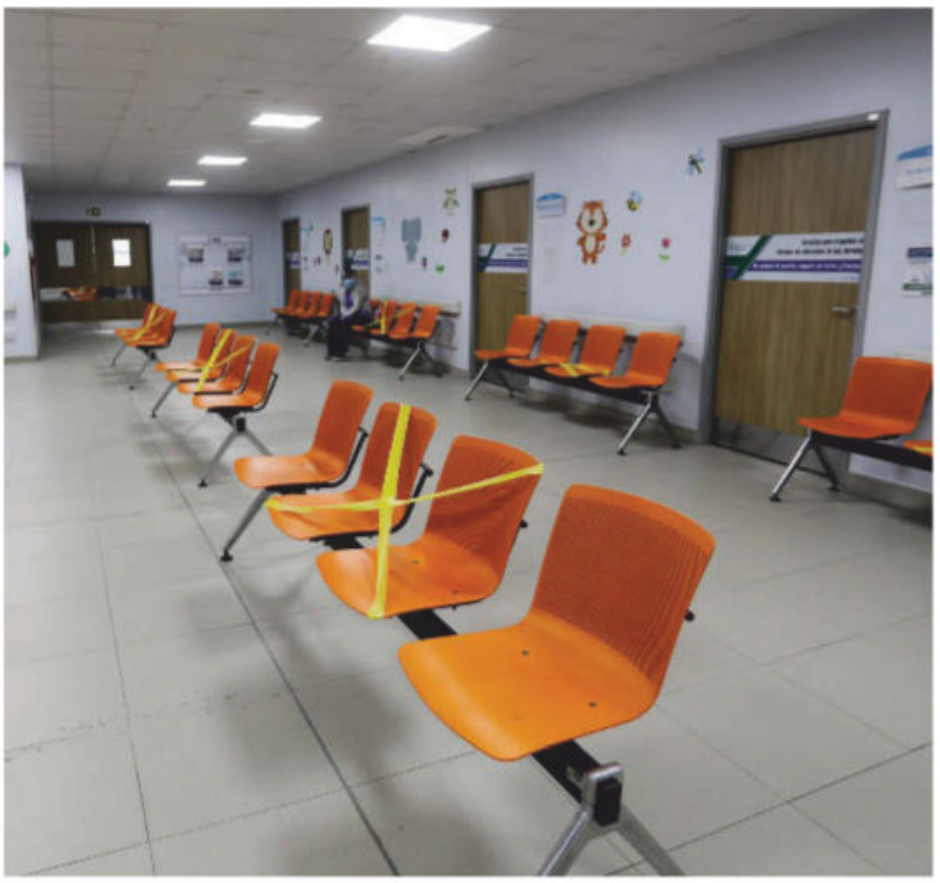
There is a further complication. All these risk estimates describe the infection fatality rate, the likelihood of dying if you have covid-19. There is also the population fatality rate, the likelihood of both catching covid-19 and dying. It is easy to mix these figures up, with consequences that can skew rational personal and public policy responses.

In May, for instance, the UK's Office for National Statistics published a report revealing big differences in the population fatality rate for various ethnic groups. It found it was almost twice as high among black people than white people. Yet news stories left many people believing that if you are black and get covid-19 you are twice as likely to die as if you are white – not that widespread health inequities make minorities more vulnerable to infection.

As for risk for infection on its own, those numbers are even more challenging to pin down because there are so many different factors that can contribute – including overall exposure to the virus.

For all the confusion, when used properly numbers can help us calibrate our natural fear and anxiety. In the context of coronavirus, the picture they present is broadly reassuring, especially if you are healthy and under 50. But that certainly doesn't mean exposure to the virus is risk-free for younger people, far from it: we are still struggling to grasp the true toll of persistent symptoms, or long covid.

And even if personal risk is low, the risk that you may spread the infection to other more vulnerable people remains. That is why, in deciding how we react and deal with the uncertainty of the pandemic, we need to ›



AGENCIA PRESS SOUTH/GETTY IMAGES

Many people have avoided critical emergency care for fear of catching covid-19 in hospital

1 in 4000

Risk of coronavirus infection passing between passengers on a full commercial flight. This drops to 1 in 8000 if the middle seat is left empty

Source: MIT Sloan School of Management

116 in 1000

Number of people in their mid-70s and older who will die if infected by the covid-19 virus. That compares with less than 1 per 1000 for people under 50

Source: Imperial College London

2x

Men have about twice the risk of death from covid-19 compared with women

Source: The Lancet

"We need to go beyond individual risk and think of collective risk"

go beyond individual risk and think about collective risk, says Nassim Nicholas Taleb at New York University's Tandon School of Engineering. "In a pandemic, individual risks can be low while collective risks are high."

This additional wrinkle comes about because infectious diseases spread and multiply through society in a way that other individual risks, like those of car crashes or heart attacks, don't. Although these other risks are stable over time, and society has the capacity to cope with them, a new outbreak adds an unexpected strain on the whole system, threatening to grind societies to a halt. "Pandemics are so unpredictable," says Taleb. When he and Pasquale Cirillo at Delft University of Technology in the Netherlands looked at mass outbreaks of infectious disease over the past 2500 years, they found that most had a relatively small impact. But a small number were disastrous.

The Black Death killed up to 200 million from 1331 to 1353, for instance. Scaled up as a percentage of world population today, that would be nearly 4 billion deaths. "A new one can die out quickly, or rapidly get out of hand and turn into a real existential threat," says Taleb. In January, he argued that extraordinary precautions were required to ensure this outbreak didn't spiral out of control. "You can't come back from ruin," he says. The collective threat of covid-19 means we are all in it together. "It's crucial people recognise that being part of a society means taking responsibility for others," says Gigerenzer.

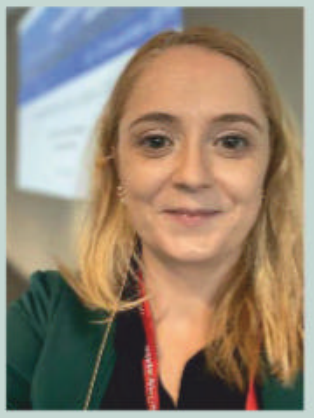
Mixed messages

So what does that look like in practice? How can we evaluate the risks we face personally – and across society – and make decisions that enable us to carry on with life? It isn't simple. Uncertain, hard-to-interpret situations create ambiguity, which elicits bigger responses in brain regions that register risk, making it all the more difficult to keep threats in perspective, says Kable. We all vary in both our tolerance for uncertainty and what we deem to be an acceptable level of risk.

That said, there are some rules of thumb that risk specialists recommend. To begin

Your contact budget

Thinking about interactions in terms of possible exposure to the coronavirus can help us manage risk, says epidemiologist **Eleanor Murray**



How did you come up with the idea of a contact budget for interactions with others during the coronavirus pandemic?
Back in March and April, most people had clear guidance about what they were allowed to do, and it wasn't very much. That made life somewhat unpleasant, but it also made life easy. When things started opening up, everybody had to make their own decisions about what they are comfortable with and what might be risky.

The way I was thinking about it is that there is a level of risk I am comfortable with. If I go to a grocery store during a really crowded time, to keep my average risk level constant, I'm probably not going to do something risky the next day. We are all familiar with the idea of financial budgeting, it is easy to translate to this situation.

How do we make a contact budget?
There are four metrics to keep in mind. First is how much risk you can tolerate. If you or someone in your household has a medical condition, then your tolerance is going to be lower.

Next is how comfortable you are knowing that you could get infected and transmit that infection. That's something we don't talk a lot about, but people have told me how guilty they felt afterwards.

The last two pieces are the amount of contact we need for our job and for our mental health.

If you are a healthcare worker or grocery store clerk, a certain amount of contacts are required as part of your job. Then there are contacts that you need for emotional reasons. It could be really important to you to deliver groceries to your elderly neighbour or to attend a religious service.

What factors give an activity a higher risk or "cost"?
Think of person, place, time and space. "Person" is about how many people are there, and how many you are in regular contact with. The less regular contact you have, the more potential for expanding your infection network.

"Place" is about whether something is inside or outside, whether it is crowded, and the risks associated with that location.

"Time" is the duration you'll be there. And "space" is whether the location is well ventilated and how well you can maintain masks and physical distancing.

Whether necessary or optional, how do you make an activity as low risk as possible? Can you eat outside or get takeaway instead? Could you get the same benefit virtually?

What if you blow your budget?
I remember friends who did Weight Watchers who would say they blew their diet so they're just going to eat whatever they want. That's the wrong way to think about this. It is better to realise that you spent a lot on a particular activity, and now you need to save up for more contact in the future.

You can also budget proactively. If it's really important to attend a friend's 30th birthday party, in the days before and after, you can make sure you are doing low-risk activities to average it out. **Interview by Carrie Arnold**

Eleanor Murray is an epidemiologist at the Boston University School for Public Health

with, try to keep perspective, both by determining whether the numbers you are dealing with represent relative or absolute risks, and by evaluating whether your emotions are amping up their significance. Also, stay up to date. While obsessively following coronavirus news can have its own mental health risks, in a situation changing this rapidly, it is important to seek out trusted sources and evaluate risk assessments as new information comes in. For instance, early in the pandemic, it seemed that surfaces could be a major source of spread. Now the latest evidence is that sharing air indoors may be the most dangerous factor. Remember too that you cannot eliminate risk altogether, and that there are trade-offs: avoiding one risk may create other, worse ones.

To help get our heads around all of this, some public health officials believe it may be useful to set yourself a weekly "contact budget" – taking into account your personal circumstances and vulnerability to severe consequences of infection, and then aiming to limit the number of activities with higher levels of potential exposure to the virus (see "Your contact budget", left). It is also critical to consider how your choices could imperil or protect other people, says Gigerenzer.

Although we aren't out of the woods yet, this pandemic will eventually pass. But will we learn anything from it? "I think this is going to change us a lot, and we'll handle this very differently in the future," says Schrager. "In many countries, including the US, risk communication has been a big public health failure. There's been no real consideration of how to make the risks associated with covid-19 meaningful, and how to communicate these in a way people can understand." Perhaps one benefit of this crisis is that it will finally serve as a wake-up call for the importance of improving how we talk – and think – about risk. ▮

Dan Jones is a freelance writer based in the UK

Great balls of fire

The source of ball lightning has been a mystery for centuries. Are we any closer to an explanation, asks **Eric Canan**

PATRICK LEGER

ON A summer's day in the early 1980s, a teenager sat in his bedroom watching an afternoon thunderstorm roll over the seaside landscape near Rome. Without warning, a glowing sphere the size of a football suddenly appeared in the corner of the room. Emitting no heat or smell, it hovered about a metre in front of him and slightly over his head. The boy was dumbfounded. The ball was dark yellow, completely opaque, with a wispy surface made from layered sheets of slowly rippling light. It floated there for about 10 seconds before vanishing as silently as it had come. He didn't even have time to be scared.

Andrea Aiello remains fascinated by what he saw as a boy – and now, as a theoretical physicist at the Max Planck Institute for the Science of Light in Germany, he is developing his own ideas about it. The most likely explanation is that he witnessed ball lightning, a rare form of atmospheric electricity that can hover gently above the ground inside or outside buildings and even pass through closed windows. Scientists around the world take the phenomenon seriously, while remaining unable to explain, reproduce or authoritatively document it.

There are plenty of hypotheses, but little certainty. Some believe the phenomenon's origins lie in the electrical power play of vast thunderstorms. Others think it might be caused by lightning strikes themselves. A few believe it is a messy tangle of electromagnetic field lines wandering Earth alone. So far, at least, none of these ideas can explain everything ball lightning seems to do. Is it time to consider some more exotic alternatives?

The bare bones of how regular lightning forms is reasonably well established: dust and ice particles inside a storm cloud undergo so-called charge separation, with the positively charged particles rising and the negatively charged ones sinking. These, in turn, induce positive charges at raised points on Earth's surface, generating powerful, widespread electric fields that steadily strengthen until the energy is released in a surge of electricity. Those surges are the lightning bolts we see from our windows.

But that explanation brushes an awful lot under the carpet. We still don't know, for example, how collisions in the air cause the charges to separate or, indeed, how an electric

“The ball floated there for 10 seconds before vanishing silently. He didn’t even have time to be scared”

field that is strong and compact enough to generate a lightning bolt is created inside a storm cloud. For an everyday phenomenon, lightning remains surprisingly mysterious. Few of its manifestations, however, are as poorly understood as ball lightning.

Aiello is far from the first to claim a sighting. Ball lightning has been repeatedly reported over the centuries. Tsar Nicholas II of Russia claimed to have seen a glowing ball glide through a cathedral during a late-night storm when he was a child. Laura Ingalls Wilder, who wrote *Little House on the Prairie*, described a winter storm during which balls of fire rolled down the outside of the stovepipe inside her home. They rolled onto the wooden floor, but left it unsinged. The physicist Nikola Tesla even claimed to have artificially produced ball lightning in his Colorado Springs lab.

Despite such apparent sightings, though, concrete evidence remains hard to come by. All records are anecdotal, and no image or video purporting to show the phenomenon has stood up to scrutiny.

There is no network to detect something like ball lightning, either. Rachel Albrecht at the University of São Paulo in Brazil has ›

used lightning detection systems to map the world's most active lightning hotspots. She says that something as dim as ball lightning, which is often reported to glow about as brightly as a 100 watt incandescent bulb, wouldn't be picked up by satellites or the various land-based lightning detection systems. To record ball lightning, she says, "it would have to be happening right in front of your camera".

Even without direct evidence to go on, Martin Uman at the University of Florida believes there is something to the phenomenon. Uman has spent nearly the entirety of his 50-year career studying lightning and has collected or reviewed hundreds of encounters with glowing spheres much like Aiello's. A blue ball glancing off a student's finger, a white ball rolling down the centre of a military tanker aircraft, a yellow ball hovering above an engineer's desktop computer. "There are a number of published papers where ball lightning was inside of a commercial airplane and all the passengers saw it as it floated down the aisle," says Uman.

Antimatter meteorites

While the details of any one account of ball lightning sound incredible, Uman thinks the accumulation of thousands of similar reports over the course of hundreds of years points to a genuine phenomenon with no sound scientific explanation.

Dozens of mind-bending suggestions have been published to explain ball lightning, ranging from mini black holes to meteorites made of antimatter, but it is more likely that something simpler is involved. Uman suspects that ball lightning is an after-effect of the electric discharge from standard lightning strikes, which could occasionally kick off strange chemical reactions capable of producing a glowing sphere.

If lightning hit a patch of ground rich in silica and carbon, for example, some researchers believe it could form a cloud of pure silicon nanoparticles, emitting light and heat as it oxidised. Any such explanation that depends on hot gases comes with problems of its own. Namely, ball lightning is consistently reported to hover in place, glide horizontally and move against the wind – none of which a hot gas should do.

"The experiments guided lightning through dozens of materials including saltwater, metals, and even bat guano"

EDUARD MUZHEVSKYI/SCIENCE PHOTO LIBRARY

Ball lightning reportedly resembles a sphere of plasma. But plasma shouldn't hover on the spot, as ball lightning seems to do

"The field doesn't need more theories," says Karl Stephan, an electrical engineer at Texas State University. "The field needs experiments and observations that are instrumented well enough to get more observational data." That's why Stephan has been pursuing ball lightning experimentally for nearly two decades, testing plenty of hypotheses that rely on an electric discharge.

In one experiment, Stephan tested an idea that some researchers claim as the ultimate explanation of ball lightning. Short-lived balls of hot, ionised gas, called Gatchina plasmoids, can be produced when high-voltage electricity is discharged near the surface of salty water. Stephan was able to steer these plasmas horizontally, but they disappeared in a fraction of a second while, like all hot gases, noticeably rising. "You take a still picture of it – it looks a whole lot like what people describe ball lightning to be," says Stephan. "But I don't think that's the whole explanation or even most of the explanation."

Uman has also conducted experiments aimed at producing ball lightning via electric discharge. By firing small rockets with trailing wires into active thunderstorms, he has triggered hundreds of lightning bolts that can then be directed through carefully designed equipment. In a single summer, he guided lightning through dozens of different materials including pools of saltwater, various metals and even bat guano in the hope of creating ball lightning. Although he and his team were able to create a few spherical sparks – albeit ones that were far too short-lived to be ball lightning – and the same kind of rising plasmas Stephan and others have made, they resolutely failed to produce the phenomenon they were after.

Other ball lightning theorists rely less on lightning bolts themselves. Robert Cameron at the University of Strathclyde, UK, thinks ball lightning might be caused by

COURTESY OF UNIVERSITY OF FLORIDA LIGHTNING RESEARCH LAB

In the hope of conjuring ball lightning, researchers guided regular lightning into different materials at the International Center for Lightning Research and Testing in Florida

electromagnetic knots: as-yet-unseen tangles of electromagnetic field lines that could be powerful enough to ionise the surrounding air. In 2018, Cameron published his theoretical work and has since connected with Stephan and Wolfgang Löffler at Leiden University in the Netherlands to refine the idea and potentially create the knots in the lab.

Electric knots

Retired physicist and independent ball lightning researcher Herbert Boerner believes Cameron's knots dovetail perfectly with his own idea that powerful, widespread electric fields produced in especially strong thunderstorms are the primary cause of ball lightning. Boerner has investigated several accounts of ball lightning where multiple spherical objects were produced simultaneously. As he correlated those sightings with European lightning detection archives, he found that ball lightning can appear several kilometres away from cloud-to-ground lightning strikes, leading him to believe that a storm's electric field, rather than an individual lightning strike, causes ball lightning. However, he had no idea how a strong electric field itself could generate ball lightning until he came across Cameron's paper. "Then suddenly things fit together," he says.

In his 2019 book on ball lightning, Boerner explains that Cameron's knot hypothesis could tally with his concept if a storm's electric field is strong enough to pull a cloud of electrons out of the ground. That cloud may then be able to act as a kind of natural antenna, channelling a pulse of electromagnetic radiation from the lightning into a knot.

"I think the basic idea is certainly good, because it works. I calculated this myself," Löffler says of Cameron's idea. Yet he doesn't think the knots will end up explaining ball lightning the way Boerner does. Stephan, too, is interested in Cameron's work more as a purely electromagnetic puzzle and less as a cause of ball lightning. He says that the radiation coming from the lightning bolt would have to be in the form of microwaves for it to last long enough to explain ball lightning – and there is no reason to think a thunderstorm produces microwaves.

While ball lightning continues to defy easy explanation, it may be useful to turn to those who have witnessed it first-hand. As perhaps the only legitimate researcher to have actually seen ball lightning in person, Aiello has an idea of his own.

One of the most puzzling aspects of the glowing ball Aiello saw as a teenager was that it appeared to be made of light that was standing still. But because light has no mass, the laws of physics require that it must always move. "My explanation is that this light moves, but in an additional dimension," he says. A quantum physicist used to thinking unconventionally, Aiello sees the problem geometrically. A cross section of an ordinary three-dimensional lightning bolt would be a two-dimensional circle. Logically, then, if you scale up by one dimension, the cross section of a four-dimensional lightning bolt would be a three-dimensional sphere. So, if an extra-dimensional lightning strike were able to break into our space-time through a wormhole, it would appear as a glowing, three-dimensional ball of light. Aiello hasn't yet published his idea, but believes a mathematical explanation of the process is possible.

Uman, Stephan and Boerner all agree that ideas like Aiello's are part of a long history of untestable hypotheses that invoke some form of new and exotic physics to solve the mystery of ball lightning without hard evidence. But with a smile and a shrug, Stephan admits: "I can't rule it out." ▮

Have you seen ball lightning? Some of the researchers in this story are collecting accounts of sightings. Report yours at bit.ly/2GDCbgD

Eric Canan is a freelance writer based in Chicago, Illinois

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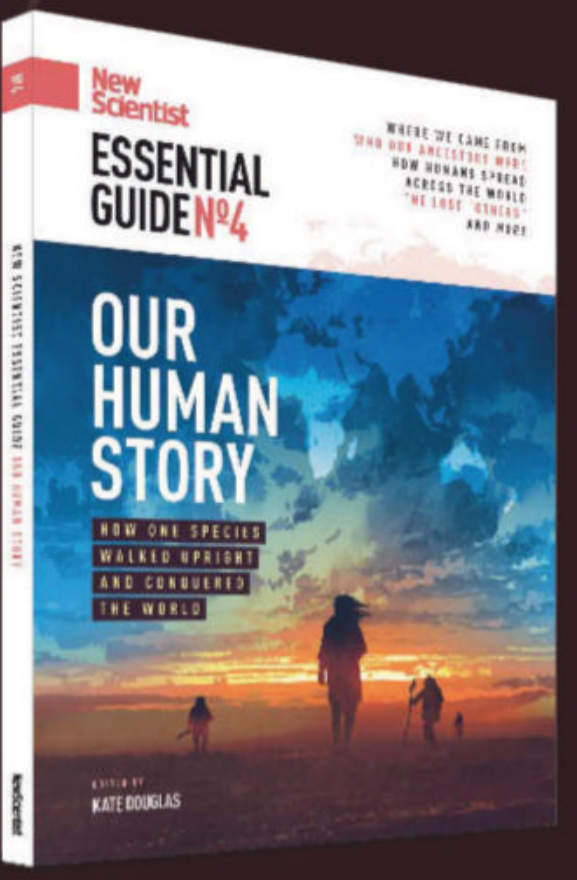

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The back pages

Citizen science

Put that down, kitty

Your cat could help nail hard evidence about their impact on the UK's small wildlife, especially birds. **Layal Liverpool** explains how

Layal Liverpool is a digital journalist at *New Scientist*. She believes everyone can be a scientist, including you. @layallivs

What you need

To be in the UK and have a pet cat that goes outdoors

The ability to access the website whatthecatdraggedin.org

A diary for recording your observations in

Citizen science will be back again in four weeks

Next week

Science of gardening

NEXT time your cat brings you a gruesome gift from outdoors, why not capture the moment with a photo or diary entry? This could really help researchers who are investigating the impact that domestic cats have on wildlife.

These pets are notorious for their opportunistic hunting, but the extent to which their predatory activities influence prey populations, such as those of small mammals, birds and even reptiles and amphibians, is still controversial.

In New Zealand, there is some evidence that cats contributed to the decline of native species there. That country's birds evolved without mammals around, other than a few bats. With no large land animals hunting them, nesting on the ground and being unable to fly were common. As a result, these birds are particularly vulnerable to predation by cats.

Since birds and small mammals in the UK evolved alongside wildcats and other carnivores, it isn't clear how much of a threat domestic cats pose to their populations. To get more evidence, researcher Hannah Lockwood at the University of Derby in the UK set up What The Cat Dragged In.

If you live in the UK and have a pet cat that goes outdoors, you can take part by registering online at whatthecatdraggedin.org. You will be asked to start a diary of all prey species brought home by your furry friend over a year.

Taking photos is optional, but it could help you to identify the prey using guides on the project's website. Even if your cat doesn't usually bring anything home, you can still provide valuable data by selecting the "no prey" option.

VASILIY VISHNEVSKIY/ALAMY

If your cat is lucky, it might be selected for the second part of the project. This time, GPS will track its movements so that researchers like Lockwood can learn more about how cats interact with the environment, and they will also be fitted with "cat-cams" to get a clearer understanding of how much prey domestic cats kill, but don't bring home.

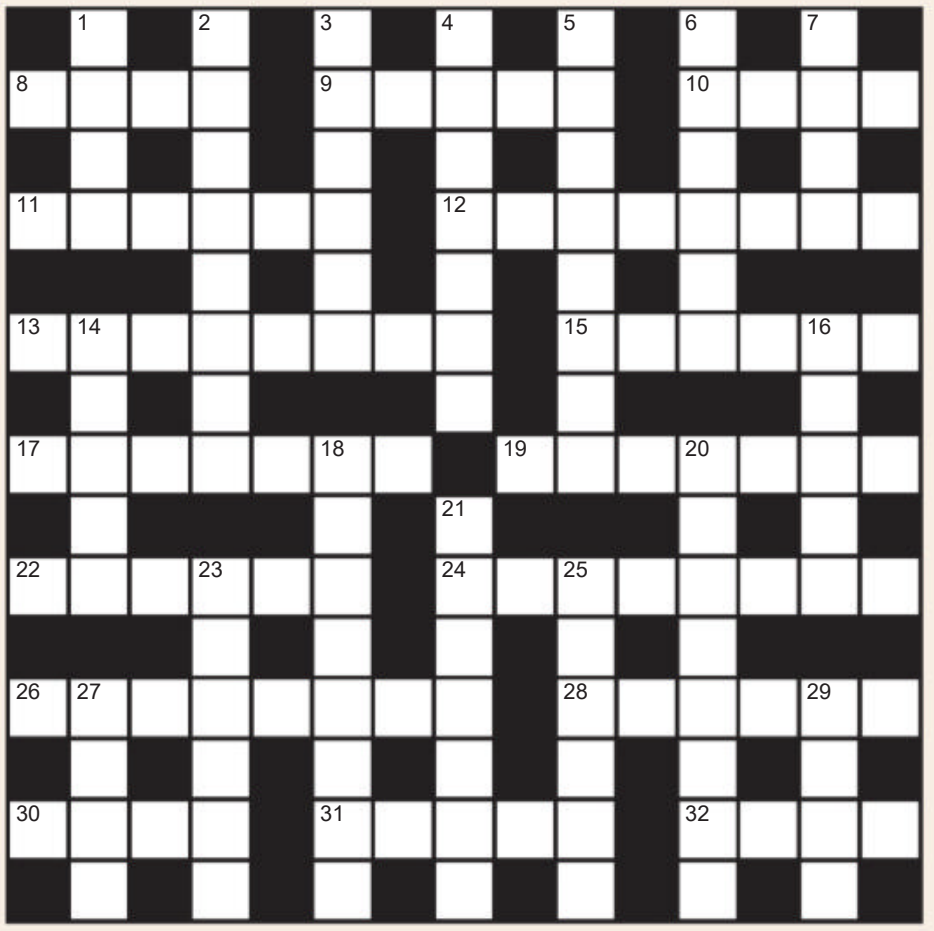
Since the project launched in 2018, hundreds of cat owners have taken part and the data from 550 pets is already providing important insights into their hunting behaviour. This shows a seasonal pattern in hunting and suggests that a small number of pets may be responsible for most of the prey captured by the UK's domestic cats every month.

There is a peak in hunting during summer, says Lockwood, when cats bring home an average of 2.5 prey each month. Most don't bring anything home, but there are super predators that can return with 50 items a month, "which is unbelievable", she adds.

Lockwood hopes the project will inform interventions, such as keeping cats in at certain times, that help to limit their impact on animals like small birds, which are already facing other threats, including climate change.

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

Quick crossword #69 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

8 Raw material for the production of paper (4)
9 ___-19, infectious disease first identified in Wuhan, China (abbr.) (5)
10 *Australopithecus* skeleton known officially as AL288-1 (4)
11 Relating to an unborn infant (6)
12 Excavation in a water environment (8)
13 ___ acid, also known as hydrochloric acid (8)
15 Period of widespread glaciation (3,3)
17 Solution of acetic acid (7)
19 System of transmitters, cables or computers, perhaps (7)
22 Constellation seen between Taurus and Cancer (6)
24 8th prime number (8)
26 Ordinal of 11 (8)
28 Breathe out (6)
30 Diesel fuel (4)
31 Tier; even (5)
32 Computer operating system developed by AT&T (4)

DOWN

1 Lymph node swelling (4)
2 British fighter aircraft designed by R.J. Mitchell (8)
3 Spotted cat of South America (6)
4 Organ known in humans as the Fallopian tube (7)
5 Sticky (8)
6 Pestilence (6)
7 Procedure that might be CT or PET (4)
14 Waste water (5)
16 Prickly plant in the genus *Ulex* (5)
18 Infectious disease such as H5N1 (5,3)
20 Work done by 1W in 1h (4-4)
21 Small marine fish in the family Engraulidae (7)
23 Of an experiment, performed on living cells or organisms (2,4)
25 Syringe (6)
27 Edible plant in the genus *Allium* (4)
29 ___ Organa, princess in the *Star Wars* films (4)

Quick quiz #74

1 Who was the first African-American woman in space?

2 Charles Drew was a US physician famous for developing methods for the long-term storage of what?

3 Which 19th-century agronomist is known for pioneering crop rotation across the southern US and inventing hundreds of uses for peanuts?

4 *Parvitermes collinsae*, named after entomologist Margaret Collins, is a species of which kind of insect?

5 Until the 1940s, the Ball method, developed by chemist Alice Ball, was the most effective treatment for which disease?

Answers on page 55

Puzzle

set by Chris Maslanka

#82 Dogmandoo

When "Hairy" Potter returned from his failed expedition to find the legendary lost city of Dogmandoo, he gave a press conference. "It was a jungle out there!" joked the great man. "Luckily for me, it wasn't the rainy season. For the whole expedition, I noticed that if it rained in the morning it was fine in the afternoon; if it rained in the afternoon it was fine in the morning. In fact, I see from my diary that it was fine on 37 mornings and 43 afternoons. Mind you, it did rain on a total of 40 days."

Back at the office of *The Daily Grind*, I found that my notes weren't quite as compendious as I had thought. On how many afternoons of Potter's expedition had it rained? If this was typical of the rainy season what (roughly) are the chances in that season of a day unspoilt by rain?

Answers next week

Hop to it

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

Pauline Provini
Interdisciplinary Research Centre, Paris, France
Why certain bird species walk while others hop is a question that scientists have tried to elucidate for decades. There are three main hypotheses, yet there are always exceptions among the huge diversity of bird species on Earth.

The first is linked to their phylogeny or place on the family tree. Bird species inherit their walking or jumping characteristics from their ancestors. This explains why closely related species are more likely to share the same types of locomotion. But this isn't always the case. Similarly, ostriches and penguins both walk, even though they aren't closely related.

Size could be a factor too. Larger birds tend to walk rather than hop, as jumping uses more energy, especially for bigger birds. However, toucans hop even though they are much bigger than pigeons, which walk.

"Is a hummingbird, which can hover in the air, a more advanced flyer than an albatross, which can soar for months on end?"

The third hypothesis relates to the arboreal way of life: in trees, it is easier to jump from branch to branch than to walk. A recent study I conducted on 1000 species of birds showed that those living in trees are more likely to hop than those that live on the ground. However, parrots walk, yet are mostly found in trees.

As you can see, there is no clear explanation, and a combination of factors probably explains why some birds hop while others walk.

@DOLANSMALIK/TWITTER

What colour are these shoes? The answer isn't so black and white

This week's new questions

Colour confusion **I see the shoes (pictured) as mint green and grey, but a friend sees pink and white. Is this due to differences in our brains? Are we continually seeing different versions of the colours around us? *David Love**, Exeter, UK*

Masses of people **The human population has more than doubled in the past 50 years, so has the mass of our planet and everything on it increased? *Geoff Hope**, London, UK*

Linda Phillips
Narrogin, Western Australia
I live in the countryside of south-western Australia and often see crows and parrots standing in the road. I decided to conduct some research by observing their behaviour while out driving. Note: no birds were harmed in the course of this research.

Parrots mostly hopped, whereas crows seemed to prefer walking. I found that, as my car approaches, crows are clearly aware of it and make judgements as to whether it is on a collision course. If a crow realises it cannot walk out of the way in time, it changes to hopping. This is faster, although it takes more energy – try hopping for any distance and you will understand. When my car drives relatively close to a parrot, it reverts to flight immediately. A crow uses the intermediate stage of hopping because it takes more effort for it to get airborne.

As to why crows like to stroll around on open roads... well, I did ask, but got no answer!

Herman D'Hondt
Sydney, Australia
The problem with this question lies in one word: advanced. Evolution isn't progressive. It doesn't lead to more advanced organisms. It leads to creatures that are better at the job they are doing. Is a hummingbird, which can hover in the air, a more advanced flyer than an albatross, which can soar for months on end? All we can say is that they need different skills for their survival, and that evolution gave them those skills.

Evolution can go "backwards" as well as "forwards", too. That is why animals have evolved eyes – and it is why cave fishes lost them. All living things are equally evolved, equally "advanced", whether it be a virus or a human. They are all the outcome of nearly 4 billion years of blind evolution.

Martin Jenkins
London, UK
Organisms aren't more or less "advanced". They are simply better or worse adapted to their environment. A bird hops or walks because it has found this to be the best means of locomotion on the ground. Neither is superior, or more advanced, than the other.

While Australian magpies may walk, the European magpies that I see most days prefer to hop. So both hopping and walking work. In evolutionary terms, that is all that matters.

Brain pain

Do the different causes of headaches create pain in different parts of the skull?

Amanda Ellison
University of Durham, UK, and author of Splitting: The inside story on headaches
Yes, is the short answer. The nuance lies in which type of headache you have. Migraine will often present in the same place. For headaches caused by sinus congestion, the location of the pain depends on which of the four sinus cavities are most affected.

Pain in your forehead indicates blockage of your frontal sinuses, located above the eyes. General headache with pain in the cheekbones and even toothache can point to a problem with your maxillary sinuses, which are under our eyes.

Inflammation of the sphenoid

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Tom Gauld
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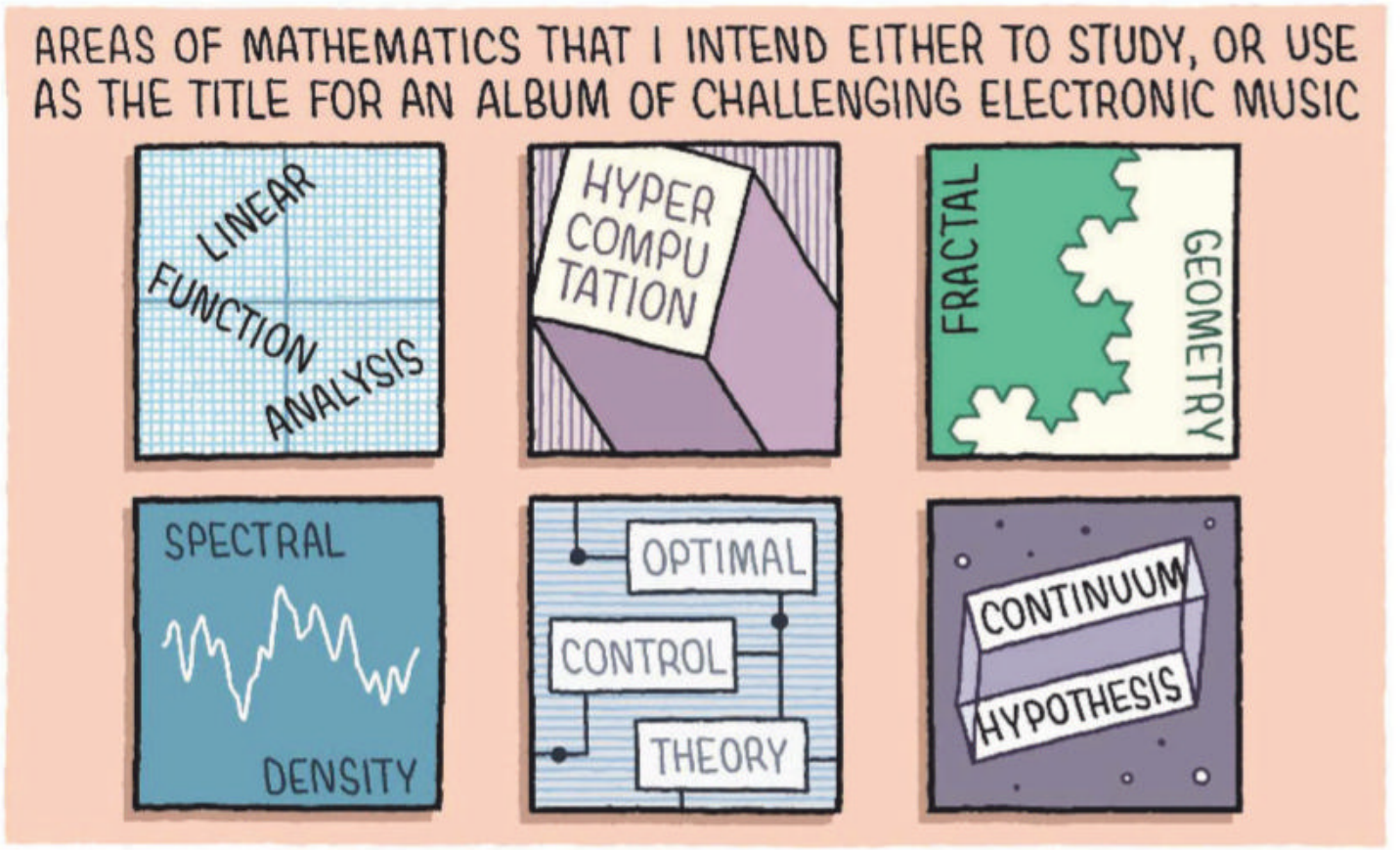


"Intuition suggests tandems are more efficient, but time trials show that solo female riders usually beat tandem riders"

sinuses, located behind the eyes, leads to a more diffuse headache that can be felt in the front or the back of the skull.

A "splitting" headache with pain behind and between the eyes that radiates to the forehead occurs due to congestion in the ethmoid sinuses, which are found between the nose and eyes.

Tension or stress headaches are other common types. The location of the pain depends on which muscle group in the head and neck is sending signals that the brain interprets as pain. This kind of headache can result from poor posture or anxiety (as emotional stress has a physical effect), or a vicious circle involving both. This happens when adrenaline released by the body to help cope with stress causes throbbing pain due to over-dilation of the blood vessels in the brain.

The type of pain experienced and its location can help unlock the mystery of why you got it, and allow you to take steps to fix it.

Cycle logic

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

Hilary Johnston
Perth, Western Australia
At a cycling event in Perth 30 years ago, a group of men brought out a 10-seater bike.

Despite much sprinting with the bike to gain enough speed to jump on and start pedalling, the men never successfully rode it because the minimum speed to maintain balance couldn't be reached. It proved impossible to keep the centre of gravity under the cyclists on such a long bike.

Jerry Shiner
Toronto, Canada
Any useful gains in the ratios between riders, bicycle, air or mechanical resistance would become more limited with each extra rider, soon becoming so minuscule as to be meaningless.

Mike Follows
Sutton Coldfield, West Midlands, UK
Intuition suggests that tandems and triples should be more efficient because of the slipstream benefit for the rear riders and the smaller mass of machine per rider. However, the men's tandem world record for 1000 metres is only just faster than that for a regular bike.

Time trials on UK roads show that there would usually be a close finish in a men's race between a regular bike and a tandem over distances of 10 to 100 miles, and that women riding solo should consistently beat a tandem.

Tandem racing ceased as an Olympic event after 1972, but continues at the Paralympics, with an athlete with a visual impairment in the rear seat. ▮

Answers

Quick quiz #74
Answer

1 Mae Jemison

2 Blood plasma

3 George Washington Carver

4 Termite

5 Leprosy

Cryptic crossword #42 *Answers*

ACROSS 7 Dolly the sheep, **8/11** Maillard reaction, **9** Rook, **10** Crampon, **12** Resin, **14** Match, **16** Accrete, **19** Stun, **20** Appetite, **22** Doppler effect

DOWN 1 Soda, **2** Slalom, **3** Ethanol, **4** Veldt, **5** Charge, **6** Keto diet, **13** Scupper, **15** Canopy, **17** Ratify, **18** Raven, **7** Tick

#81 A bridge too far
Solution

Tom can take 9 minutes to cross the bridge and the group can still cross in 17 minutes. Call the four students A, B, Tom and Tim. If A takes 1 minute and B takes 2 minutes then:
A and B cross (2 minutes),
A returns (1 minute),
Tom and Tim cross (10 minutes),
B returns (2 minutes),
A and B cross (2 minutes).

From this it can be seen that Tom can take 9 minutes and not affect the total time.

Excel-ent

Feedback has sympathy with the news that Public Health England – a body with, one would hope, much expertise in dealing with bugs – lost track of a goodly number of positive covid-19 tests reportedly because of a 65,000-row limit for spreadsheets in the version of Microsoft Excel it was using.

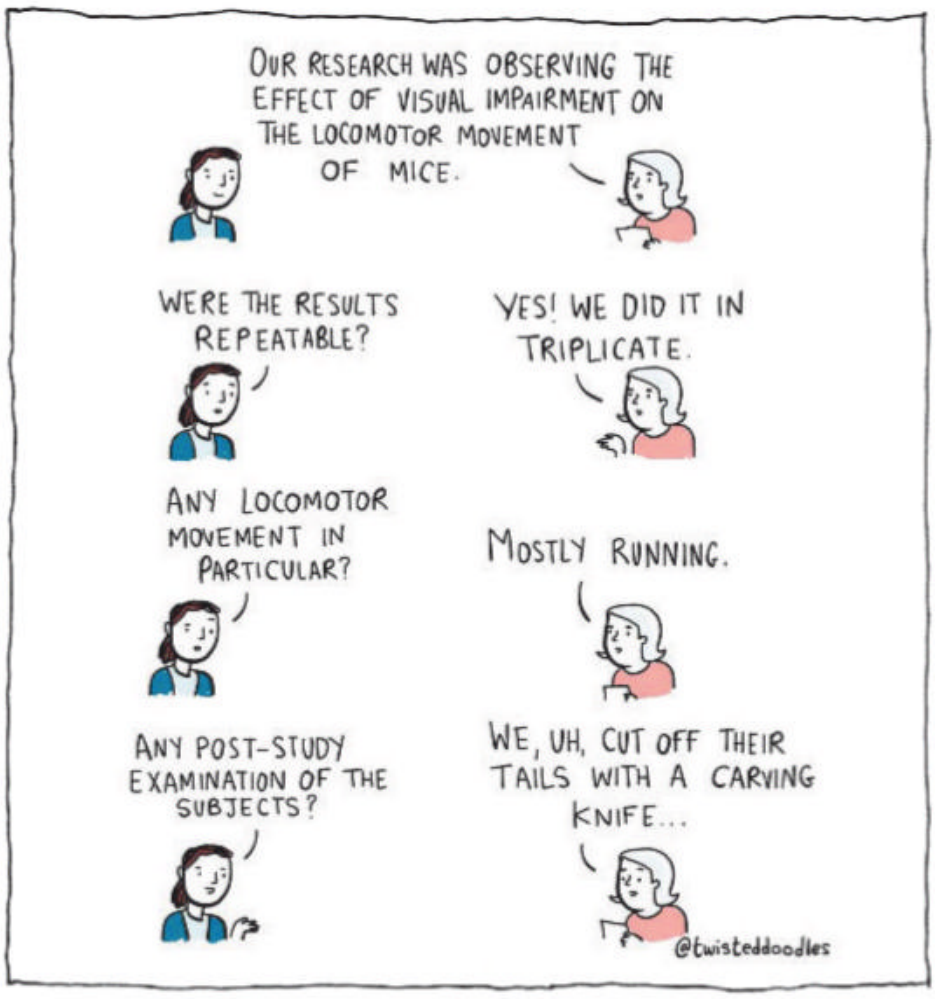
A similar fate recently befell our own file recording instances of nominative determinism, and the last 15,841 examples you sent in have sadly been lost to history.

Thankfully, most of the treasures of Feedback's memory are recorded on thinly sliced tree. We dutifully duplicate this story to add to the bulging files "UK coronavirus omnishambles" and "Minor programming error brings about end of civilisation" in our extensive piling system.

Browsing that second category, we are reminded of old favourites such as NASA's $125 million Mars Climate Orbiter, which was downed by a missing imperial-to-metric unit conversion. Another semi-forgotten classic is the 1988 Morris worm, when a badly coded randomisation mechanism turned a piece of software that was intended to test security flaws into the internet's first massive denial-of-service attack. More entries are always welcome from your experience, dear readers.

Such stories fuel our nagging fear that when the robots finally turn against us, or the world is consumed in thermonuclear Armageddon, it won't be because anyone particularly wanted that to happen, but because someone attempted to divide by zero in cell BB3935, worksheet 2.

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

Gallic shrugs

Talking of digital transitions, and in the interests of reassuring our UK readers that there is still plenty of international competition for the title of coronavirus über-omnishambles, France's *secrétaire d'Etat chargé de la transition numérique*, Cédric O – we freely admit to including this item partially for the pleasure of seeing our subeditors scramble to check that is no typ-O – responded to a journalist's question as to why several French government ministers hadn't downloaded their own official coronavirus tracing app by saying they were just "being very French".

Feedback assumes this to be an oblique reference to Charles de Gaulle's cri de coeur: "How can you govern a country that has 246 varieties of cheese?" But we do feel that the behavioural scientists behind this particular app might have taken into account the possibility that quite a few of its users might actually be French – perhaps, we don't know, by offering a glass of pastis, a game of pétanque and a free ride around the Boulevard Périphérique for every download.

The eagle has landed?

Meanwhile, as is standard, confusion reigns on a quantum interpretation. The US government recently announced the launch of quantum.gov, or <quantum¦gov>, the website of the National Quantum Coordination Office, together with its new official seal.

As this is the US, the seal comes with an eagle (apologies for those already confused, it doesn't get any better): in this case, a bald eagle in flight encased in a ¦ket> vector. Cue attempts to apply principles of linear algebra to evaluate the quantum state of the eagle.

Feedback is a rank amateur, but our best guess is that the eagle is indeed in flight, but we don't know exactly where it is. Or perhaps we do know where it is, but we don't know where it is going. Suppressing any desire to see a metaphor for the US's current trajectory, we instead enjoy alternative seals (with eagles) dreamed up by people on Twitter, including eagles that are both dead and alive and eagles with cats of ambiguous status in their claws.

Carrying the can

Talking of our friends across the pond, Gary Branum gets in touch from Wichita, Kansas, with a listing from the website of the industrial supplies company W. W. Grainger: "Acetone, 5 gal., Solvent, VOC Free". Feedback shares Gary's doubts as to what he is actually paying for once the volatile organic compounds are removed from the acetone. We don't know, Gary, but don't sniff it to find out.

We have more faith in the listing for a microwave that Brent Benson stumbled across while browsing US retailer Best Buy's website – the advertised product width of 29 and 53/57 inches smacks of true precision engineering. If you could get us one, Brent, we will pay you back later. We just got the micrometer out and it turns out our stationery cupboard has a slot exactly that size.

nom_det.csv

A lost printout rediscovered while measuring cupboard dimensions...
Name, Occupation, Sender:
Charles Pain, deputy chief health officer Northern Territory Australia, Wendy Akers
Amy Freeze, weekend meteorologist WABC-TV New York, Bruce Ter
Christopher Scull, early medieval archaeologist Cardiff University, Sally Adams
Christine Organ, school of health and life sciences Glasgow Caledonian University, Alistair Bell
Cheryl Fryar, tracking US fast food intake* (New Scientist, *22 August, p 20), Alex Fraser & David Staunton
Loggerhead turtles, being used to log Atlantic Ocean conditions* (New Scientist, *29 August, p 20), John Benham & Derek Bolton
Thanks, many thanks, that's enough EOF.