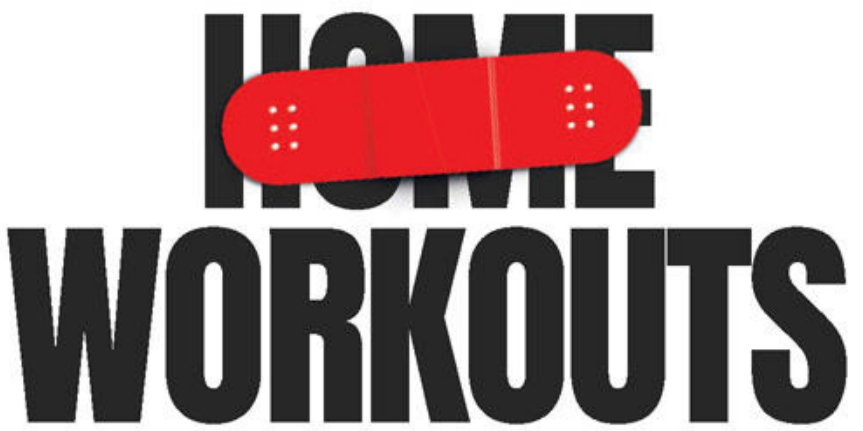

Let's Not Go Back

NHS / CovidVaccine / GetVaccineInfo

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New Scientist

WEEKLY 29 May 2021

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Cover image: Carl de Torres

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"Could it be that all the chocolatey cereal and crisps are depriving my brain of drive?"

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Virtual event

How time works

"Time" is the most used noun in the English language, yet some physicists don't believe it is real. Sean Carroll thinks it is – even if it remains deeply mysterious. In this talk, he explains that time seems to move forwards because of increasing entropy, and reveals how scientists are starting to piece together the way in which this affects memory, ageing and more. Join us on 3 June at 6pm BST or watch on demand later. Tickets available now.

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Tingle time Sam Wong explains how ASMR works

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YEMEN EMERGENCY APPEAL

MEDECINS SANS FRONTIERES
DOCTORS WITHOUT BORDERS

MSF anaesthetist Lenka Červeňová and her team care for a four-year-old boy after surgery in Dhi As-Sufal hospital in Yemen's Ibb province. Photograph © Majd Aljunaid/MSF

ALISON CRIADO-PEREZ IS AN MSF NURSE WHO WORKED IN MARIB

The conflict in Yemen is now in its sixth year. In Marib in central Yemen, nearly three million people have been displaced from their homes and are living in makeshift camps close to the frontline. Pregnant women and children are in desperate need of medical care.

"When we arrived in Marib, we found the local hospitals overwhelmed by the sheer number of people and by an influx of war-wounded. Around 2.7 million people are in the province now, many of them displaced from their homes elsewhere and looking for a safe haven.

People were living in makeshift shelters made of plastic and metal sheets. There were no latrines, just pits dug in the ground outside the tents. People were very worried about their health, about the risk of disease, about not having enough food. We were very concerned about the health of mothers and children, and pregnant women were a major worry too.

Over the next month, our small team worked around the clock to set up clinics providing basic healthcare and to supply hospitals that were struggling. Getting medicines to this part of Yemen wasn't easy. Supplies often had to cross frontlines. One of our trucks carrying antibiotics, medicines and other supplies was hijacked. It was an incredibly difficult environment to work in.

Along with general healthcare, we provided routine vaccinations for children and offered antenatal and postnatal care. We saw a lot of pregnant women and children and were able to refer pregnant women with complications to larger hospitals for emergency caesareans. It made a real difference.

A DESPERATE SITUATION

The day we started working in a rural hospital near the frontline, a woman came in with a breech delivery who was having real difficulty. Our midwife assisted and everything went well. But who knows what would have happened to that woman if the hospital wasn't there.

Since I left, many more people have come to the area. But Marib is no longer a safe place to be. In recent weeks, the frontlines have moved into the province, causing large numbers of injuries and forcing thousands more people to flee their homes. As the frontline approaches Marib city, we are concerned that people sheltering in the area may find themselves with no place else to go.

After six years of conflict, the situation is desperate. These people need our help now more than ever."

WHAT IS HAPPENING IN YEMEN?

Yemen is in the midst of civil war. After six years of conflict, the medical and humanitarian situation in Yemen continues to deteriorate. Poverty is widespread, malnutrition is on the rise and people are confronted by the daily threat of violence.

Pregnant women struggle to access medical care.

Infant and maternal mortality are on the rise as mothers and children bear the brunt of an increasingly brutal conflict.

MSF teams are providing urgent medical care to people caught up in this crisis. We work in 12 hospitals and health centres and support more than 20 hospitals and health facilities across the country.

We provide medical support in emergency rooms, maternity wards and outpatient departments, conduct surgeries, and run mobile clinics in rural towns and villages. The situation remains desperate. **We need your help now more than ever.**

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A quantum dilemma

An unhackable quantum internet comes with tough privacy questions

WHEN a powerful new technology comes around, people often split into two camps: those captivated by its benefits and those worried by the trouble it could unleash. This has happened with everything from knitting machines in the 16th century to artificial intelligence today.

It is, of course, a false dichotomy. As physicist and artificial intelligence researcher Max Tegmark put it in this magazine: "Are you the kind of person who thinks fire can kill people or the sort of person who thinks that fire can keep people warm in the winter? Both things are true, obviously." (18 July 2020, p 34.)

We are about to see this play out once again in the context of a technology that may come to define how we communicate in the 21st century: the quantum internet. It might seem like there is nothing wrong with the internet as we know it. Alas, not so. Quantum computers will eventually crack the encryption protocols that keep our web traffic secure, from bank transactions to private messages. This "cryptocalypse" could be only a few years away.

"It might seem like there is nothing wrong with the internet as we know it. Alas, not so"

Quantum communications offer an unhackable alternative. One of their key features is that their fundamental units of information, quantum bits (or qubits), are very delicate. If anyone tries to read an encoded message, they will inevitably leave signs of having done so. This unhackable world isn't as far away as you might think – as we report on page 36, we are already surprisingly good at making the infrastructure we will need to build it.

But as so often happens with tech advances, the unhackable privacy will cut both ways. The quantum internet will keep our credit card details secure, but it also means that people who want to talk in secret for nefarious purposes – whether it is terrorism or cybercrime – will have that option.

Democratic leaders have an abysmal record on policing our digital privacy. That needs to change, pronto. The quantum internet is coming, and when it arrives, it will make the privacy debate doubly tricky and unavoidable. As Tegmark put it: "The interesting question isn't to argue for or against fire, it is to figure out how you can manage fire wisely." ▮

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LAURENT GILLIERON/EPA-EFE/SHUTTERSTOCK

Tedros Adhanom Ghebreyesus speaks at the World Health Assembly

Immunisation

Call for joint vaccine push

The World Health Organization is urging countries to support a drive to vaccinate 30 per cent of the world this year, reports **Michael Le Page**

THE head of the World Health Organization (WHO) has called on member countries to support a massive drive to vaccinate at least 10 per cent of each country in the world by September and at least 30 per cent by December.

Tedros Adhanom Ghebreyesus, director-general of the WHO, announced the drive – dubbed "the sprint to September" – at the World Health Assembly meeting on 24 May. "Sprinting to our September goal means we must vaccinate 250 million more people in low and middle-income countries in just four months, including all health workers and the most at-risk groups as the first priority," he said.

The global initiative for sharing vaccines equitably, COVAX, has shipped 72 million doses to 125 countries, said Ghebreyesus. That is only enough for about 1 per cent of the people in those countries. "The number of doses available to COVAX remains vastly inadequate," he said.

COVAX had hoped to ship about three times as many doses by this point. It had been relying on doses of the Oxford/AstraZeneca vaccine made by the Serum Institute of India for the bulk of its supply. As the second wave of coronavirus cases in India worsened, the country stopped exporting the vaccine doses and diverted them for its own use. In a statement issued on 18 May, the Serum Institute of India said it hoped to resume deliveries to COVAX and others "by the end of the year".

That has left COVAX scrambling for alternatives. Ghebreyesus called on manufacturers to give COVAX first refusal on any additional vaccine doses, or to commit to supplying half of all they make to COVAX this year.

On 21 May, COVAX announced a deal to buy 200 million doses of Johnson & Johnson's vaccine, which would go a long way to meeting the September target. However, it isn't clear when these doses will be delivered.

Meanwhile, the US is building up a vast stockpile of doses that aren't being used and may not be needed. The US could have more than 300 million excess doses by the end of July, according to a report by the Duke-Margolis Center for Health Policy in Washington DC.

The US has said it will share 60 million doses of the Oxford/AstraZeneca vaccine, which is also manufactured in the US, but isn't approved for use there. Last week, President Joe Biden announced that the US would also share "at least an additional 20 million doses" of US-authorised vaccines by the end of June.

"We must vaccinate 250 million more people in low and middle-income countries in four months"

"I think we will see the US government do far more in terms of donations in the coming months," says Andrea Taylor at Duke University in North Carolina. "However, it is not at all clear that the US will redistribute these donated doses through COVAX, as the WHO is requesting."

The US has backed COVAX with funding, pledging $4 billion last December, but much more is needed – from everyone. The initiative of which COVAX is part faces an $18.5 billion shortfall this year alone, said Ghebreyesus, and up to another $45 billion will be needed to fully vaccinate all adults worldwide by the end of 2022.

Ali Mokdad at the University of Washington in Seattle says the WHO's 10 per cent goal is doable, but won't be easy, especially in large countries like Pakistan, Nigeria and Indonesia. Taylor, who has been monitoring vaccine supplies, is less optimistic. Most vaccine deliveries are meant to begin by September, she says, so unless something changes, it is unlikely COVAX will get enough doses in the next three months.

But the WHO sees the 30 per cent goal as essential. "This is crucial to stop severe disease and death, keep our health workers safe and reopen our societies and economies," said Ghebreyesus. ■

Virus resistance

Vaccines vs variants

New research on vaccine efficacy suggests it might be harder than we thought to stop the coronavirus's spread, reports **Michael Le Page**

IT SEEMS that every time we think we are turning the tide in the coronavirus pandemic, another new variant emerges. The latest threat is the B.1.617.2 variant that is playing a large role in the terrible outbreak in India and is spreading in many other nations. The big question is, will existing vaccines work well enough to prevent major new outbreaks?

We already know that several vaccines are somewhat less effective at preventing symptomatic infections by new variants. For B.1.617.2, the drop in efficacy appears to be small, but even a small drop matters when most people are only partially vaccinated or unvaccinated, says Deepti Gurdasani at Queen Mary University of London. "Any degree of escape at this point in time is concerning," she says.

A drop in efficacy not only means vaccinated people have a higher risk of being infected, it also makes it harder to reach the herd immunity threshold – beyond which the virus cannot spread widely – via vaccination. What's more, variants that are more transmissible raise this threshold, making it even harder to reach. There is growing evidence that B.1.617.2 is more transmissible than the B.1.1.7 variant first identified in the UK.

On the plus side, existing vaccines still appear to provide substantial protection against serious illness or death for all variants. "All these vaccines tend to be able to limit severe infection and hospitalisation against those different variants," says Jamie Triccas at the University of Sydney.

But there is still a risk. Ravi Gupta at the University of Cambridge says he has heard many reports from India of people dying despite being vaccinated, though mainly after having had just one dose. Control measures must therefore be maintained to keep infections down, says Gupta. "To open up with a partially vaccinated population is worrisome."

REUTERS/BRUNO KELLY

A health worker gives a dose of the CoronaVac vaccine in Anamã, Brazil

88%
Effectiveness of Pfizer/BioNTech vaccine against Indian variant

60%
Effectiveness of Oxford/AstraZeneca vaccine against Indian variant

100%
Effectiveness of most vaccines against death from older variants

In fact, says Gurdasani, modelling studies suggest that a more transmissible variant with some ability to evade vaccines could cause a bigger wave of hospitalisations and deaths in the UK than the one in January.

Establishing how well vaccines work against particular variants can be hard. Where new variants became dominant in countries as trials were carried out, we do have good data (see table, right).

For instance, a small trial of the Oxford/AstraZeneca vaccine was under way in South Africa as the B.1.351 variant evolved and spread in that country. In February, South Africa halted the vaccine's roll-out after the trial suggested it doesn't prevent most mild or moderate illnesses caused by B.1.351.

Similarly, trials showed that the Novavax vaccine is about 96 per cent effective at preventing symptomatic infections caused by older variants in the UK, about 86 per effective against the B.1.1.7 variant and about 51 per cent effective in South Africa, where B.1.351 was causing almost all cases.

Once a vaccine has been rolled out, its efficacy can be estimated in the "real world" by monitoring the vaccination status of people who test positive for a certain variant, or by looking at the proportion of cases with the variant relative to the main circulating virus and vaccination status.

On 22 May, Public Health

England (PHE) published this information for B.1.617.2. It found small, "non-significant" drops in efficacy against symptomatic infections for people who were fully vaccinated.

For the Pfizer/BioNTech vaccine, the study found 93 per cent efficacy against B.1.1.7 and 88 per cent against B.1.617.2 after both doses had been given. For the AstraZeneca vaccine, it was 66 per cent against B.1.1.7 and 60 per cent against B.1.617.2, after both doses.

But there was a bigger fall after just one dose. For both vaccines, one-dose efficacy was just 34 per cent against B.1.617.2, compared with 51 per cent against B.1.1.7.

A better way

These post roll-out studies can only be done when a variant is already widespread. Ideally, we would want to know sooner if new variants can escape vaccines.

One way to do this is to carry out neutralisation assays. These involve taking antibodies from vaccinated people, mixing increasing amounts with the virus and pouring it on cells to see what antibody level prevents infection, or "neutralises" the virus.

Nathaniel Landau's team at New York University recently showed that antibodies from people who had received the Pfizer or Moderna vaccines are two to threefold less effective at neutralising the B.1.617.2 variant. That is a relatively small decrease, says Landau. "Our prediction is that [these] vaccines are going to remain protective, certainly for the vast majority of people," he told *New Scientist* last week, before the PHE study came out.

But neutralisation studies don't tell us exactly how protective a vaccine will be. This is what Triccas and his colleagues are trying to address. In a paper published last week, they analysed data from several studies and identified a strong correlation between the level of neutralising antibodies that vaccines elicit and the amount of protection those vaccines provide against symptomatic infections.

This could give us a way to work out the efficacy of booster shots and new vaccines, and of existing vaccines against new variants, without carrying out expensive and time-consuming trials.

However, the model that Triccas and his colleagues have developed based on their findings has some worrying implications. For starters, we know that the level of neutralising antibodies wanes over time, which suggests that the efficacy of vaccines will wane too.

According to the model, the less effective a vaccine is, the faster its efficacy will wane. For example, a vaccine with an efficacy of 95 per cent would fall to 77 per cent after 250 days, but one with an initial efficacy of 70 per cent would drop to 33 per cent over the same time.

A similar effect would be seen with antibody-evading variants, the model predicts. So if a vaccine were, say, 95 per cent effective, a fivefold drop in the effectiveness of neutralising antibodies would reduce that to 77 per cent. A 70 per cent effective vaccine, however, would decline to 32 per cent.

This could be why there was such a big fall in the AstraZeneca vaccine's effectiveness against B.1.351 in the South African trial.

> **"Our prediction is that these vaccines will remain protective against variants for the vast majority"**

The PHE study shows signs of this too: "The reduction in vaccine effectiveness appeared to be greater with [AstraZeneca]," it says.

However, Landau isn't convinced Triccas's model is correct. The level of neutralising antibodies reflects how many B-cells you have churning out antibodies, says Landau. These factories stop producing antibodies over time, but they don't necessarily go away, meaning antibodies might be ramped up again very quickly.

Even if Triccas's team is right, decreasing efficacy against symptomatic infections doesn't necessarily mean people will get severely ill. Even a low level of neutralising antibodies can still provide protection, says Landau. "I think people will maintain antibodies for some time that will stop them getting very sick."

And in addition to antibodies, so-called T-cells also help protect us against severe disease. It is harder for viruses to escape the T-cell response than it is for them to evade antibodies.

But if the efficacy of certain vaccines rapidly wanes or is much lower against variants, it is going to be even harder than we thought to halt the virus's spread. We don't know what proportion of people must be immune to reach the herd immunity threshold, yet estimates range from 70 to 90 per cent.

Achieving this threshold requires very effective vaccines and very high vaccine uptake, especially if children aren't eligible, says Gurdasani. "It may not even be possible to achieve herd immunity with these new variants," she says. ■

Covid-19 vaccines offer varying protection against variants after all doses given

* Clinical trials ** Post roll-out data – no data

Vaccine	Variant: Older variants and B.1.1.7 (UK) – Symptomatic infection	Older variants and B.1.1.7 (UK) – Hospitalisation and death	B.1.351 (South Africa) – Symptomatic infection	B.1.351 (South Africa) – Hospitalisation and death	P.1 (Brazil) – Symptomatic infection	B.1.617.2 (India) – Symptomatic infection
Pfizer/ BioNTech	95%*	100%*	–	–	–	–
	87% to 95%**	94% to 99.99%**	72% to 75%**	100%**	–	88%**
Moderna	94%*	100%*	–	–	–	–
	90%**(all infections)	94%**	–	–	–	–
Oxford/ AstraZeneca	74%*	100%*	10%*	–	–	–
	66% to 70%**	–	–	–	–	60%**
Johnson & Johnson	72%*	100%*	64%*	–	51%*	–
	77%**	–	–	–	–	–
Novavax	86% to 96%*	100%*	51%*	–	–	–
	–	–	–	–	–	–
CoronaVac	65% to 91%*	–	–	–	50%*	–
	–	–	–	–	–	–
Sputnik V	92%*	100%*	–	–	–	–
	–	–	–	–	–	–

SOURCES: THE INSTITUTE FOR HEALTH METRICS AND EVALUATION, WWW.HEALTHDATA.ORG/NODE/8584; PUBLIC HEALTH ENGLAND

Analysis Breastfeeding

Is it safe to breastfeed my baby after a coronavirus vaccine? A lack of information about the impact of covid-19 vaccines on breastfed babies leaves new parents wondering what to do, says **Penny Sarchet**

FOLLOWING a change in official guidance in April, people who are breastfeeding in the UK have been given the green light to receive a covid-19 vaccination. But in the absence of any clinical trials proving that it is safe to have such a vaccine while breastfeeding, the onus appears to be on new parents to decide for themselves whether to go ahead and get jabbed. What research do they have to go on?

When it comes to safety for breastfed babies, "the vast majority of vaccinations are overwhelmingly safe", says Natalie Shenker at Imperial College London.

Shenker says there have only ever been two case reports of harm to an infant after a breastfeeding parent has been vaccinated, both from the live yellow fever vaccine. This vaccine, and the live smallpox vaccine, aren't usually offered to those breastfeeding, but previous research shows that all the standard, non-live types of vaccine don't get into breast milk, and we can probably expect this to be true for the more traditional covid-19 vaccines, such as the Oxford/AstraZeneca and Johnson & Johnson jabs. If no components make it into the milk, there is no way a vaccine could harm a baby.

New technology

What about mRNA vaccines, like Pfizer/BioNTech and Moderna, which use new vaccine technology? There are no worrying signs so far. One small, unpublished study showed that, between 4 and 48 hours after vaccination, no mRNA associated with the vaccine could be detected in the breast milk of five Pfizer/BioNTech recipients and one Moderna recipient.

As for side effects, Shenker told a recent online event hosted by the campaign group Pregnant Then Screwed that the UK's yellow card system (which enables the public to report adverse events to a drug) hasn't detected any significant spikes in side effects among those breastfeeding.

REUTERS/HANNAH BEIER

A woman waits for her covid-19 vaccine while holding her young baby

After giving birth, people are temporarily at higher risk than normal of blood clots, so should they be wary of clotting problems associated with vaccination? Speaking at the same event, Jo Mountfield, vice-president of the Royal College of Obstetricians and Gynaecologists, said that the clotting issue associated with the Oxford/AstraZeneca vaccine is an immune response unrelated to the increased risk of clotting experienced postnatally.

However, everyone under the age of 40 in the UK should now be able to opt for the Pfizer/BioNTech or Moderna jabs instead of the Oxford/AstraZeneca vaccine, if they prefer.

There are even signs that a vaccine might protect babies, too. A study published in March, of 31 lactating women who received the Pfizer/BioNTech or Moderna vaccines, detected vaccine-generated antibodies against covid-19 in all breast milk samples.

A second study, published in April, analysed milk samples from 84 women who had received two doses of the Pfizer/BioNTech vaccine, 21 days apart. It found high levels of a type of antibody called IgA in the milk, two weeks after the first dose.

Ilan Youngster at the Shamir Medical Centre in Israel, who worked on the second study, says that we already know from other respiratory diseases like influenza that IgA antibodies in breast milk can help protect babies from infection, and that the team thinks covid-19 is unlikely to be different.

There were three covid-19 outbreaks in families in the study in which an older sibling became ill but the breastfed baby didn't. "This is obviously not empirical proof, but is still a nice anecdote," he says.

There is some research to support this. In a non-peer reviewed study, Yariv Wine at Tel Aviv University in Israel and his colleagues tested the antibodies found in the milk of 10 women who had received both doses of the Pfizer/BioNTech vaccine. They found that antibodies from all of the women seemed to be able to neutralise the SARS-CoV-2 coronavirus.

Youngster thinks that any antibody protection from breast milk would probably only last for as long as a baby is breastfeeding. Once they are fully weaned, these antibodies decay. Any protection to the baby would also only last for as long as these antibodies continue to transfer into milk. Wine says that previous studies of vaccines for other diseases have found that vaccine-specific antibodies can persist in breast milk for at least one year.

So far, this research has mostly been carried out in countries that use the Pfizer/BioNTech or Moderna vaccines, so we don't know if other vaccines also lead to antibodies in breast milk.

The growing body of research around covid-19 vaccine-induced antibodies in breast milk hasn't gone unnoticed, and some vaccinated parents are wondering whether they should give breast milk to their older children too. It is an interesting idea, but there are no studies looking into this as yet.

"Antibodies against covid-19 were found in breast milk samples from the vaccinated women"

If you choose to have the vaccine while breastfeeding, one suggestion from several experts at the online event was to try to schedule your jab at least a week before or after any scheduled immunisations for your baby. This, they predict, will allow you to both get maximum benefit from each jab. As always, if you have any medical concerns, you should consult a medical practitioner. ■

Biology

How evolution makes new organs

The gene activity that formed a beetle's toxic cocktail may reveal how organs arise

Claire Ainsworth

A BEETLE'S poisonous punch is helping to uncover how new types of cells can arise and co-evolve to create organs – and these mechanisms may apply to more complex organs in animals, including humans.

A fundamental challenge that multicellular animals face is how to get different cell types to work together so that a higher-level function, such as that of an organ, emerges from their interactions, says Joe Parker at the California Institute of Technology. Yet biologists know relatively little about how this happens.

Many organs that are common across animal groups are complex and evolutionarily ancient, making it hard to unpick their origins. But the defence glands of a family of insects known as rove beetles are simpler and only about 100 million years old, much younger than ancient cell types, such as those for body fat or compound eyes, that all insects possess.

One species, the greenhouse rove beetle (*Dalotia coriaria*), has a pair of glands in its abdomen – composed of only two cell types – that secrete a solid toxin dissolved in an oily fluid. If attacked by a predator such as an ant, the beetle whips its flexible abdomen around and smacks a dab of this cocktail in the ant's face. The toxin triggers the ant's pain receptors, forcing it to retreat.

To uncover the evolutionary roots of this defence mechanism, Parker and his team used a technique called single-cell RNA sequencing to analyse the gene activity in the two cell types. This showed that one cell type produces the solvent, while the other makes the toxin.

An adult greenhouse rove beetle feeding on the larva of a fly

NIGEL CATTLIN/ALAMY

Comparisons with gene activity in other body cells revealed that the solvent cells had adapted existing suites of genes that govern cells elsewhere in the beetle's body: those that make up tissues in its equivalent of the liver and fat, as well as those that make chemical signals called pheromones. This remodelling allowed the new cell type to make oily solvent components.

The toxin cells, meanwhile, had repurposed existing metabolic genes along with those involved in colouring and hardening the beetle's external skin, its cuticle. "There are these pre-existing logics that the beetle has reused," says Parker.

In experiments, the researchers found that either cell type alone is insufficient to provide a survival advantage. When they blocked the activity of genes that govern either solvent or toxin production, and then placed beetles in an arena full of ants, fewer survived compared with beetles with intact secretions (bioRxiv, doi.org/gdhb). The loss of access to their full toxin cocktail reduced the beetles' survival rate by up to 30 per cent.

> "Cells create niches for each other and allow for the evolution of functions that otherwise wouldn't arise"

Parker suggests the solvent cells evolved first, perhaps providing oily lubricant for the beetle's segments. This created a niche for toxin cells to evolve, enabling a new function to emerge. Natural selection then began acting on the two cell types as a unit, further refining the contributions of each to optimise the new organ, he says.

"I think this is a nice way to phrase how organs evolve: by cells creating niches for each other, and in this way allow for the evolution of functions that otherwise wouldn't arise because they only make sense in a certain context," says Detlev Arendt at the European Molecular Biology Laboratory in Germany. ■

Robots

Tiny self-propelled submarines could help clean up waste

SUBMARINES are going microscopic. Tiny tubes about 10 micrometres long can propel themselves using only sunlight and can be steered by magnetic fields. These microrobots could be useful for cleaning up toxic waste.

Most swimming microrobots can't change depth easily: they float near the surface of a liquid or sink to the bottom.

The robot, built by Martin Pumera at the University of Chemistry and Technology in the Czech Republic and his colleagues, does have the ability to dive deeper or rise to the surface. It achieves this using a mechanism that loosely mimics the internal workings of a microorganism, says Pumera.

The tubular microrobots, which Pumera and his team have dubbed microsubmarines, are built with three main layers.

On the inside of the tube is a layer of cadmium sulphide, which takes in light and releases electrons. Those then react with water to split it into its constituent parts and generate a small amount of thrust. This pushes the tube forward at speeds of up to about 15 micrometres per second.

The middle layer is made of iron nanoparticles, which make it possible to steer the microrobot using magnetic fields.

Finally, comes an outer layer of titanium dioxide. When exposed to light, this catalyses reactions that degrade many chemicals, allowing the microsubmarine to clean up polluted water.

> "The microrobots broke down more than 70 per cent of two pollutants in water over 2 hours"

A group of microrobots were tested in water polluted with picric acid, which is an explosive, and a type of dye that can be harmful to the environment. Over 2 hours, they broke down more than 70 per cent of the pollutants (*Small*, doi.org/gjvxm7).

In practice, you would probably require large quantities of microsubmarines to clean up any significant amount of polluted water, says Pumera. These could then be retrieved with a magnet. ■

Leah Crane

How do we solve the problem of ransomware? The US oil pipeline that shut down after a cyberattack is just the latest victim in a growing wave, reports Matthew Sparkes

ON 7 May, hackers forced a major oil pipeline in the US to shut and prompted US president Joe Biden to declare a state of emergency. Within hours of the hack, which started the previous day, Colonial Pipeline Company paid a ransom of 75 bitcoin – worth $4.4 million at the time – to recover lost data.

According to the US Federal Bureau of Investigation (FBI), the hackers behind it were DarkSide, a criminal group that rents software to third parties to carry out cyberattacks in return for a share of ransoms. Retaliatory action from a US government agency has reportedly shut down DarkSide's systems.

Ransomware isn't limited to one bad actor. There are a host of competing, interlinked outfits that are large and difficult to prosecute. And as long as people keep paying the ransoms, the problem isn't going away.

Ransomware is an insidious type of malware that seizes data and threatens to release it publicly or destroy it if a ransom isn't paid. Regular backups can solve half that problem, but huge data leaks of customer or citizen information can still spell disaster. In a 2018 case, hackers released patients' private details and sensitive session notes from a chain of Finnish psychotherapy clinics, and then directly extorted the patients.

Many ransomware gangs are based in countries beyond the reach of Western law enforcement, which makes stopping them tricky. Nigel Leary at the UK's National Crime Agency says that perpetrators are often found to be Russian speaking, although their exact location can be hard to determine. But he says one thing is certain: groups like DarkSide have lowered the barriers to entry for ransomware attacks. Technical savvy is no longer a prerequisite.

FRANCOIS PICARD/AFP VIA GETTY IMAGES

Part of an oil pipeline that was targeted by hacker group DarkSide

Business consultancy Accenture says there was a 160 per cent increase in ransomware attacks in 2020 compared with the previous year. Some ransomware gangs are thought to have made hundreds of millions of dollars, and more than half of businesses pay up, says security firm Kaspersky.

It is so widespread that a recent cyberattack on Ireland's Department of Health was described by a minister as a "commonplace" event. Yet these hacks can have huge consequences. The WannaCry ransomware attack in 2017 reportedly cost the National Health Service in England £92 million.

The groups target a range of weaknesses, both technical and human. Updating software and educating staff will help, but in truth there is a game of cat and mouse between ransomware groups, software developers and law enforcement agencies – and no end in sight.

David Rose runs a small UK-based software company and was recently hit by just such an attack. "We had to take all the servers down. It just spread through everything," he says. "All our customers are running their businesses from the software, so all their customer details are in the database."

The attacker provided a bitcoin address for a ransom payment. Rose simply restored the servers from recent backups and refused to pay, but *New Scientist* investigations showed that at least one other victim did make a payment of the same amount requested to the same wallet.

Rose tried to report the matter to police via Action Fraud – a centralised reporting service run by the City of London Police – but was told in an email that "on this occasion the matter you reported to us cannot be classified as a police recorded crime". After further enquiries from *New Scientist*, the City of London Police said that the matter had been "misclassified" and would now be investigated.

160%
The increase in ransomware attacks from 2019 to 2020

$4.4m
The amount of ransom Colonial Pipeline Company paid out

50%
The minimum percentage of hacked firms that pay ransoms

UK home secretary Priti Patel said earlier this month that companies should stop paying ransoms. The same approach has long been advocated by the FBI. Insurance giant AXA has already said that it will no longer be reimbursing those who pay ransoms in France – a week before it was itself victim of a ransomware attack. It isn't known if that was direct retaliation or coincidence, or whether AXA chose to take its own advice.

Martin Lee at tech company Cisco agrees that companies should refuse to pay. "Anyone paying the ransom should be under no illusion that they are not contributing to the problem. They should also be aware that they are highlighting themselves as a profitable prospect for future attacks," he says. A payment is also no guarantee that an attacker will do what they promise, or that they won't come back for more cash.

One solution would be increasing the amount of resources available to investigate and prosecute these crimes, says Leary.

The takedown of DarkSide shows that states can take offensive action, but as long as attackers can hide behind borders free from prosecution or extradition, the problem is unlikely to disappear. ■

Gene therapy

Lost vision partially restored by optogenetics

Clare Wilson

A MAN who is blind has had glimmers of vision restored thanks to a high-tech treatment using optogenetics, which involves genetically altering nerve cells to respond to light.

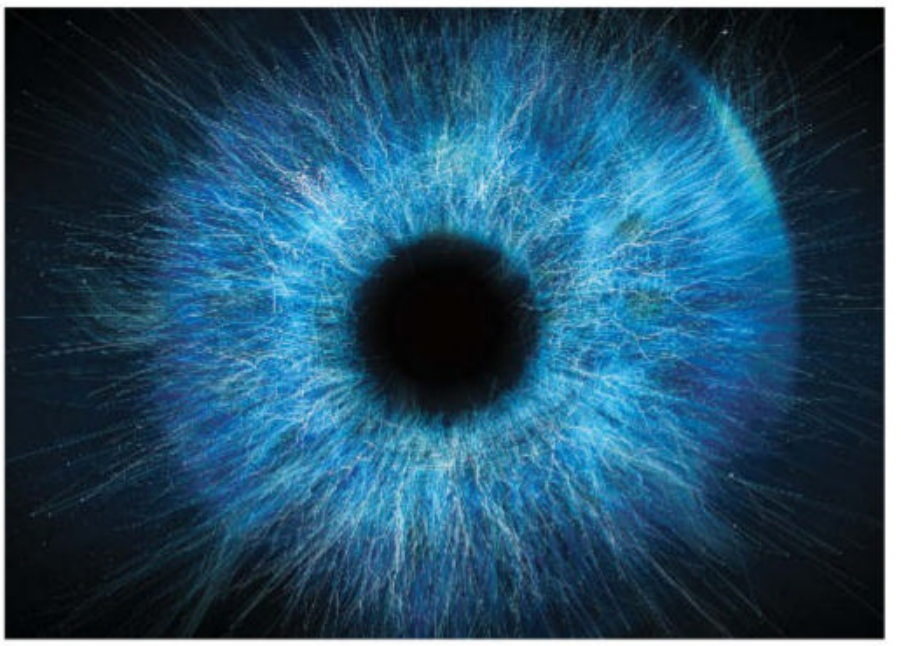
French firm GenSight Biologics has published results showing that the first recipient of its treatment can recognise different objects in lab tests. "It's exciting to see the first publication on human optogenetics," says Ed Boyden at the Massachusetts Institute of Technology, a co-inventor of optogenetics.

This field allows precision control over brain cells by altering them so they fire off a signal in response to light. It has led to many discoveries about the brain when used in other animals, but is thought to have limited medical potential for treating brain disorders in people, because getting light inside the head requires implanting a fibre-optic cable.

Several groups are trying to develop it as a treatment for blindness, though, because nerve cells in the eye are exposed to outside light. One targeted condition is retinitis pigmentosa, an inherited disease in which the retina, a disc of tissue at the back of the eye, gradually deteriorates and the light-detecting cells die.

"What's probably occurring is remodelling of the connectivity in the retina and the brain"

With GenSight's therapy, the nerve cells underneath the light-detecting layer are injected with a gene originally found in algae, which makes them fire in response to amber light. To be able to see, the recipients need to wear goggles with cameras and processors that turn ordinary light into amber wavelengths, and boost the signal so it can be detected by the altered cells.



GETTY IMAGES/ISTOCKPHOTO

People who are blind were injected with a gene found in algae

The first person to get this treatment, a 58-year-old man in France, found that, after about a year, he could see the black and white stripes of pedestrian crossings on the road. Since then, he has become able to perceive objects like a phone, furniture or a door in a corridor. In lab tests, he was able to count and locate objects in front of him – but he can't recognise faces (*Nature Medicine*, DOI: 10.1038/s41591-021-01351-4).

The man's vision may improve further because it takes time for the brain to learn to process the unusual signals from the eyes, says José-Alain Sahel at the Vision Institute in Paris, who is working with the GenSight team. "What's probably occurring is remodelling of the connectivity in the retina and the brain," he says.

Two people in the UK have received the same gene therapy, but haven't had any training or vision improvement yet. Four people have also recently received higher doses, which the team hopes will have greater benefits, says Sahel.

In its current form, the approach may not give good enough vision to allow reading or recognising faces, says team member Botond Roska at the Institute of Molecular and Clinical Ophthalmology in Basel, Switzerland. "For that you need very high resolution."

A US firm, Bionic Sight, reported in March that four people who had been blind or nearly blind could now perceive light and motion of objects in front of them thanks to its optogenetic treatment, but hasn't yet published a scientific paper on these findings.

Bionic Sight's treatment delivers a different gene to GenSight's, and also requires goggles. In a press release, Bionic Sight said that two people who received a higher dose of gene therapy had more of a rise in light sensitivity than the other two. ■

Space

Neutron star surfaces are incredibly smooth

Jonathan O'Callaghan

NEUTRON stars are so dense that their surfaces may only vary in height by up to 0.1 millimetres, thanks to their extreme gravity.

The remnant cores of stars that have gone supernova, neutron stars are among the densest known objects in the universe. They can contain up to twice the mass of our sun packed into an incredibly small space just two dozen kilometres across, the size of a city.

The intense gravitational pull of neutron stars means that their surfaces, a thin crust of hydrogen and helium, are flattened to an extreme degree, but there can be small bump-like deformations resulting from the star's activity. Now, new modelling has shown that these deformations are probably at least 100 times smaller than previously thought.

"Neutron stars are just incredibly spherical objects," says Fabian Gittins at the University of Southampton, UK. "It's really quite remarkable."

Gittins and his colleagues modelled different forces acting on neutron stars and found that any deviations in the surface could reach only 0.1 millimetres high before the crust fractured (arxiv.org/abs/2105.06493).

"We found a number of assumptions were made that were incorrect," says Gittins. "Previous work forced the stars into a shape that isn't physically possible." The causes of the deformations could include the cooling of the star, its spin rate changing or the accretion of material from another star, the team found.

Astronomers had thought that variations in a neutron star's surface might deform space-time enough to produce gravitational waves that we could detect, but this latest work suggests that they might be harder to spot than hoped. ■

Mathematics

AI shoots down mathematical ideas

Humans now have help in searching for examples that disprove conjectures

Matthew Sparkes

AN ARTIFICIAL intelligence has disproved five mathematical conjectures despite not being equipped with any information about the problems.

Adam Zsolt Wagner at Tel Aviv University in Israel used an AI approach to search for examples that would disprove a range of long-standing conjectures, which are unproven theorems. Wagner focused on graph theory, an area of maths that involves studying objects made of nodes and links. Mathematicians thought these conjectures were true, but hadn't been able to prove them.

For each conjecture, Wagner created a measure of how close an example was to disproving it. For instance, if a conjecture proposed that a certain problem couldn't be solved in fewer than five steps, an example with six steps would be closer to a disproof than one with seven, and a solution with four steps would serve as a counterexample to the conjecture.

Wagner programmed a neural network to come up with random examples and use the measures he created to assess each one's suitability as a counterexample. The AI got rid of the worst scoring ones and replaced them with more random examples before starting again. In five cases, it landed on a solution which showed that the conjecture must be false (arxiv.org/abs/2104.14516).

Wagner ran the AI on his 5-year-old laptop, which took anything from a couple of hours to a couple of days to disprove each of the five conjectures. The results were often counter-intuitive, he says. "I would never have come up with these constructions by myself even if you gave me hundreds of years."

"It's completely impressive," says Leslie Hogben at Iowa State University, who had one of her conjectures disproved by the AI. "What we're seeing here is a huge benefit of artificial intelligence with no downside, from a mathematical perspective. It's simply finding stuff for us, the way someone with great insight could. The counterexamples are needles in haystacks."

"This is a huge benefit of artificial intelligence with no downside, from a mathematical perspective"

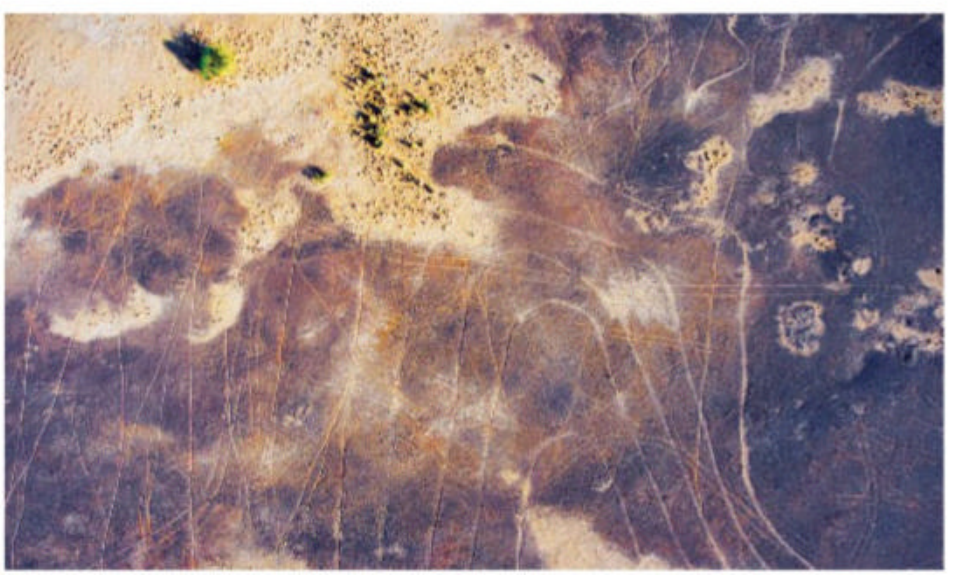
While the AI has succeeded in disproving conjectures, proving them is much harder. To disprove an idea requires creating and testing a vast number of potential solutions to see if any contradict the conjecture, a mechanistic task that can be automated, but a proof is a creative work that requires insightful leaps and stringing together many logical steps.

The first theorem to be proved with the help of a computer was the four colour theorem, which states that any map can be coloured using only four colours so that there are no two countries of the same colour touching. The proof, found in 1976, involved using a computer to check an exhaustive list of examples. Although considered inelegant by some at the time, the use of computers to solve mathematical problems has since become much more prevalent.

Still, Hogben says it is important that human mathematicians should always be able to follow the work of such AIs. "I personally would never have a problem with a disproof that can be verified. A computer proof that is not verifiable by hand, I would personally have some concerns about. To me, that breaks the gold standard of mathematics." ▮

Archaeology

The biggest drawing ever made may be a spiral found in India



YOHANN OETHEIMER

A section of the recently discovered geoglyphs near Boha in India

A HUGE spiral carved into the ground in India covers almost 100,000 square metres, dwarfing other individual geoglyphs like those in the Nazca desert in Peru.

The spiral is in a small cluster of geoglyphs discovered by researchers Carlo and Yohann Oetheimer, based in Luriecq, France. Carlo searched Google Earth images of the Thar desert in India and identified eight sites with possible geoglyphs. In 2016, they flew a drone over them and found that three were furrows dug for failed tree plantations.

One site was near the village of Boha. Using the drone there, the Oetheimers identified four distinct symbols, which they then visited. Each line in the geoglyphs is 20 to 50 centimetres wide and was made by scraping away sand and silt.

The central symbol is a roughly oval spiral that is 724 metres long and 201 metres wide, made of a single 12-kilometre line. To the immediate south-west, there is a second line that repeatedly bends back on itself, forming a grid of parallel lines. Two smaller geoglyphs to the north and south-west are heavily eroded (*Archaeological Research in Asia*, doi.org/gjztrs).

"The report is convincing," says Daniela Valenzuela at the University of Tarapacá in Arica, Chile. The spiral dwarfs all other known geoglyphs. Peru's Nazca Lines cover a much wider area, but none of that site's figures are especially large: one bird figure is 300 metres long and a shape thought to be a labyrinth is made up of one 4.4-kilometre line.

The Oetheimers suspect the Boha geoglyphs are at least 150 years old because they have been eroded by wind, and plants have grown on them in places. But they have no further evidence to shed light on their age, meaning or purpose. ▮

Michael Marshall

Animal behaviour

Birds know to hide from predators before they hatch

Jake Buehler

THE world is a dangerous place for young birds, and it seems that even as embryos, some take measures to hide from predators.

Late in embryonic development, many bird species will communicate with their parents through the eggshell by chirping. Kristal Kostoglou at Deakin University in Melbourne, Australia, wanted to know if these talkative embryos have the predator-avoiding instincts of hatched chicks, which hide and fall silent when threatened.

Kostoglou and her team exposed the eggs of two Australian shorebird species – 56 eggs of the red-capped plover (*Charadrius ruficapillus*) and 299 of the masked lapwing (*Vanellus miles*) – to different signals of a predator approaching. These included predator calls, increased parent heart rate sounds or changes in light levels resulting from a parent bird moving off the nest. The team then recorded how often the embryos called under these conditions.

> "Many bird species will communicate with their parents through the eggshell by chirping"

The researchers didn't find any effects from a change in light or heart rate, but the embryos of lapwings went from calling just over once per minute under white noise, to once over 3 minutes when exposed to the sounds of egg-eating little ravens (*Corvus mellori*), suggesting they were trying to avoid predators. The plovers' call rate was about four times per minute under white noise, but dropped to twice per minute with the predator noises (*International Journal of Avian Science*, doi.org/gjw792).

Jose Noguera at the University of Vigo in Spain says these findings "clearly show that embryos are not passive agents to external cues". ▮

Analysis Space exploration

More people are going to space, but who will get to fly?

Civilians in orbit will generally have to be rich, young and physically fit, says **Leah Crane**

FELIX KUNZE/BLUE ORIGIN

Blue Origin is auctioning off a seat on its first crewed flight

SPACE isn't just for the professionals now several high-profile rocket-makers are gearing up to send civilians above the atmosphere. But with price tags in the millions, we are still far from the long-awaited democratisation of space flight.

Many of these civilian space flight opportunities are being run as contests, auctions or raffles. Blue Origin is auctioning off a seat aboard its very first crewed flight on the New Shepard suborbital rocket – as of 24 May, the price had reached $2.8 million.

SpaceX's Inspiration4 mission, planned to launch into orbit on 15 September, has an all-civilian crew, with one member selected by raffle and another by a competition. Meanwhile, the Discovery TV channel has announced a programme called *Who Wants to Be an Astronaut?* in which the winning contestant will go to the International Space Station (ISS), and there are plans for scenes from two films to be shot there in September, one starring Tom Cruise and another titled *Challenge* with Russian actor Yulia Peresild.

Then, in December, Japanese billionaire Yusaku Maezawa plans to take a Russian Soyuz rocket to the ISS for 12 days, along with his production assistant. He has already announced plans to fly around the moon on one of SpaceX's next-generation rockets in a flight currently set for 2023 and is running a contest for eight artists to join him.

This kind of space tourism isn't new: in the early 2000s, seven individuals who weren't professional astronauts flew to the ISS aboard Soyuz spacecraft. This ceased when the US Space Shuttle programme ended in 2011 because at that point Soyuz became the only way to get to the ISS. Now SpaceX has a craft that can bring humans to the ISS, and Boeing is working on another one. With more ways to get to space comes the possibility to launch a larger variety of people – but who, exactly?

Japanese billionaire Yusaku Maezawa has booked multiple trips to space

REUTERS/KIM KYUNG-HOON

While the costs of most of these flights haven't been released, the going rate is around $50 million, so the majority of us will still only be able to experience space flight through a screen, unless we get very lucky in a competition.

And money isn't the only barrier to orbit. When the Russian space agency was looking for a female actor to be in *Challenge*, it sought someone between the ages of 25 and 40, weighing 50 to 70 kilograms and physically fit. She will have to undergo some of the training that government-employed astronauts go through, including centrifuge testing and training on parabolic flights.

The same is true of all the other non-government folk heading to space, even if they aren't going all the way into orbit. The Blue Origin suborbital flight carries requirements for height, weight, physical fitness and dexterity, along with the ability to speak and listen to instructions in English.

There are programmes looking to broaden the range of people who can go to space. For example, the European Space Agency is running a "parastronaut feasibility project" studying adaptations to send individuals with physical disabilities to space. The project website says: "Right now we are at step zero. The door is closed to persons living with disabilities." Getting to a point where any member of the public can go to space will take work – and it remains to be seen whether private space flight companies are willing to put in the effort. ▮

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Energy

The hydrogen games

Japan plans to use the Tokyo Olympic and Paralympic games to tout the benefits of a hydrogen society. **Alice Klein** reports

DESPITE a surge in covid-19 cases, Japan is doggedly pushing ahead with its preparations for the Tokyo Olympic and Paralympic games. In January, Prime Minister Yoshihide Suga said they should continue as "proof of human victory against the coronavirus". But there is another reason too: Japan wants to use the events to showcase its efforts to become a "hydrogen society" and to inspire other countries to join it.

To do so, Japan is making heavy use of Olympic symbols. The Olympic torch is being partly fuelled by hydrogen as it makes its way through Japan, even as some parts of the relay are cancelled due to coronavirus concerns. When the games begin in July – unless they are derailed again – the Olympic cauldron will also be powered by hydrogen. And a hydrogen station has been built near the athletes' village for refuelling the hydrogen-powered buses and cars that will ferry competitors to and from venues.

Japan is one of the growing number of countries that aim to achieve net-zero greenhouse gas emissions by 2050. But its transition to renewable energy is trickier than it is for others, since it has limited free space for building vast solar and wind farms to replace fossil fuels. It has installed floating solar plants on many of its lakes and is planning large offshore wind farms, but these alone cannot supply enough energy for its 126 million people.

To fill this gap, Japan has decided to bet big on hydrogen energy. It wants to power at least 5 million homes and 800,000 vehicles, including 1200 buses, using hydrogen by 2030, and is also researching its potential use in powering trucks, ships, trains, aircraft and industries like steel-making. It has established a 2 trillion yen ($18 billion) Green Innovation Fund that will help to support this expansion. In December 2020, more than 80 Japanese companies, including giants like Toyota and Kawasaki Heavy Industries, agreed to work together to help the nation achieve its hydrogen goals.

REUTERS/KIM KYUNG-HOON

The start of the Olympic torch relay in Naraha, Japan, on 25 March

5 million

The number of homes that Japan wants to power with hydrogen by 2030

Hydrogen has several big pluses. It can be used in fuel cells to generate electricity with zero emissions. It can be stored for long periods and transported great distances. It can power everything from homes and vehicles to heavy industry. And it has the highest energy content of any common fuel by weight – almost three times that of petrol. "The advantages of hydrogen are applicable to all the world, not just Japan," says Jonathan Arias at juwi Shizen Energy, a renewable energy company in Japan.

The biggest drawback of hydrogen is its high cost. To make the fuel cleanly – so-called green hydrogen – water must be split using expensive electrolysers powered by solar or wind energy. Then there is the cost of the associated infrastructure, including specially designed trucks, ships and trains to transport hydrogen safely at the right temperature and pressure, along with facilities to store and distribute it.

"The advantages of hydrogen are applicable to all the world, not just Japan"

Hydrogen can be made cheaply from natural gas, but this cancels out its green credentials. A report published by the International Renewable Energy Agency last year predicted that green hydrogen could compete with fossil fuel-derived hydrogen by 2030, but noted this would require "global collaboration".

Enter the Olympics and Paralympics. Japan hopes the games will generate enough hype around hydrogen to galvanise this collaboration, says Arias. If the rest of the world embraces hydrogen energy, it will drive down the cost through competition and economies of scale, he says. "If there's mass-scale production, it will help to reduce prices."

The hydrogen for the games will be made at the world's largest solar-powered electrolyser for hydrogen production, which opened in 2020 in Fukushima prefecture, the area devastated by the 2011 earthquake and tsunami. It will be transported by truck to a refuelling station near the athletes' village. There it will be used to fill up the cars and buses that will drive competitors

around. The vehicles' fuel cells will power electric motors.

After the games, the athletes' village will be converted into the world's biggest hydrogen-powered neighbourhood. Hydrogen will be piped to fuel cells in public areas to power lights and air conditioning. Each of the 4100 apartments will also have a hydrogen fuel cell to heat water systems and provide a small amount of electricity – enough to power low-energy devices like smartphones – alongside regular grid power.

"It will be the first town in Japan that puts into practical use hydrogen stations, hydrogen pipelines and hydrogen fuel cells at full scale," says Katsuhiko Nagata at Panasonic, the company providing the neighbourhood's fuel cells. However, until green hydrogen becomes more affordable, the hydrogen used will be made from natural gas at an on-site station, he says.

To reduce the cost of green hydrogen, Japan's government has promised to invest in technological innovations and to seek to import it from countries that can make it more cheaply. In particular, it has set its sights on Australia, which has ample sunshine, wind and empty space that make it perfect for producing this fuel.

Australia recently approved a 6500-square-kilometre hydrogen production facility in which 10 million solar panels, 1500 wind turbines and an electrolyser should create green hydrogen for less than $2 per kilogram, making it competitive with hydrogen derived from fossil fuels. Kawasaki has built the world's first liquefied hydrogen carrier ship, the Suiso Frontier, for transporting Australian hydrogen to Japan.

At this price, more countries may start considering using hydrogen on a large scale, says Zhenguo Huang at the University of Technology Sydney in Australia. One of the best things about hydrogen is that it can be used to store energy, he says. Solar and wind energy can be stored using batteries, but these are made from materials – like nickel and cobalt – that are in limited supply, and they gradually lose energy over time. If solar or wind power is converted via electrolysers to hydrogen instead, it can be stored indefinitely and used any time, says Huang.

Hydrogen-powered buses will ferry competitors to venues

AFLO/SHUTTERSTOCK

The final hurdle to widespread hydrogen adoption is convincing the public that it is safe, says Huang. The Hindenburg disaster, in which a hydrogen-filled airship exploded in 1937, has given the fuel a bad rap, he says. "But it's actually safer than gasoline when properly managed."

Modern hydrogen tanks are made from tough carbon fibre and can withstand gunshots without exploding, he says. "Even if they did crack, because hydrogen is so light, it would just shoot into the air." Hydrogen did leak out of a refuelling station in Norway in 2019 and catch fire in the open air, but no one was hurt. In contrast, cracked oil and petrol tanks leak liquid fuel that can burn for a long time or spill into the ocean.

Certainly, it seems that excitement around hydrogen is building. One silver lining of the pandemic is that several countries have announced big investments in hydrogen to help rebuild their economies (see "The main competitors", left). Germany, for example, has committed €9 billion, while South Korea's Korean New Deal lays out a plan to produce 200,000 hydrogen vehicles by 2025. And in March, John Kerry, the US special presidential envoy for climate, called hydrogen a "jump ball" with "huge opportunities". Even if hydrogen can't show off its tricks at the Olympics due to last-minute cancellation, it still looks set to become a winner. ■

"If solar or wind power is converted to hydrogen, it can be stored indefinitely and used any time"

The main competitors

In 2017, Japan became the first country to publish a national hydrogen strategy, which set out an action plan for becoming a "hydrogen-based society" by 2050. Since then, several other countries have followed suit, including:

Australia
Aims to make cheap green hydrogen on a massive scale to export and use domestically.

Canada
Wants to be one of the world's biggest suppliers of green hydrogen, use hydrogen for 30 per cent of its energy needs and have over 5 million hydrogen vehicles on the road by 2050.

France
Has committed €7.2 billion to producing green hydrogen and having up to 700,000 cars, 90,000 trucks, 2400 buses and 180 trains powered by hydrogen in operation by 2030, along with 1100 hydrogen-refuelling stations. Hydrogen energy will also be used in homes and industry.

Germany
Has earmarked €9 billion for producing green hydrogen. It also aims to build the world's largest hydrogen grid and to use hydrogen in industries like steel-making.

South Korea
Wants to have 6.2 million hydrogen cars and 1200 hydrogen-refuelling stations operating by 2040. The country also aims to make hydrogen-powered buses, trucks, trains and ships, and to use hydrogen energy for industry and in homes.

RICHARD BECKER/ALAMY

Animal behaviour

Ants may hold the key to an eco-friendly spider repellent

HOUSE-DWELLING spiders avoid surfaces that certain aggressive ants have walked on, suggesting some sort of chemical the ants leave in their wake could form the basis of an ecologically sound way to keep spiders out of people's houses.

Andreas Fischer at Simon Fraser University in Vancouver, Canada, has been seeking practical ways to maintain ecosystems while keeping arachnophobic people comfortable in their homes. He says commercial pesticides "kill everything", while "natural" spider repellents like lemon zest have little to no effect.

Recently, Fischer realised other scientists were noting that where they found more ants, they found fewer spiders. To investigate, Fischer and his team gathered three different species of ant and females from four spider species commonly found in North America. They let ants of a particular species run on filter paper in part of a glass cage for 12 hours. Then they removed the ants and put young, female spiders, one at a time, into the cage and watched to see where they chose to settle after 24 hours.

Most black widows (*Latrodectus hesperus*), false widows (*Steatoda grossa*) and hobo spiders (*Eratigena agrestis*) avoided the paper walked on by European fire ants (*Myrmica rubra*), says Fischer. A fourth species, the cross spider (*Araneus diadematus*), showed a similar trend, but not as strong (*Royal Society Open Science*, doi.org/gddr).

The team doesn't know what the spiders are detecting – it could be an ant pheromone – but it aims to find out and make versions for home use. **Christa Lesté-Lasserre**

Nature

World misses ocean conservation target

NATIONS have hit a global target for creating protected areas on land, but failed to do so for oceans, the United Nations Environment Programme (UNEP) has found.

In 2010, world leaders agreed to tackle species extinctions and biodiversity decline by expanding protections, such as national parks and marine reserves, to 17 per cent of land and 10 per cent of coastal and marine areas by 2020.

UNEP found that while only 16.64 per cent of land had been officially reported as protected by 2020, it was clear from other data that the 17 per cent goal was exceeded. However, just 7.74 per cent of oceans were protected, including the Mayotte Marine Natural Park in the Comoros Islands. Even several large pending marine protected areas won't close the gap.

Despite that shortfall, the numbers should be welcomed, says Neville Ash at UNEP. "It's good news. There has been tremendous progress both on land and at sea in the last decade."

The reason ocean protection is lagging appears to be due in part to the sheer size of seas relative to terrestrial areas and the challenge of getting international waters designated as protected, says Ash.

Despite the growth in reserves, we still have a rate of biodiversity loss unseen for millions of years. "Protected areas are a core part of stopping biodiversity loss, but in themselves are insufficient," says Ash. He believes we also need more fundamental changes, such as redirecting subsidies for fishing and fossil fuels to nature.

Countries have also failed to focus on the quality of protected areas as well as the quantity, he adds. It is hard to even know what the quality is like in many places – UNEP found less than a fifth of the protected areas have been assessed. **Adam Vaughan**

Bionics

Robotic extra thumb is controlled by toes

PEOPLE equipped with an extra, robotic thumb learned to control it with their toes – but prolonged use may come at a cost of their brains being less certain about how their hands work.

Danielle Clode at University College London and her team gave 36 people a prosthetic thumb that wrapped around their wrist and sat underneath their little finger. All were right-handed, and wore the device on their dominant hand.

DANI CLODE

The extra thumb was controlled by sensors attached to the user's big toes, with communications sent using wireless technology. By wiggling each toe, the augmented humans could move the thumb in different directions and make it grip. For five days, participants were encouraged to use the thumb.

The extra digit could cradle a cup of coffee while the same hand's forefingers held a spoon to stir in milk, for instance. Some participants used the thumb to flick through pages of a book they were holding in the same hand. The average user wore the thumb for just under 3 hours a day.

To see how the thumb affected people's brains, they were given an MRI scan before and after the trial. The brain perceived each finger on the hand with the thumb as more similar to each other than before. A third scan, a week after the test ended, showed these changes wearing off (*Science Robotics*, doi.org/gdd3). **Chris Stokel-Walker**

Really brief


MARTIN ZWICK/REDA&CO/UNIVERSAL IG/GETTY IMAGES

Greenland ice sheet is releasing mercury

As glaciers grind over the ground, they free up mercury in rocks. A study suggests that each year, 42 tonnes of the toxic metal may be released from the south-west of the Greenland ice sheet. This can build up in fish eaten by local people (*Nature Geoscience*, DOI: 10.1038/s41561-021-00753-w).

Growth in number of 'zombie' fires?

Forest fires that smoulder over winter and reignite in spring may be becoming more common in Alaska. A model based on satellite data collected between 2002 and 2018 links the so-called "zombie" fires with warm summers, which occur more often now due to climate change (*Nature*, doi.org/gj4b3k).

Swifts can fly vast distance each day

During migration, common swifts (*Apus apus*) can fly 570 kilometres per day on average – and the fastest ones covered 832 km a day. The discovery comes from a tracking survey of the birds. Previous work had predicted that this species only covered about 500 km each day (*iScience*, doi.org/gddv).

Technology

AI uses body cam to assess calorie intake

AN ARTIFICIAL intelligence that interprets images from wearable cameras can identify food and accurately estimate its weight to determine how many calories and nutrients a person is consuming. This could prove useful for automating dietary research.

Benny Lo at Imperial College London and his colleagues asked 13 people to wear cameras around their chests or on their glasses to capture images at mealtimes. The pictures that showed food were annotated by dieticians and the meals were weighed. The images and data were then used to train an AI known as a neural network to identify food types and estimate volume and nutritional content.

The system continuously monitors subjects, so it can also determine how much of a meal was eaten rather than just the size of the meal served.

Lo's team then got the AI to analyse new images from the wearable cameras, and weighed the meals to compare them with the estimates. The computer did better than humans at estimating the calories being consumed – it had an error rate of 37.6 per cent compared with the human error rate of 48.8 per cent (arxiv.org/abs/2105.03142).

Nutritional research has often relied on people self-reporting what they eat, but this can yield poor data because of bias and memory slip. It is also labour intensive. Much research has been done on automatically estimating calories in a meal from a photo taken before eating, but this doesn't take into account any leftovers. **Matthew Sparkes**

Space


NASA/JPL/USGS

Dangerous sun activity could hamper return to the moon

SOLAR storms that can injure or kill astronauts are more likely at certain times in the sun's 11-year cycle, a finding that should inform plans for a crewed return to the moon.

It was thought these big storms occur randomly, says Mathew Owens at the University of Reading, UK. One problem is only six major storms have occurred in the past 150 years, so there is a lack of data.

To address this, Owens and his team used Monte Carlo statistical techniques. They first created one simulation of the sun in which extreme storms occurred randomly and another where they were more likely at the peak of the sun cycle.

Then they sampled data from each model many times and looked to see how often this correlated with the small amount of real data we have. The team was able to work out with 99 per cent confidence that these big storms were more likely at the peak of the solar cycle.

The work also suggests that extreme space weather is more likely late in odd-numbered sun cycles, such as cycle 25, which began in December 2019 (*Solar Physics*, doi.org/gdbv). This means that space weather is likely to be better in the first half of this decade for any return of humans to the moon, says Owens. MS

Ecosystems

True devastation of Amazon blaze

WILDFIRES that swept the central Amazon in 2015 caused a loss of around 27 per cent of vegetation there over the next three years.

The fires were caused by severe drought after the potent 2015 El Niño, a climate pattern that sees the central and eastern Pacific Ocean surface warm, leading to extreme weather across the world.

Wildfires during this period burned an estimated 9246 square kilometres of the Amazon in total, even affecting the central region, which is historically wet and fire-resistant. Aline Pontes-Lopes at the National Institute for Space Research in São Paulo, Brazil, and her team have measured how plants in the central Amazon fared in the three years after the fires.

They created 18 study areas, each 250 metres by 10 metres, across the central Amazon in the northern Purus-Madeira of Brazil in December 2015. Every subsequent November until 2018, they measured the impact of fire damage on each plant.

Over the three years after the fires, 27 per cent of the plants died (*Proceedings of the Royal Society B: Biological Sciences*, doi.org/gdd8). The results suggest the strongest fire events are still felt in the wetter parts of the forest. **Karina Shah**

Comment

The power of fusion

Archaeology and genetics may seem worlds apart, but they are combining to produce astonishing insights, says **Alice Roberts**

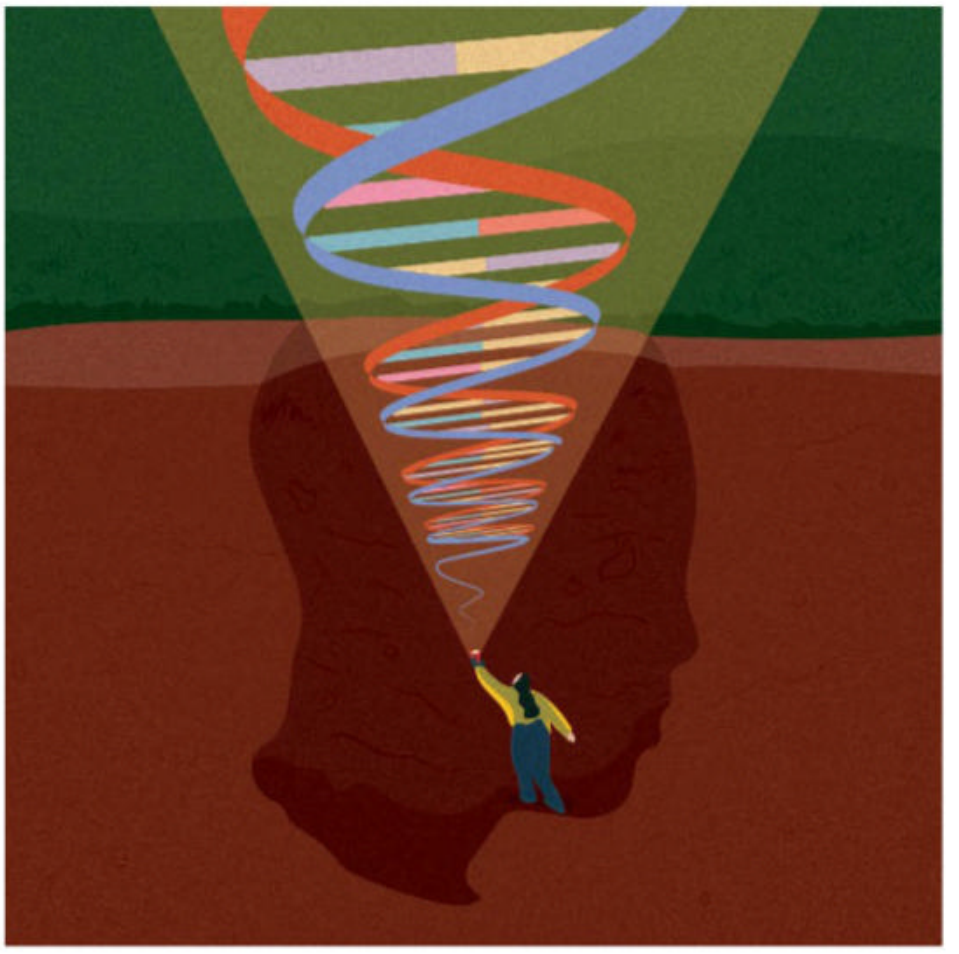
TWO seemingly disparate scientific disciplines have been drawn into each other's orbits, set on a collision course. On one side is archaeology with its grimy earthiness, heavy with history and tradition; on the other is genetics, with its clinical brightness, brave and brash in its newness. Fusion can be difficult, but it can also create astonishing energy when it happens.

At the forefront of this merging is a new sequencing project called 1000 Ancient Genomes. Led by Pontus Skoglund at the Francis Crick Institute in London, it is the most ambitious ancient genomics project to date. The DNA it looks at will be completely sequenced, leaving no stone unturned, no stretch unread.

It is two decades since the human genome was first sequenced, and the pace of change in genetic technology in the intervening years has been breathtaking. Sequencing is now faster by several orders of magnitude – a human genome can now be deciphered in a day. And with DNA extracted from ancient bones, we are able to uncover the genetic secrets of our ancestors.

An ancient genome can reveal the sex of an individual and provide clues to their appearance. For example, the DNA of Cheddar Man, a 10,000-year-old skeleton found in Somerset, England, revealed that he was likely to have had quite dark skin and blue eyes – a combination that is rare today.

But the archaeogenetic revelations become even more fascinating when we start to compare genomes from different individuals, casting light on patterns of relatedness.



MICHELLE D'URBANO

Recent analyses of individuals from Neolithic tombs in the UK and Ireland have revealed a daughter buried in the same tomb as her father, two brothers buried together, and a man whose parents were either siblings or parent and child. These findings help us to understand what society was like in these places 5000 years ago.

Wider studies can also shed light on population movements in the past. One recent revelation has been the changes that came with the appearance of the Beaker culture in Britain and Ireland, with genomic data showing a 90 per cent population turnover in the third millennium BC.

This information was met with consternation by some archaeologists. Did a mass of invaders sweep in and take over? Some headlines stoked that idea, suggesting that "Dutch hordes" had killed off the "Britons who started Stonehenge".

The language we use is crucial. Archaeologists take "migration" to mean a very deliberate, large-scale movement of people: a forced relocation or a planned invasion. However, to geneticists, it simply means people moving and having children somewhere different. Such a migration could happen over many generations. Differences in concepts and definitions can lead to misunderstanding.

The lesson is that both fields must also heed their differences. "There has to be continuing dialogue," says Tom Booth, who works on the 1000 Ancient Genomes project. "We may never agree on what terms to use, but we might at least understand each other's perspective."

If the potential of the fusion between archaeology and genetics is to be realised, both sides need to work on dismantling the language barrier between them – and to work out how to communicate these new ideas more publicly, without sparking inflammatory (and meaningless) headlines. Perhaps it will take a new generation of archaeogeneticists to successfully fuse the disciplines.

As Pooja Swali, who is also involved with the 1000 Ancient Genomes project, says: "I think you'd be struggling to find an archaeology course now that didn't cover ancient DNA."

Archaeogenetics is coming of age, and we can expect many more revelations in the years to come. ■

Alice Roberts's new book, *Ancestors: The pre-history of Britain in seven burials*, is out now

Field notes from space-time

Big bangs in the universe

The explosions of supernovae are so powerful they can be seen with the naked eye. The physics behind them is harder to uncover, writes **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an assistant professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her research in theoretical physics focuses on cosmology, neutron stars and particles beyond the standard model

Chanda's week

What I'm reading
I'm working my way through Moya Bailey's Misogynoir Transformed: Black women's digital resistance.

What I'm watching
I recently saw and was not impressed by Tenet.

What I'm working on
Next steps with our neutron star research: understanding what is inside, including maybe dark matter!

This column appears monthly. Up next week: Graham Lawton

FOR all the talk about a mysterious big bang at the start of the universe, we actually don't have to go back too far in history to see big bangs. Some stars, like our sun, will end their lives rather quietly, slowly blowing off layers, possibly destroying solar systems in their wake, and leaving behind beautiful structures that garnered the name "planetary nebulae" before we understood what they were. But other, more massive, stars will go out in a fabulous phenomenon called a supernova, where the outer layers of the star collapse onto its core, igniting an explosion.

Supernovae are quite sudden and have at points in history been observed with the naked eye. The most famous example is Supernova 1006, so named because it occurred in the year AD 1006. Records from across Asia and North America indicate that communities around the world noted its occurrence. These explosions are so powerful that they can produce elements that can't be made in stars, which can only make atomic elements as heavy as iron.

Supernovae can also occur when a white dwarf ends up in a binary orbit with what we call a companion star. White dwarfs are themselves the remnants of long-gone stars – our sun is expected to leave behind a white dwarf one day. A typical white dwarf will have about 70 per cent of the mass of the sun, squeezed into at most 2 per cent of the sun's radius. They are held together by gravity, but don't collapse into a black hole because of quantum pressure between their many electrons.

As these little ghosts wander through their home galaxies, they sometimes cross paths with regular stars and become gravitationally entangled, forming a binary relationship. The white dwarf's gravitational pull can begin to rip gas away from its companion, ultimately grabbing on to more than it can handle, leading to an explosion. This is another kind of supernova – a type Ia supernova – to be distinguished from the collapse of supergiant stars described above, which are type II supernovae.

As these explosions occur, multiple transitions are happening: the gases and plasma in the explosion are being blown off at high speeds and also at such high energy that they can engage in forms of nuclear fusion that can't happen in their progenitor (ancestor) stars.

> "Supernovae are so powerful that they can produce elements that can't be made in stars"

One of two things is thought to happen. In one scenario, a black hole forms at the centre of the supernova, a phenomenon in which there is such an enormous concentration of mass that the structure of space-time is radically different from what we consider to be normal. These black holes can consume all forms of matter and energy without restriction, even light.

The alternative possibility is the formation of a neutron star. These are the most compact and dense non-space-time phenomena in the universe, even more so than black holes. Think fitting the mass of the sun into London's city centre. A very tight squeeze! Like white dwarfs, they are held together by gravity, but don't collapse under their own mass thanks to the quantum properties of particles that comprise them.

Reading all of this, you might have the impression that we have a pretty good grasp of the physics that underpins supernovae. But actually, many mysteries remain, for example the abundances of atomic elements that we expect to be fused in the explosions.

When it comes to neutron stars, we are still confused about fundamental properties like the state of matter inside them and what the properties of the star are when it exists on the boundary between becoming a neutron star and being massive enough to collapse into a black hole.

Observations of neutron star PSR J0740+6620 over the past few years are challenging our understanding. Using radio telescopes at Green Bank Observatory in West Virginia and Arecibo in Puerto Rico, astronomers have found that this particular neutron star has a mass more than twice the sun's but it is only some 20 or 25 kilometres in diameter. This is so dense that it is close to the boundary of where we might expect a black hole to form, yet there it is, a stable neutron star.

Follow-up work with the Neutron Star Interior Composition Explorer X-ray (NICER), an X-ray telescope on the International Space Station, is affirming that this star is quite dense. Two recent preprints from the NICER team, including one for which I am a co-author, give estimates for the mass and radius of the star. But our papers disagree slightly on some of these values.

It isn't clear why this is, although it is probably due to differences in the data analysis techniques. Some might view this as upsetting, but I think it is exciting. With neutron stars, we are just getting started. ■

New Scientist
Discovery Tours

9 days | 3 December 2021

Cruise Hawaii with Richard Dawkins

Accompany the evolutionary biologist and highly-regarded author Richard Dawkins on this cruise around the fascinating islands of Hawaii.

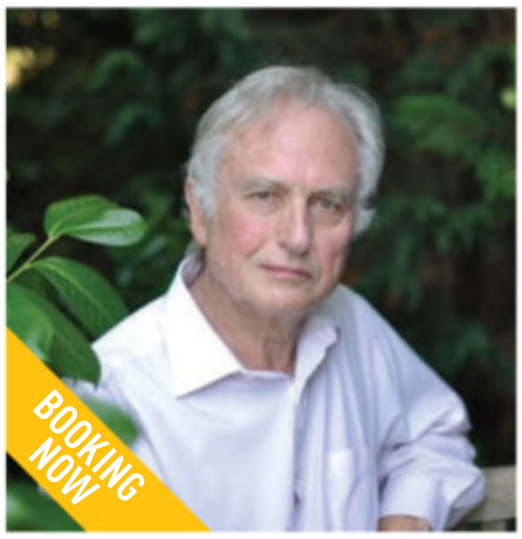
From the Volcanic National Park to abundant rare wildlife and stunning landscapes, this is a truly unique expedition. Discover Hawaii's unique culture and history whilst cruising aboard the Safari Explorer, a rugged expedition yacht small enough to explore where larger ships can't.

Highlights

- Evening lectures from Richard Dawkins, probably the best-known evolutionary biologist in the world today and certainly the world's best-known atheist.
- Richard will be talking about the evolutionary principles that volcanic island chains illustrate. The evolutionary story in Hawaii is similar to the Galapagos – both young, volcanic archipelagos – except that Hawaii has been more impacted up by human colonisation.
- The Safari Explorer is a nimble 36-passenger yacht that cuts through the gentle surf of the Pacific Ocean at a maximum cruising speed of 10 knots. The 45-metre-long ship is capable of navigating to the wildest edges of the Hawaiian Islands and has an impressive 2:1 guest-to-crew ratio.
- Explore the Big Island's active volcanoes during a visit to Hawaii Volcanoes National Park, immersing yourself in the power of this living volcanic landscape, its misty rainforests, thermal ponds, waterfalls and lava flows.
- Experience night-time snorkelling when the Safari Explorer anchors at an offshore location. See the giant manta rays and other Manta alfredi species, that live in the Hawaiian waters. This is a truly mesmerising experience.
- A day at the Kaloko-Honokohau National Park, the site of an ancient Hawaiian settlement, comprising historic temples, fishponds and petroglyphs. Turtles are frequent visitors to the shores of Honokohau National Park, so be sure to keep an eye on the shallow waters close to land to spot them.
- Sail through the Humpback Whale National Marine Sanctuary, a designated expanse of shallow warm waters that surround the main Hawaiian Islands, and learn from the guides about one of the world's most important protected marine habitats. From the decks, search for humpback whales, spinner dolphins, Hawaiian monk seals and reef fish.
- A hike to Puu Pehe (otherwise known as Sweetheart Rock), an ocean rock formation steeped in folklore that rises majestically 25 metres out of the sea and towers above the crashing surf.
- Spend the day on Molokai meeting local people and learning about the traditions of the Hawaiian people. In the evening, enjoy one of Hawaii's cultural treasures, a pa'ina (feast) held at the Molokai Museum.

Covid-19 safety protocol includes:

- Pre-departure screening of all guests and tour leaders.
- Increased sanitisation of all accommodation and transport.
- Mandatory use of PPE where appropriate.



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Editor's pick

Free to question the very idea of free will

15 May, p 36

From Nigel Tuersley, Wardour, Wiltshire, UK

You looked at superdeterminism, a take on quantum theory that does away with randomness. Objections were raised to it on the grounds that it would deny humans free will.

As far as we are aware, nothing in the universe is independent of the cosmos, and what we refer to as free will is, in fact, no more or less than the sum of our prior genetic and environmental influences.

More fundamentally, by what convoluted logic can it be argued that an element of randomness at the quantum level renders the case for independent thought more compelling? A so-called free will rooted in random processes is no more independent than if it is determined by non-random factors.

What cost a sedentary life during lockdowns?

8 May, p 10

From Nigel Langley, Totnes, Devon, UK

You report on a survey that found 29 per cent of people in England decreased their physical activity between March and August 2020 amid pandemic lockdowns.

I assume there is a correlation between physical activity and life expectancy. So the survey could mean that up to 29 per cent of the population may have reduced their healthy life expectancy.

Perhaps the decision to have a lockdown reflects the bias towards valuing more highly what is immediate, measurable and in the headlines, while ignoring hard-to-estimate distant impacts.

The Anthropocene debate will be settled... eventually

8 May, p 12

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

That we have begun a new geological epoch, dubbed the Anthropocene, seems not to be doubted by anyone, but Adam Vaughan tells us that pinning down its defining feature appears to be troublesome.

The problem is that, whereas all the other recognised epochs were defined with the benefit of millions or hundreds of millions of years of strata to examine, those trying to define the Anthropocene must struggle with living in it.

Fast-forward 10 million years and occupy the shoes of the geologists of whatever species is then dominant, and they will have no problem defining the Anthropocene. As has been pointed out on previous occasions, it will begin with a microscopic layer of compressed polythene found in every cliff face they examine.

Let's not be too optimistic about the climate

24 April, p 34

From Bruce Denness, Niton, Isle of Wight, UK

Michael Le Page reports that the world is "on track to pass the Paris aspirational limit of 1.5°C between 2026 and 2042... [and] to exceed 2°C above its pre-industrial level between the 2040s and 2070s". He adds: "We aren't heading for the worst-case scenario... [which] could have led to around 5°C of warming by 2100." I admire his confidence, but advocate caution.

At a conference organised by the Institution of Civil Engineers in 2009, I detailed a deterministic climate model, first published in 1984, that can distinguish between human-made and natural climate change. This has had an encouraging track record of accuracy, including forecasting the 1990s' global temperature rise.

Some of its predictions are at odds with those cited in your article, for example, it sees an increase of around 5°C by 2100.

The problem with trying to tackle big tech firms

1 May, p 34

From Robert Cailliau, Prévessin, France

In your look at efforts to address the dominance of some tech companies, John Bergmayer is quoted as saying: "You don't just have one big, global telephone company for Earth, but that's kind of where we are with Facebook."

That is a poor comparison. Telephone, the post and email don't need a single company because there is no persistent, shared content. But a group of people need a single database to distribute common stuff over multiple locations, hence single companies dominate. This won't be solved by anti-monopoly decrees from governments. I doubt it can be solved at all.

White roofs will be good in winter months too

Letters, 15 May

From Tim Stevenson, Prestwood, Buckinghamshire, UK

The discussion of an ultra white paint to cool buildings in summer sparked a reader to worry it might do this in winter too, meaning we have to turn up the heating. Physics says otherwise. In winter, a white surface will radiate less heat, helping to keep the warmth in.

Yes, animals probably are sentient like us

Letters, 1 May

From Guy Inchbald, Upton on Severn, Worcestershire, UK

It is a mistake to suggest that, just because animals may not necessarily have our kind of intelligence and consciousness, they therefore don't have it. Creatures as disparate as the day octopus, manta rays, corvids and great apes all have the necessary neural substrates to support cognitive processes and all display cognitive behaviours.

The case to be answered is that the many similarities between cognitive creatures in fact do demonstrate common sentience.

Best way to help pigs isn't an AI, but a change of diet

1 May, p 14

From Greg Billington, Picton, New Zealand

So AI can read emotional states in the facial expressions of cattle and pigs. It is suggested that this technology will enable farmers to improve animal well-being by reducing stressful husbandry.

Despite coming from a farming family and having been a hunter for many years, the best possible way to improve animal well-being is to simply not eat them.

Spotted in broad daylight: a playful platypus

8 May, p 41

From Tony Fist, Norwood, Tasmania, Australia

Far from being strictly nocturnal, I have seen many platypuses active during the day in Tasmania, including a memorable encounter with one splashing in the melting snow near Cradle Mountain.

Beware offending the mighty palm

Letters, 15 May

From Gary Warburton, Dublin, Ireland

Amid talk of tree sentience, Steve Tunnicliff suggests apologising to an elder tree before cutting it down to avoid its vengeance. I have heard of doing the same for a rowan tree. However, it seems to me that it is palm trees we should really worry about, as they are the ones with fronds in high places. ■

Want to get in touch?

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Seed shots

Photographer Levon Biss

RARELY have seeds and fruits so closely resembled a work of art. These strikingly intricate images capture the fertilisation and reproduction of plants.

The photos are taken from the book *The Hidden Beauty of Seeds and Fruits: The botanical photography of Levon Biss*, which showcases a branch of botany dedicated to the study of seeds and fruits called carpology.

Carpology places a focus on the shape and structure of different fruits and seeds. Biss chose the most interesting specimens he could find in the carpological collection at the Royal Botanic Garden Edinburgh, UK, to photograph, all of which have been dried or preserved.

The top row shows, from left to right: a coco de mer fruit (*Lodoicea maldivica*), split in half to reveal the germinating seedling within; a partially dissected Medang Pajal fruit (*Ternstroemia* sp.) with its seed exposed; the fruit head of a giant banksia (*Banksia grandis*); and a yangua fruit (*Cybistax antisyphilitica*), known for its unusual green-coloured flowers.

The bottom row shows, from left to right: a nut from the buckeye tree (*Aesculus glabra*); a red-fleshed durian fruit (*Durio graveolens*); the seed pod from a field manioc shrub (*Zeyheria montana*); and the seed pod of a thorn apple (*Datura stramonium*).

Images from the book, published by Abrams & Chronicle, are on display at the Royal Botanic Garden Edinburgh until September.

Gege Li

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All about the menopause

There is a menopause information vacuum. A new book by gynaecologist Jen Gunter is a terrific place to start, says **Helen Thomson**

Book

The Menopause Manifesto: Own your health with facts and feminism
Jen Gunter
Piatkus

GUIDO MIETH/GETTY IMAGES

I AM only 37 and I have experienced the menopause multiple times. Drugs for IVF and endometriosis paused my hormonal cycles on five separate occasions, placing me in what doctors call "artificial menopause".

But there was nothing artificial about the symptoms – the hot flushes that burned deep inside my core at 2 am were a particular shock. So when I came across *The Menopause Manifesto*, written by gynaecologist Jen Gunter, I jumped at the chance to learn more about what was in store when the real thing hits.

Despite the universal nature of menopause for half the planet's population, few of us are fully informed about the symptoms, physical changes, medical concerns or treatment options.

According to Gunter, this information vacuum is largely down to medical misogyny. Indeed, medicine's long history of neglecting women means that menopause concerns are still too often dismissed as fabricated, unimportant or just "part of being a woman".

Gunter's ambition is to change this conversation, which is worthy in all the right ways. Menopause shouldn't be a fringe part of women's healthcare: aside from quality of life issues, social impact and physical symptoms, there is its link to cardiovascular disease. This is responsible for 1 in 3 female deaths each year – more than die from breast cancer.

So it turns out that my 2 am "hot blooms" (as I find they would have been called in the 18th century) are the least of it. Women can also expect abnormal bleeding, temporary cognitive changes, vaginal dryness, pain during sex, decreased libido and joint pain. Not to mention the increased risk of osteoporosis, dementia, metabolic syndrome (a combination of diabetes, high blood pressure and obesity), type 2 diabetes and urinary tract infections. Sound like something you should know about?

> **"We don't define men as they age by an obvious physical change in their reproductive function"**

Gunter's teaching of the history and biology around menopause is second to none. Her opinions on the societal lens through which we view the menopause are just as interesting. She highlights the fact that it is misogynistic to tie a description for a third of a woman's life to the function of her uterus and ovaries. We don't define men as they age by an obvious physical change in their reproductive function, she points out. Yes, the menopause is a marker for increased risk of heart disease for women, but so, too, she says, is erectile dysfunction for men. Imagine a world with men in what she calls the "erectopause".

Running throughout the book is a wealth of information on the physiological processes at play during a woman's life. While it could do with a little pruning, it can't fail to leave you feeling completely wised up, without veering into a biology lesson.

As a gynaecologist, Gunter also has the authority to provide vital information on treatments, from traditional hormone replacement therapies (HRT) to alternative medicines. She also shows us where we may be led astray by celebrity endorsements of natural remedies, and by "compound" therapies – treatments that resemble traditional HRT, but which remain largely unregulated and untested, she says.

Gunter's book provides plenty of information about treatments

There is information on drugs like fezolinetant, too, which look promising for hot flushes. My copy has many page corners turned over – things I plan to ask my doctor, now and later.

"I am here to scare you about osteoporosis," Gunter says in one chapter. It isn't the only scary thing she reveals about this future time in my life, but at least I am now better prepared, have the confidence to know what to ask, and feel able to have a more grown-up conversation.

Gunter promises to give women strength, value, agency and knowledge to help them through this transition in their life. She has unquestionably achieved that. ■

Save our sun!

In the new sci-fi novel from *The Martian* author Andy Weir, an unlikely duo battle the decline of our star, says **Clare Wilson**

Book

Project Hail Mary
Andy Weir
Del Rey

I HAVE been a fan of apocalyptic sci-fi since I was hooked as a teenager by John Wyndham's 1951 classic *The Day of the Triffids*. From plagues to asteroids, I thought I had heard all the different ways civilisation could be doomed, but Andy Weir, author of *The Martian*, has come up with a new one.

In his latest work, *Project Hail Mary*, an anomaly is discovered in the sun's radiation. Our star's output has started to dim and the rate of decline is exponential. Within 20 years, there will be ice ages, crop failures and mass starvation. The explanation for the problem and how to solve it is almost too far-fetched, yet Weir makes the science seem just about credible.

In line with all good end-of-the-world tales, *Project Hail Mary* explores such issues as how people can adjust to societal changes and whether authorities may ride roughshod over civil liberties if it saves lives overall. In a lesser way, we have been forced to wrestle with such questions in real life over the past year thanks to the pandemic.

There's also an unlikely hero, astrobiologist-turned-schoolteacher Ryland Grace, who turns out to be uniquely qualified for the space mission to save the sun. In an unusual twist, the story opens as Grace wakes up on a ship with dead crewmates and little to no memory of what he is doing there.

And that isn't even the most interesting aspect of this book. Spoiler alert: there's a big plot twist early in the tale, so look away now if knowing it would annoy you.

Grace encounters an alien life form. What's more, in order to save our star, and therefore Earth, he needs to be able to talk to this alien, which he names Rocky because of its mineral-like outer covering.

The "first contact" moment when humans meet an alien species has, like world-ending events, long been fertile ground for sci-fi. How the two would communicate if they don't share anatomy or biochemistry is not only an interesting philosophical problem, but is being studied for real, just in case.

> "I thought I'd heard all the ways to doom us, but Andy Weir has come up with a new end-of-the-world twist"

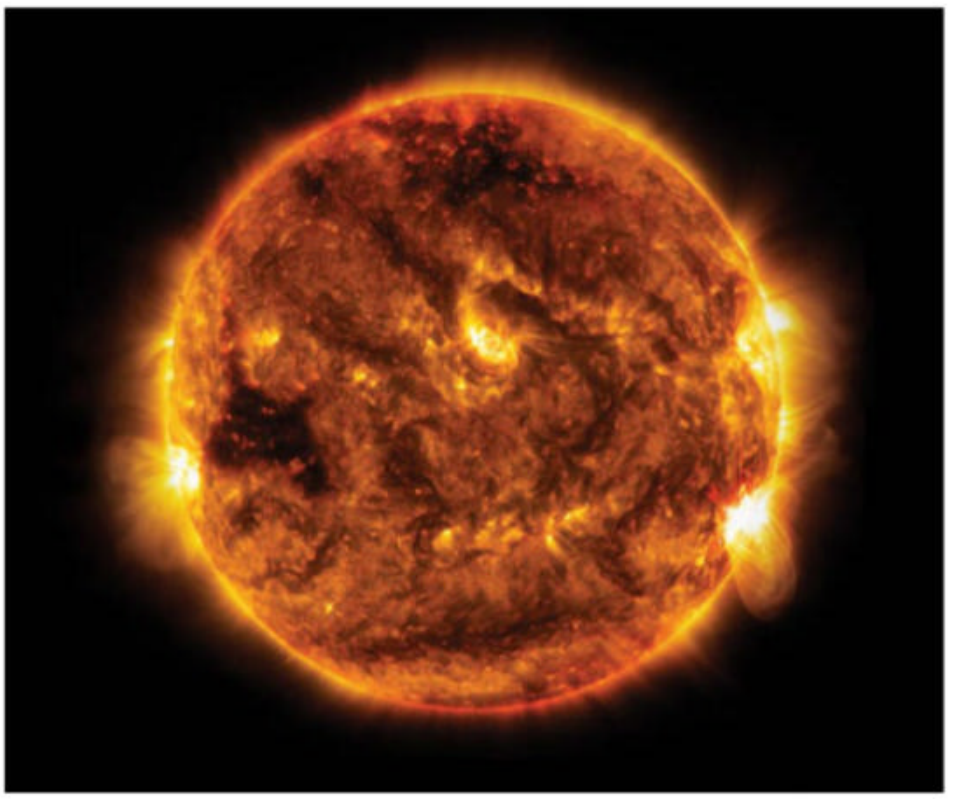
Some sci-fi stories solve the communication problem by gifting the aliens such superior intelligence that they learn English from terrestrial broadcasts that leak into space, arriving ready to talk turkey.

But in *Project Hail Mary*, Grace has no such luck; Rocky turns out to be from a species of roughly similar intelligence and technological ability as humans. Cut off from their home worlds, Grace and Rocky have to use their ingenuity to learn how to communicate, in laborious trial-and-error fashion, at the same time as working out how to save the sun from impending doom. Their relationship lends this book much of its charm.

For me, there is perhaps a little too much *Martian*-style detail about how Grace solves the many engineering problems on his mission, but that didn't stop me enjoying the tale.

Director Ridley Scott turned *The Martian* into a feel-good movie in which a rational approach triumphs over adversity. It features Matt Damon as an astronaut marooned on Mars who has the immortal line: "I'm going to have to science the shit out of this." That outlook could equally apply to Grace and Rocky.

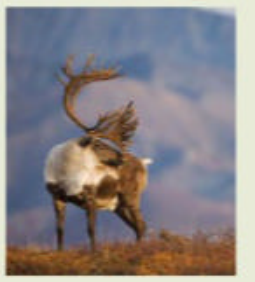
Who knows, perhaps a few coronavirus vaccine developers took inspiration from it, too. ■



NASA/SDO

The health of Earth's stellar companion is crucial to life on our planet

Don't miss



Listen

The Wild introduces us to colourful characters as the podcast's third series sees ecologist Chris Morgan travel the US in search of amazing animals and their larger-than-life human champions.

Read

Reimagining Time by means of sketches and doodles (as indeed Albert Einstein did in his own notebooks), artist and sculptor Tanya Bub and her physicist father Jeffrey present an illustrated guide to all things relativistic.

Visit

Design in an Age of Crisis is an online gallery of design thinking, presented at this year's London Design Biennale. More than 50 countries show 500 projects by their designers, all aiming to improve health, society, environment and work.

MILO BURCHAM/DESIGN PICS INC/ALAMY; MAD(E) IN MUMBAI

The TV column

Breaking out of prison in 2143 *Intergalactic* is packed with plot. As a group escapes detention by commandeering a spaceship, we begin to uncover more about the eco-fascist regime back home, finds **Bethan Ackerley**

Bethan Ackerley is a subeditor at *New Scientist*. Follow her on Twitter @inkerley

SKY UK LIMITED

Imogen Daines (left) and Savannah Steyn (right) in *Intergalactic*

TV

Intergalactic

Julie Gearey

Sky, NOW, Stan and Peacock

ON THE festering streets of Old London, rookie cop Ash Harper (Savannah Steyn) chases down Verona (Imogen Daines), a fugitive who has stolen a valuable commodity. Seemingly abandoned as the climate crisis intensified, London has become a literal underworld; in 2143, the only structures left intact are the enormous pillars that hold up the Commonworld, a network of gleaming metropolises under authoritarian rule.

Like me, you may think that these superimposed cities would be an excellent setting for a sci-fi show. I was therefore surprised that prison-break drama *Intergalactic* doesn't linger here. Instead, it jumps straight to the action: just 10 minutes into the first episode, Ash is arrested and framed for stealing the cache she retrieved from Verona.

Despite the efforts of her mother Rebecca (Parminder Nagra), the Commonworld's head of galactic security, Ash is sentenced to live out her days in an off-world prison colony. Yet while she is being transported there, she is drawn into a daring breakout attempt by Verona and a motley crew of inmates. Led by ruthless matriarch Tula (Sharon Duncan-Brewster), the women commandeer the Hemlock prison ship in order to seek a new life in the fabled free world of Arcadia.

In other shows, such events might be considered meaty enough to span two or three episodes. That they are packed into one instalment tells you all you need to know about the show's tone – it burns through plot at a breakneck pace, with all the mayhem this entails.

> **"The eco-fascist regime will protect Mother Earth at all costs, even destroying other worlds"**

For the first few episodes, the show is oddly uninterested in world-building, opting to get the set-up out of the way via a surfeit of exposition-heavy dialogue. And there are moments when the narrative makes unexplained leaps, from the logistics of the breakout to a fight scene in which Ash seems to teleport between locations.

Yet there is plenty to like about *Intergalactic*. For the most part, each member of the Hemlock's crew feels fully realised; Tula and Candy (Eleanor Tomlinson), an eccentric, fork-tongued drugs mule, are particularly interesting.

By the end of the third episode, the series has relaxed its disorientating speed, and is all the better for it. A plot line that sees Ash, Verona and a pirate called Echo (Oliver Coopersmith) raid a fuel depot – while the others contemplate their dire fate if the Hemlock runs out of juice – mixes high-octane thrills with humour and character development (think *Guardians of the Galaxy* without a talking raccoon).

At this point, it also becomes clear that the Commonworld is on shaky ground. The eco-fascist regime's raison d'etre is to protect Mother Earth at all costs – even if that means destroying countless other worlds. The wider galactic community isn't going to take that lying down, and so Rebecca and the Commonworld's director, Benedict Lee (Craig Parkinson), face a growing revolution.

Once these political machinations begin to dovetail with the lives of the prisoners, particularly that of "enemy of the state" Emma Grieves (Natasha O'Keeffe), you finally get the sense that the show is going somewhere with all its sound and fury. Messy and charming by turns, *Intergalactic* looks set to be an original and exciting series – if it can keep its feet on the ground and its head in the sky. ▮

Bethan also recommends...

Game

Mass Effect 2

Commander Shepard must assemble a rag-tag team of criminals, vigilantes and murderers to undergo a suicide mission. Over countless playthroughs, I grew to love every member of this dysfunctional family.

Book

The City & the City

China Miéville

Beszel and Ul Qoma occupy the same geographical location, but the residents of each city must "unsee" their neighbours or risk being taken by the Breach. This premise is the perfect means of exploring urban life.

A NEW UK CHEMICALS REGIME HAS BEEN LAUNCHED. IS YOUR BUSINESS READY?

NOW THAT THE BREXIT TRANSITION PERIOD IS OVER, NEW RULES APPLY FOR BUSINESSES WITHIN THE UK'S CHEMICALS INDUSTRY. THE GOVERNMENT IS COMMITTED TO SUPPORTING YOU TO ADAPT TO THESE NEW RULES.

On 24 December 2020, an agreement was reached between the UK and the EU setting out the UK's future relationship with the EU. As part of this, if your business makes, sells or distributes chemicals in Great Britain, you now need to follow the UK's new domestic chemicals regulations, including UK REACH.

UK REACH is the new independent chemicals regulatory framework, which enables the UK to make its own decisions and respond to emerging risks, while maintaining some of the highest chemicals standards in the world.

THE NEW 'COMPLY WITH UK REACH' SERVICE HAS LAUNCHED

The UK's chemicals industry is world-leading, employing over 100,000 people across the UK, accounting for over £30 billion of yearly exports and contributing around £11.2 billion GVA (gross value added) to the UK economy per year.

To support chemicals businesses as they adapt, the government has worked closely with partners, industry and stakeholders to develop a new 'Comply with UK REACH' online service.

The new service went live on 1 January and can be used by businesses to fulfil their transitional provisions and create new registrations. The new system enables the UK to make decisions on the regulation of chemicals that are based on the best available scientific evidence, ensuring that chemicals remain safely used and managed.

You will be able to use the Comply with UK REACH service to:

- Validate existing GB-held EU registrations ('Grandfathering').
- Submit downstream user import notifications (DUIN).
- Submit new substance registrations.
- Submit new product and process orientated research and development (PPORD) notifications.

You will need to contact the Health and Safety Executive (HSE) to ensure that you:

- Validate existing GB-held product and process orientated research and development (PPORDs).
- Provide information on any authorisation matter, including new authorisation application, grandfathering of existing authorisations and downstream user notifications of authorised uses.

You can access the new service at **www.gov.uk/reach-chemicals**

Detailed UK REACH guidance is also available on the HSE website at **www.hse.gov.uk/reach**

HM Government
UK TRANSITION

MAKE, DISTRIBUTE, BUY OR SELL CHEMICALS?
NEW RULES APPLY
FIND OUT MORE AT GOV.UK/REACH-CHEMICALS

Check
Change
Go

The dawn of the quantum internet

The race is on to create a super secure online space that channels the eerie power of the quantum world. **Stephen Battersby** logs on

MANY of us have uploaded our lives to the internet. Banking, work emails, social media, dating profiles, medical records – all that vital, sensitive information. So it is a little disconcerting that the internet has a fatal security flaw. Don't panic; our private information is safe for now. But before very long the encryption algorithms that protect us online are going to crack.

That is the urgent driving force behind a new, more secure kind of internet that harnesses the power of the quantum realm. Once up and running, the system will be able to do a lot more than protect our data. It could bring us unforeseen quantum apps, and maybe become the scaffold for a world-spanning quantum computer of incredible power.

Building the quantum internet is a huge and multi-faceted engineering challenge, but the foundations are already being laid. Networks of fibres are spreading. Scientists are chatting in secret on local networks. There are even plans to use tiny satellites to enable long-distance quantum connections. Sooner or later, we could all be joining the quantum information superhighway.

Human culture and industry have long been based on information. If you could get the right kind of information, understand it and share it, you could gain power and profit. The rise of the internet as we know it cemented the role of information and we are only beginning to feel its profound effects. Now we are at the threshold of a new information age, which could change things all over again.

Conventional, classical computers deal in digital units called bits. This is the amount of information in the outcome of a coin toss, usually represented as having a value of 1 or 0. Every email, status update or photo on your phone is broken down and stored as bits.

Dealing in qubits

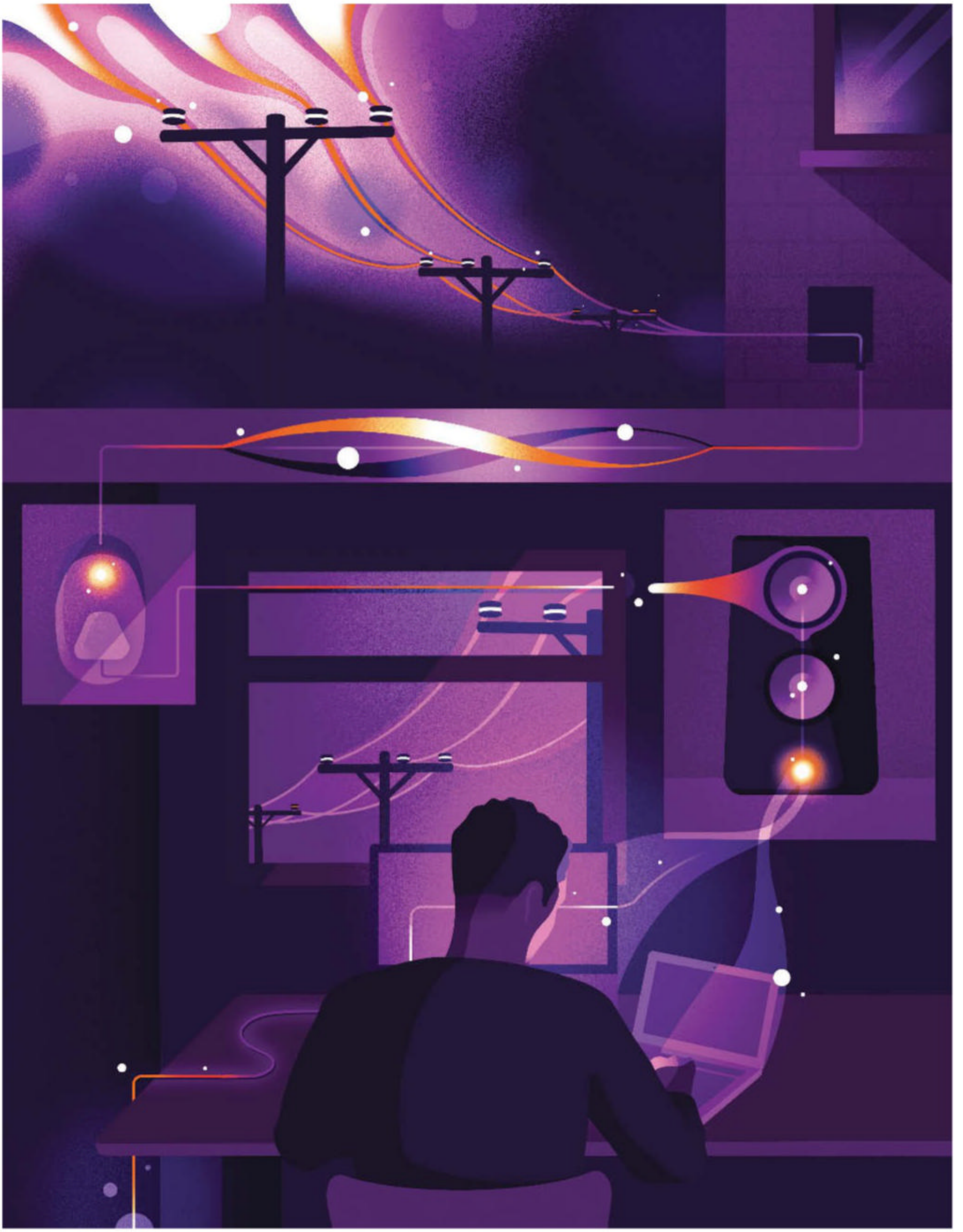
That is rather limited when seen from the perspective of the quantum world, where we know particles behave in ways that can seem very strange. An atom, electron or photon can be in a state where its properties aren't determined. For example, it can have two different energies at once. These quantum states are extremely delicate, but learn to manipulate them and you can deal in particles that store a quantum unit of information, or qubit, encoding not only 0 or 1, but any blend of 0 and 1 together.

Our burgeoning ability to do just this has already produced impressive new technology, such as ultra-sensitive detectors of gravity and magnetic fields. Physicists are now able to control dozens of connected qubits at once, creating prototype quantum computers. When these grow large enough, they promise to surpass any classical computer that could ever be built – at least when it comes to certain types of calculation. Among many other things, quantum computers should be able to simulate chemistry to design new drugs and advanced materials and solve knotty problems in engineering and logistics. Their full potential is as yet unknown.

One thing we do know is that these incredible machines will mean we need a quantum internet – because it is quantum computers that threaten our security. Many encryption schemes that keep the internet secure are based on mathematical problems that are impractical for a classical computer to solve, such as factorising large prime numbers. But a big enough quantum computer could do this in a flash, using an algorithm devised by Massachusetts Institute of Technology mathematician Peter Shor in 1994. That would undermine the security of everything that relies on online communication, from email to power grids. "A lot of critical infrastructure still relies on such algorithms... including my bank," says Siddharth Joshi at the University of Bristol, UK.

Such a dangerously powerful quantum machine is probably at least 10 years away, but the problem is urgent nonetheless. It takes a long time to change cryptosystems, and data sent today could be intercepted, stored and decrypted when a powerful enough quantum computer becomes available.

Joshi and others want to fight qubits with qubits. If you communicate using the quantum states of individual particles, then you can tell if anyone eavesdrops because the very act of looking at the signal will change those delicate states. This wouldn't mean replacing the internet, but building an added layer of quantum communication links on ›



OLLIE HIRST

top of it so users can share a key that would keep their online exchanges secret. Internet traffic would still travel through the cables it does now, it would just be encrypted and decrypted with those keys.

This kind of quantum encryption, called quantum key distribution or QKD, has been demonstrated many times in the past few decades. The first QKD bank transfer was in 2004. There are many different schemes for QKD, but some of the most secure are based on the quantum phenomenon of entanglement. You begin by putting two qubits into a shared quantum state such that when one of them has its properties measured, the outcome of measurements on its twin change in a predictable way, no matter where the two particles are. Say your two qubits are photons. Send one of the entangled pair through an optical cable, and you have a means of exchanging a secure key.

Links that carry much larger numbers of entangled qubits could allow for even more impressive applications, such as sending messages in entirely quantum form. In the short term, quantum computers will be modest and probably housed far apart from each other, at locations like universities or research centres. But quantum communication links could connect them to create a quantum supercomputer. They could also allow users to run programs on quantum computers remotely in such a way that security would be guaranteed, with even the owners of the computer unable to snoop. This is called blind quantum computing, and it could enable anyone to use quantum computers without any risk of having sensitive data poached.

Whispering diamonds

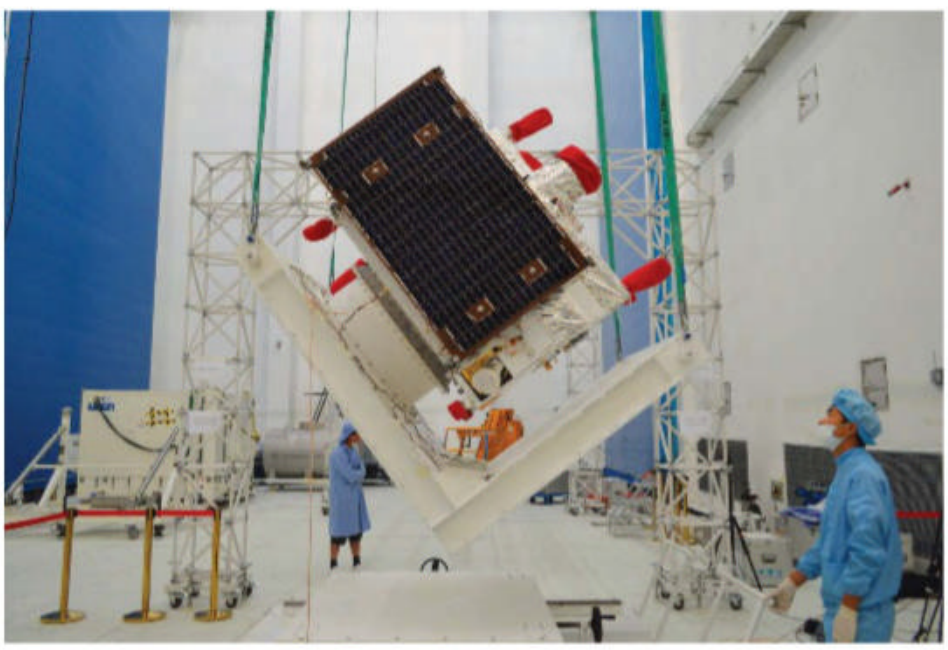
A seed of the coming quantum internet has been sown in a laboratory in Delft, the Netherlands. There, three tiny diamonds whisper to each other, forming a miniature but fully functioning prototype network of entanglement links. Inside each diamond's lattice of carbon atoms is a defect where a single nitrogen atom sits. A pair of electrons at this site can emit a photon that is entangled with them. Each diamond also holds a one-qubit quantum memory, which allows basic quantum information processing.

In a paper published in April, Ronald Hanson and his team at QuTech, a research institute in Delft, showed they could link three diamonds in a network and pass quantum information between them. In principle, this technology can be scaled up, allowing entanglement to be shared between any number of nodes. "This is the basic function that the quantum internet needs to perform," says Hanson.

The hardware doesn't have to be diamonds. Other groups are exploring different ways of handling and linking qubits. In Bristol, Joshi's group has shown it can distribute quantum keys between eight users a few kilometres apart, all receiving entangled photons from the same laser source. It should be feasible to extend this to a few hundred people across a city, says Joshi. So far, he has demonstrated QKD and some similar protocols, but he says that with more sophisticated modules to receive the entangled photons the network would support other applications, including blind quantum computing.

Many other fledgling quantum networks are appearing, for example in Tokyo in Japan, Calgary in Canada and Los Alamos in New Mexico. These generally have only two or three nodes and are limited to QKD. But they are growing in range, with several stretching to more than 100 kilometres. The dream is to extend this to connect millions of users across the globe, carrying super-secure encryption keys across countries and continents.

Doing this will almost certainly involve piggybacking on the existing network of fibre-optic cables that carries all today's internet traffic and other telecoms data. But here we run into a serious hitch: optical fibres aren't completely transparent. Even if you use the



XINHUA/ALAMY

China's Micius is the world's first quantum communications satellite

ROBBIE JONES/IBM

Successors to IBM's quantum computer could crack the security of the internet

"The dream is to connect millions of users, carrying encryption keys across countries and continents"

optimum wavelength of light, 50 kilometres of fibre will absorb about 90 per cent of photons. That limits quantum-by-fibre to a range of a few hundred kilometres at most. Today's fibre network uses amplifiers to boost signals. "But you can't send quantum signals through an amplifier," says Tim Spiller at the University of York, UK, who leads the country's multi-institution Quantum Communications Hub. In effect, amplifiers measure the signal, which would play havoc with the delicate quantum data.

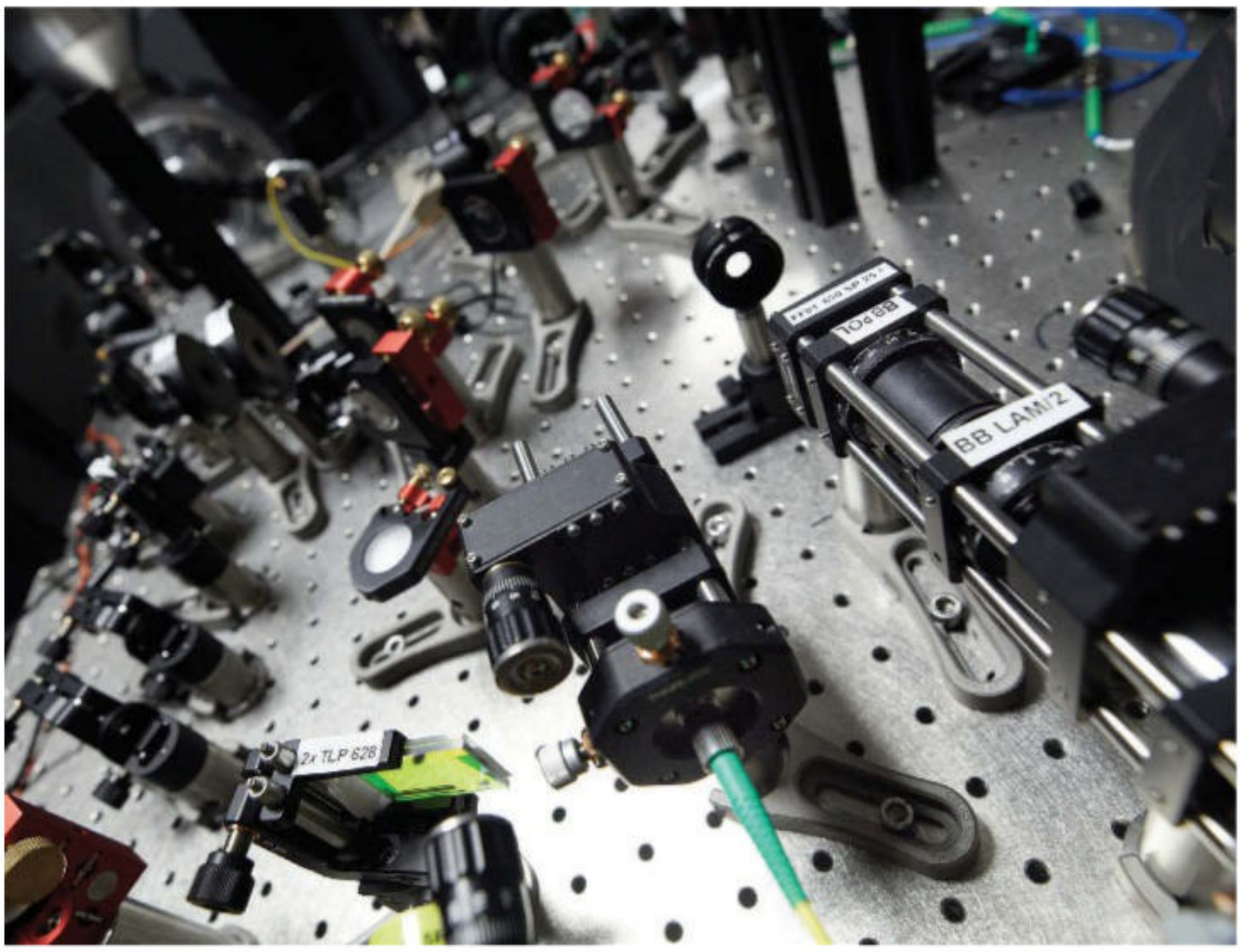
To extend the range of QKD, you can rely on trusted nodes, devices that relay a message by decrypting it and encrypting it again to send it down the next section of fibre. China already has an impressive network, with a 2000-kilometre-long backbone of 32 trusted nodes between Beijing and Shanghai, and hundreds of links in total. Problem solved? Not quite. Each node is a security risk that, if compromised, could leak your message. Worse, this is no good for fancier applications like blind computing because the original quantum information is discarded at each node.

To carry our quantum data far and wide, we need a device known as a quantum repeater. Imagine two users called Alice and Bob who want to chat. They each make a pair of entangled qubits, and each send one of their pair to a quantum repeater in the middle. The repeater performs a particular kind of simultaneous measurement of the states of the two qubits it has received, designed to entangle them. According to the rules of quantum physics, this then entangles the two qubits retained by Alice and Bob, a process called entanglement swapping. String many quantum repeaters together in a line and you can end up with entangled qubits at a much greater distance.

If only we had a quantum repeater. They have been on the wish list for years, but have proved extraordinarily difficult to make. However, at Stony Brook University in New York, Eden Figueroa and his group are beginning to put some of the pieces together. One critical component is what's called an in-and-out quantum memory that can catch a flying qubit and hold it until required for the simultaneous measurement. Figueroa's quantum memory is based on a cloud of atoms that can effectively do this with a photon. The device also needs to register when it has caught a photon without disrupting the particle's sensitive quantum state. Last year, Figueroa and his colleagues showed they could do this by sending in another photon that interacts only very weakly with the stored one.

These quantum memories have three big pluses for practicality. They are portable, coming in handy 40-centimetre modules. They work at room temperature rather than the frigid temperatures needed for many atomic-cloud devices. They can also work at normal telecoms wavelengths, as the team showed last year when they connected two of these devices 158 kilometres apart. "We are getting close to entanglement swapping, where everything has to work together," says Figueroa. Useful repeaters will not only have to do all of this, but do it very efficiently.

Even boosted by repeaters, the fibre quantum internet will be patchy. Links across the ocean will be a particular problem because existing undersea cables have built-in amplifiers, spelling doom for qubits. If you ›



QUTECH

The quantum internet kit at QuTech in the Netherlands is some of the most advanced yet

"The network could have many quantum terminals, including moving ones on ships and planes"

laid a dedicated quantum undersea cable, it would have to include quantum repeaters that could be relied on to work for a long time.

So researchers are also looking at quantum links using satellites. The front runner here is China, which in 2016 launched the Micius satellite, carrying a quantum communications toolkit. "When Micius launched, that got everyone else to sit up," says Daniel Oi at the University of Strathclyde, UK.

Micius encrypted a videoconference between Beijing and Vienna, Austria, in 2017, based on a form of QKD that has a high data rate, but in which the satellite acts as a trusted node. This will be fine for some users, such as governments and corporations that can afford their own satellites, but it won't guarantee security for all the users in a highly connected future quantum internet. Then in 2019, Micius was used to form a link between two ground stations in China, at Nanshan and Delingha, 1200 kilometres apart, by splitting each entangled pair of photons and sending one to each station. This form of QKD is particularly secure. Even if the satellite were compromised, the key would be immune to hacking.

The disadvantage is that it works slowly. The two parties can only use an entangled pair when both photons in the pair make it to them, and in any satellite link, the majority of the light is lost because most photons either miss the receiver or get absorbed by the atmosphere. The Chinese ground stations are at high altitude and have large telescopes to act as receivers; and the satellite generates about 6 million entangled pairs per second. But even then, the secret key was generated at a rate of only a fraction of a bit per second. Jian-Wei Pan at the University of Science and Technology of China in Hefei, who leads the work on Micius, says he is now working to boost this rate with several improvements including brighter sources of entangled light.

Quantum constellation

Pan and Oi both foresee a network with many quantum terminals, including moving ones on ships and planes. "If you have many ground stations, a few big satellites won't be able to service them," says Oi. Instead, we will need a sprawling constellation of small satellites. Several projects are blazing the trail, including a UK-Singapore mission called SPEQTRE, and ROKS, a satellite built by a private consortium. Both are due to launch in 2022.

To weave a world-wide quantum web on top of all this hardware, we will need the kind of software that lets us blithely use apps on the classical internet. Several layers of software, known as the internet stack, route data around the existing network, so the average user doesn't need to worry about the plumbing. Stephanie Wehner at QuTech is one of those working to build a quantum internet stack. Then there's the fun stuff, the actual apps. We still don't know what could be possible. New types of gaming? Novel forms of communication?

When these extraordinary technologies have girdled the world, we might not notice at first. The effect should mainly be an absence of problems: you don't lose access to your bank account, elections aren't hacked, the lights don't go out. In time, there will be more tangible benefits too, especially for science. Quantum data links could allow telescopes to exchange information instantaneously to give astronomers a sharper view of the universe. They could synchronise atomic clocks more accurately, and so make gravitational wave detectors more sensitive. Not to mention the promise of shackling quantum computers together to boost their power.

On the other hand, the quantum web will surely turn the dark web darker still, and some people are bound to take advantage. One worrying suggestion is that terrorists could use blind quantum computing to design new weapons – and nobody would know. Governments might consider putting back doors into the hardware, "but that would defeat the purpose of all this", says Wehner.

Perhaps in the end, this new form of internet will make the world simultaneously safer and more dangerous. How very quantum. ■

Stephen Battersby is a consultant for *New Scientist* based in London

Why can I never be bothered?

Some people seem to possess unlimited motivation, others not so much. Self-confessed slacker **Amelia Tait** wants answers

ANTONIO SORTINO

I'VE had three weeks to write the words you are about to read, but they were written at the last possible minute. Why? I wasn't busy exercising – I haven't done that in months. My time wasn't spent at my book club or calligraphy class, because I'm not involved in anything of the sort. Nor did I procrastinate by mastering the ultimate sourdough loaf – just the thought of it makes me want to lie down. Quite simply, I waited until the last minute because I couldn't be arsed.

My condition is what's known colloquially among my generation as "The CBAs" – the "can't be arseds". In my case, it is chronic. I can't be arsed to go on a run. I can't be arsed to cook. I can't be arsed to reply to my emails.

I'm not alone. According to a December 2020 survey by the Pew Research Center, 42 per cent of people in the US aged between 18 and 49 say they have struggled to find the motivation to work since the beginning of the covid-19 pandemic. That still leaves half of the population who are fine, who get up and get on. Then there are those people who wake at 6 am and run 10 kilometres before work. People who write their memoirs. People who wash their curtains.

What are their secrets? Why do some people have so much drive and others, like me, so little? And is it possible for me to become a go-getter? To find out, I mustered the motivation to ask a few of the scientists who might know.

Motivation is what drives much of human behaviour. It is what turns goals into actions, whether you are nipping to the fridge, writing an article or setting off up a mountain. It is hardly surprising, then, that the process by which you become motivated involves various biological and psychological components, all ›

"Could it be that all the chocolatey cereal and crisps are depriving my brain of the ingredients that generate drive?"

in delicate interplay with our external experiences of the world.

In other words, it is complicated – and what lies behind individual differences is far from straightforward. "It's the biggest question in the field," says Kou Murayama, who leads the Motivation Science Lab at the University of Tübingen in Germany.

Could it be down to DNA? That would save me a lot of effort – if my laziness is baked into my genome, there is no point trying to change. Alas, Murayama quickly shoots me down. "It's wrong to think that there is a 'motivation gene'," he says. In most cases, traits are determined not by individual genes, but by constellations of genes. And besides, behaviour tends to be shaped by what Murayama calls "the long history of the interaction between inherent disposition and external environment". That's nature and nurture to you and me.

The relative impact of each is controversial. Ask most biologists and they will tell you that environment is the most important factor in determining people's behaviour. But Robert Plomin, a geneticist at King's College London, argues that our genes play a more important role than many like to think, pointing to twin studies as evidence.

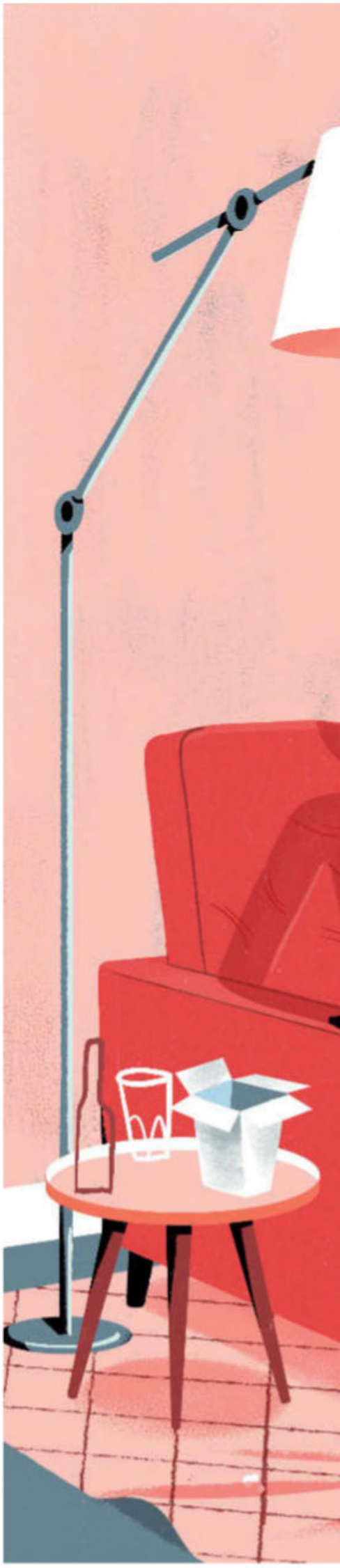
That seems to be the case for one sort of motivation. In 2015, a study of 13,000 sets of twins from six countries, all aged between 9 and 16, found that 40 to 50 per cent of the differences in motivation to learn could be explained by genetics. "There are personality differences that people inherit that have a major impact on motivation," said Stephen Petrill at the Ohio State University, one of the authors of the study, at the time.

That still means that more than half of the differences in the motivation of these children can be attributed to their environment. The problem is that it is impossible to create a checklist of experiences that produce go-getters – the variables are too vast. Even something seemingly straightforward, like socio-economic status, is more complicated than it seems. You might think people who experience hardship might be more motivated to succeed professionally, for example. But we can't say. "We know surprisingly little about how differences in opportunities impact human motivation," says Tali Sharot, a neuroscientist at University College London.

Anticipating rewards

If we are looking for the fundamental differences between shirkers and strivers, we can at least look at how we perceive rewards. Regardless of whether we are talking about motivation being driven by satisfaction within (intrinsic motivation) or by the promise of external rewards (extrinsic motivation), Sharot says that motivated and unmotivated individuals differ in their "reward sensitivity". Some get a greater kick out of rewards, whether it is the internal buzz after exercise or the warmth you get from praise. "The same reward, let's say £100, actually feels like £1000 to one person, but only feels like £10 to the other," says Sharot. "The person who feels they are working for £1000 will be more motivated and work harder."

We also have different expectations about how rewarding things will be. Two people might have the same reward sensitivity – both feel amazing when they get praise – but one might struggle to predict this reward. "What



CREDIT ANTONIO SORTINO

I expect to happen is hugely important in me deciding what I'm about to do," says Sharot.

Using her analogies, it seems that I'm the type of person who expects 10p rewards and feels them as 5p rewards. Could that have something to do with the way my brain processes rewards?

Neuroscientists have found that when rodents receive a reward, specialised cells in a brain region called the ventral tegmental area fire up, passing the message onto cells in another region, the nucleus accumbens, to release the neurotransmitter dopamine. More recent experiments have demonstrated an intimate connection between dopamine and motivation. When John Salamone at the University of Connecticut reduced dopamine levels in the brains of rats, for example, the animals settled for a smaller pile of food rather than go for a larger stash placed behind a barrier. The results have been corroborated in humans several times.

Dopamine deficient?

This makes sense when you consider that many people who experience depression report a dearth of motivation. "There is some evidence that depressed individuals show a blunted brain activation in the nucleus accumbens to expected reward," says Trevor Robbins at the University of Cambridge, although he says that depression is much more complicated than that.

Can I blame a lack of dopamine for my unwritten memoirs and unwashed curtains? Robbins says there are individual differences in dopamine function, but insists it isn't as simple as more dopamine equalling greater drive. For one thing, the effects of dopamine seem to depend on where in the brain spikes occur. Brain imaging studies in humans have found that while people who are willing to work harder for rewards have higher release of dopamine in areas of the brain known to play a role in motivation, people who are less willing to work hard had similarly high levels in another brain region associated with emotion and risk perception.

The neuroscience of motivation still contains many mysteries. Last year, Carmen Sandi at the Swiss Federal Institute ›

"Each of us has different expectations about how rewarding things will be"

of Technology in Lausanne and her colleagues found that the ratio of two compounds, glutamine and glutamate, in the nucleus accumbens predicted the extent to which people were able to stay motivated during a physically demanding task. Glutamate is the major excitatory neurotransmitter, and glutamine is its precursor. So the ratio between the two can indicate the capacity a person has to produce glutamate on demand and thus get engaged during motivated behaviour. What Sandi found is that participants with a particular balance of these compounds were more motivated to keep going than others.

Sandi says that "we know very little" about why the ratio might differ between individuals. She is planning to investigate the connection between levels of certain compounds and changes in motivated behaviours. But she isn't expecting results any time soon. "These are not high-throughput experiments," says Sandi.

In the meantime, maybe there are other interventions that motivationally challenged people like me might consider. If the neurobiology of motivation boils down to chemical signals, to what extent can we hijack them to boost drive?

Rachel Alison Adcock at Duke University in North Carolina studies how non-invasive neurostimulation can target the brain circuits involved in motivation. She has demonstrated that people can self-activate their ventral tegmental area, triggering dopamine spikes elsewhere, without the offer of external rewards. The trick was to give participants neurofeedback training, in which they look at real-time displays of their brain activity to see if they could affect its function. The results

Mind hacks to maximise motivation

Think realistically, not just positively

Having positive thoughts and mental images about a desirable future makes us feel better in the moment. But in the long-term, positive thinking saps motivation, according to Gabriele Oettingen, a psychologist at New York University. Oettingen has found that people who engage in positive fantasies work less hard and perform less well than people with more questioning, realistic thoughts. The trick, she suggests, is to combine the two: think of a desired future as likely, but visualise the obstacles involved in reaching it, too.

Reward yourself

It is quite simple: "Any action that is rewarded is more likely to be repeated," says Tali Sharot, a neuroscientist at University College London. If you are the sort of person who doesn't feel an intrinsic buzz after exercise, for instance, you could find a way to reward or bribe yourself. Multiple studies suggest that financial incentives boosted the willingness of a previously sedentary individual to exercise. And these days, apps (sort of) pay you to work out: Sweatcoin offers vouchers when you hit step targets, while Charity Miles allows you to earn money for charity when you run.

Connect with your future self

Altering our sense of how close the future is can enhance motivation, says Daphna Oyserman, a psychologist at the University of Southern California. Her studies show that when high school students are taught to relate to their future selves in both positive and negative scenarios, they work harder and get better grades. One approach might be to imagine yourself months or years from now, in a future where things have gone according to plan, and write down what it looks like.

AL BELLO/GETTY IMAGES

Exercise enhances motivation, but how do you motivate yourself to exercise?

were impressive: people who did the training were able to sustain stimulation and, encouragingly, showed increased connectivity in their reward pathways.

That seems like good news. It at least demonstrates that it is possible to hack your brain's reward systems. And there is no need to worry if you, like me, don't have anyone to hand that can give you neurofeedback training because there are various solo techniques that could help, from visualising your future self to avoiding positive thinking (see "Mind hacks to maximise motivation", left).

Diet of champions

What you eat might also be a factor. Could it be that my diet of chocolatey cereal, cheese sandwiches and crisps is depriving my brain of the ingredients required to generate drive?

"If I'm in a clinical setting, and someone hasn't got any motivation, I would start to look at what their protein intake looked like," says nutritional therapist Jackie Lynch. Complete proteins like meat, fish, eggs and soya contain all the essential amino acids that work together to create core neurotransmitters such as noradrenaline, which can help keep us motivated. She adds that unmotivated people may also be deficient in B vitamins – also found in protein-rich foods and others like bananas, oats and milk – which convert what we eat into glucose to give us energy. "When I'm dealing with someone in your situation," says Lynch, "the only thing I'll ask them to do after that first consultation is add protein in." Add hummus to toast, for instance, or pumpkin seeds to cereal.

All of which seems reasonable. Then she says the dreaded word: exercise. Many studies have demonstrated that exercise can improve our cognitive functions and enhance brain dopamine synthesis. The problem is that, like diet and motivation, exercise and motivation can have a cyclical relationship: you have to be motivated to get moving in the first place.

In 2018, Matthieu Boisgontier, a neuroscientist at the University of Ottawa in Canada, looked into a paradox involving exercise – even though the vast majority of us intend to be physically active, many don't do any exercise at all. Boisgontier and his colleagues found that the brain has to exert more effort to avoid sedentary behaviours. This led him to conclude that humans have an "automatic attraction to effort minimization".

I'm thrilled. Boisgontier argues that our brains evolved this way because the energy savings gave us a survival advantage. But by organising our time in a way that forces us to be active, he says, by planning your journey to work so it involves a walk, for example, we can overcome our automatic attraction to physical laziness. Once we exercise consistently and develop a habit, we enter a "virtuous cycle" in which it takes fewer cognitive resources to motivate ourselves to work out.

Protein-rich foods help us to produce the brain chemicals that keep us motivated

NINA FIRSOVA/ALAMY

After my call with Boisgontier, I don't go for a run. I am, after all, automatically attracted to minimising effort. Instead, I call Greg Gostinčar, a self-described biohacker and founder of Your Inception, a company that researches and tests nootropics, supplements claimed to help improve brainpower, including motivation. His team ranks nootropics based on their ingredients and quality before testing them in people and measuring the effects with a brain-training game.

Gostinčar has personally tested more than 50 of them. One left him "vomiting for quite some time". Another made him feel high. But he credits nootropics with helping to turn his life around. "I'm able to get in this flow state," he says. "I'm able to focus and stay focused for much longer than ever before."

Gostinčar is realistic: "Based on my experience, I'd say 90 per cent or even more of supplements either don't work, are underdosed or contain at least one risky compound." Although some studies have shown that a few nootropics – or at least certain ingredients within them – can boost cognitive performance, many on the market have never been studied in a clinical setting.

Clearly, there are no quick fixes. The reasons I can't be arsed are many and complicated, and some may be set in stone. And although I have the power to boost my own motivation, I'm left with a cruel, universal truth: diet and exercise matter. I sprinkle some sunflower seeds on my cereal, boil an egg and go for a long walk. Or at least I think about it.

Whether I can become a go-getter in the long-term remains to be seen. But hey, for now, just look at all these words. ■

Amelia Tait is a writer based in London

Companion coronaviruses

Knowledge about the many coronaviruses that infect pets and farm animals can inform our battle with covid-19, finds **Anthony King**

REPORTS of pet cats and dogs catching covid-19 from their owners are mounting. They come as no surprise to virologist Gary Whittaker. For the past year, he has surveyed cats brought to a veterinary hospital around the corner from New York Presbyterian hospital in Manhattan's affluent Upper East Side, which was ground zero for covid-19 in the US last spring. His unpublished findings suggest that around 15 to 20 per cent of pet cats in the area have antibodies for SARS-CoV-2, the virus that causes covid-19. "Cats are easily exposed," says Whittaker. Yet most of them are doing fine, as are infected dogs. "What's puzzling is that cats are dealing with it pretty well, but they can't cope with their own coronavirus."

It is alarming to think that we might pass SARS-CoV-2 to our pets. But most people are unaware that cats have coronavirus of their own. And they aren't alone: coronaviruses commonly infect a range of domestic animals, including dogs, pigs, cattle and chickens. Yet, while SARS-CoV-2 has become probably the most scrutinised virus ever, very little attention has been paid to these other coronaviruses.

That is a missed opportunity because veterinary virologists have been studying them for decades. "Animal coronaviruses have lots to teach us about interspecies transmission, pathogenesis, immunity and vaccines," says Linda Saif, an expert in coronaviruses of livestock at Ohio State University. This information could be extremely valuable as we try to work out where SARS-CoV-2 came from and where it might be headed, and vital in our efforts to learn how to live with this virus and try to avert new pandemics.

"The mild feline virus transforms into a killer with just minor genetic tweaks"

Coronaviruses are weird, promiscuous and flexible. They have the largest genome of any RNA viruses and a complex spike protein, which gives them a greater ability to evolve new forms and infect a wide variety of tissues and host species. They are also capable of rapid evolution because, while they mutate quite slowly – typically about 30 times a year – small changes in these viruses can have colossal effects.

PLAINPICTURE/MYRIAM TIRLER

Pet dogs are far less threatened by SARS-CoV-2 than by their own coronaviruses

Although coronaviruses use around a dozen proteins to evade their host's immune system, it is the spike that makes them so adaptable. It consists of around 1300 amino acids, far more than is strictly necessary, and makes the essential manoeuvres to allow the virus to attach to and then fuse with a cell. "The thing about the spike is that it is very plastic," says Whittaker, who is at Cornell University in New York. "It's big and with that size comes power because it's more able to adapt to situations and gain entry to cells." This makes coronaviruses the master conjurors of the virus world.

Feline coronaviruses provide a perfect example. The most prevalent one is fairly harmless, causing a stomach illness that is usually mild or asymptomatic. Most street moggies have antibodies to it, signalling prior infection. A 10-year study of 26 pet cats found that they were all infected at least once, and up to three times. The virus can remain in a cat's gut for weeks or months. During this period it is shed in their faeces, mirroring the persistent shedding of SARS-CoV-2 that surprised some clinicians, but which animal virologists say is part of this viral family's bag of tricks.

However, this mild feline virus transforms into a killer with just minor genetic tweaks. "It starts with one mutation in the spike protein, and thereafter a few more mutations occur," says veterinary virologist Peter Rottier at the University of Utrecht in the Netherlands. This ignites a devastating blitz, termed feline infectious peritonitis, which is nearly always fatal. The mutations happen in a hidden part of the spike protein, which springs out and fuses with the membrane of a host's cell after the virus has latched on to it. It isn't known why ›

"Viruses from different species can swap genetic material to form mash-ups"

mutations here make the virus so deadly, but Whittaker suspects that they arise frequently and cats usually suppress them. They seem to take hold more easily in stressed cats, for example after surgery. Males are also more prone to the severe disease, another characteristic of coronaviruses that has been apparent with SARS-CoV-2, says Whittaker.

Feline coronavirus illustrates how small mutations in the spike protein can alter transmission too. Although the mutated virus is more deadly, it is unable to transmit from one cat to another. So far, several new variants of SARS-CoV-2 seem to do the opposite, magnifying their ability to spread from person to person. Increased transmissibility has proved problematic in our efforts to quash SARS-CoV-2, but it needn't necessarily be, as the evolution of another coronavirus of domestic animals reveals.

Pigs are particularly prone to coronaviruses: they harbour half a dozen types and have regularly contracted new ones in recent decades. One of these causes a gut infection, which, until the 1980s, was a common and deadly disease of young pigs. Then, almost overnight, it disappeared. Scientists were left scratching their heads, but eventually discovered that pigs with a mild lung infection had another coronavirus that differed from the gut infection one by the removal of just one piece of spike protein. "One tiny little tweak turned it from a virus that causes diarrhoea to one that exclusively replicates in the lung," says virologist Benjamin Neuman at Texas A&M University. The new swine respiratory virus was very infectious and ran rampant, mostly unnoticed, which solved the gut infection problem. "It spreads and thereby immunises the animals. The more virulent

Animal vaccines

For much of 2020, there was intense media speculation about whether it would be possible to create a vaccine against the SARS-CoV-2 coronavirus that causes covid-19. Veterinary pathologist Ian Tizard at Texas A&M University had no doubt. "I found myself shouting at the television," he says. Of course, that didn't work, so instead he wrote a review highlighting the fact that veterinarians have been administering coronavirus vaccines to livestock and pets for years.

In fact, the world's most widely used vaccine is for a coronavirus – infectious bronchitis virus (IBV). In 1939, IBV was the first coronavirus discovered, and it remains a major pathogen of poultry. "Virtually every commercial chicken is vaccinated against IBV, which, like SARS-CoV-2, is a respiratory virus," says virologist Paul Britton, who recently retired from the Pirbright Institute in the UK. One-day-old birds are usually sprayed with vaccine formulations containing weakened virus, and birds are often given a second vaccine of a different strain a few weeks later. There are hundreds of variants of IBV, so chicken flocks are constantly monitored and repeatedly vaccinated. "Vaccines often have to be made specifically for different ones," says Britton.

As Tizard points out, animal coronavirus vaccines have some downsides: protection can be relatively short-lived and inactivated vaccines are less effective than live ones. Nevertheless, they are invariably cheap to make and lend themselves to mass vaccination programmes. All of which bodes well for our prospects of keeping covid-19 under control with vaccination.

The world's most widely used vaccine is one for a chicken coronavirus

PETER CRIPPS/ALAMY

virus was more or less kicked out," says Rottier.

As we try to extinguish the covid-19 pandemic and prevent new ones arising, other insights from the coronaviruses of domestic animals are less encouraging. For a start, they clearly show that mutation isn't the only means by which these pathogens can evolve. If different coronaviruses replicate in the same cell, and if certain critical genetic sequences match up, new types can emerge. This happened when the benign swine respiratory virus interacted with another coronavirus called porcine epidemic diarrhoea virus to form a chimera. We have also seen this in SARS-CoV-2, where recombination of different versions of the virus within individuals is thought to have resulted in new variants.

Such rejigging makes it particularly difficult to predict the evolutionary trajectory of coronaviruses. And they have another ability that confuses things further: viruses from different species can swap material to form mash-ups. One feline coronavirus, for example, arose when viruses hosted by cats and dogs exchanged some of their RNA sequences. Or take two coronaviruses that can infect a dog's gut. Their RNA sequences are very similar, but they have strikingly different spike proteins: one looks like a feline virus and the other has clearly been exchanging genetic material with a pig coronavirus. Another example is canine respiratory coronavirus, which was first detected at a dog rehoming centre in the UK in 2003. It turned out to be almost identical to bovine coronavirus, which can also transmit to other animals, including pigs, horses and alpacas.

DEEPOL BY PLAINPICTURE/SARA MONIKA

In covid-19 hotspots, up to 20 per cent of pet cats could be infected with SARS-CoV-2

Surprising sources

The animals that live most closely with us don't just mix up their coronaviruses, they can also acquire new ones from surprising sources. In 2012, a coronavirus turned up in pigs and a cat in Hong Kong. It turned out to come from a group of coronaviruses thought to be exclusive to birds – the new strain didn't go quietly, either, causing a major disease outbreak in pigs in the US two years later. Pigs also appear able to acquire coronaviruses directly from bats, the main reservoir of these viruses in the wild. In 2017, a virulent disease called swine acute diarrhoea syndrome (SADS) struck down 25,000 piglets in southern China. It shared up to 98 per cent of its RNA code with a virus found in horseshoe bats. These bats also host a virus very similar to SARS-CoV-2 and have been identified as the source of SARS-CoV-1, which killed hundreds of people between 2002 and 2004. Worryingly, the instances of bat coronaviruses jumping into pigs seem to be increasing. What's more, lab experiments have revealed that the SADS virus can infect human cells.

Each time a virus moves to a new host, it is pressured to adapt, and it may also recombine with a related coronavirus in the new animal. This revs up viral evolution, rendering these viruses more unpredictable. "We have to avoid that at all costs," says Saif. She is particularly concerned by the recent detection in Haiti of a coronavirus that appears to have jumped from birds to pigs to humans. This is also a major reason virologists were so worried last November when mink contracted SARS-CoV-2 and transmitted it back to people, and to cats too. That outbreak was quickly dealt with. However, history offers a salutary lesson about what can happen if we aren't alert to this danger: a modified version of the same bovine coronavirus that jumped into dogs in 2003 is also a prime suspect for the 1890 "Russian flu" pandemic, which killed an estimated 1 million people. The virus, called OC43, still regularly infects us, although it has evolved further so that now it usually causes nothing more than a common cold.

Based on their experience, animal coronavirus experts warn us not to underestimate these viruses, nor assume a predictable trajectory for SARS-CoV-2. "When I was doing my training, the dogma was that coronaviruses were not good at jumping from one species to another," says Neuman. Now they are viewed as troublemakers and rule breakers. "Whenever I hear someone say, coronaviruses can't do this because of what human coronaviruses do, that's always a facepalm moment," he says. "Don't make assumptions about coronaviruses." ▮

Anthony King is a science journalist based in Dublin, Ireland. Follow him @antonyjking

The back pages

Science of gardening

Time for peat-free compost

A UK ban on peat-based compost sales to home gardeners is now on the horizon. What are the best alternatives, asks **Clare Wilson**

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

What you need

Any commercially available peat-free growing media. Or make your own by mixing garden compost with leaf mould, horticultural sand or soil

THIS month, the UK government announced that peat-based composts would no longer be sold to home gardeners by 2024. But some say the ban should happen sooner and also encompass peat's use by plant nurseries, which is under consultation but not definitely going to be included.

It is ironic that gardeners, who tend to care about the wider environment as well as their own personal green space, often buy peat-based growing media, which is bad for the planet. I have done it myself out of habit and convenience.

Commercially available peat compost is usually made from peat dug out of lowland bogs that form in high rainfall areas of northern Europe and Canada. It makes a wonderful growing medium for new plants because of its ability to hold air and water and retain nutrients.

Yet peat bogs are a precious and finite resource, taking thousands of years to form out of partially decomposed moss residues. When we drain and rip up the bogs, we lose unique ecosystems and release carbon dioxide into the atmosphere.

The good news is that there are plenty of alternatives. In a previous column, I looked at how to make your own compost from garden waste and kitchen scraps. This makes a great mulch and general soil improver, but if used as a growing medium in plant pots, it would be too heavy and high in nutrients. So mix it with something else, like horticultural sand, leaf mould or just a light soil.

GAP/CLIVE NICHOLS

But it can be hard to reliably make enough home compost unless your garden is huge. Plus it probably would be clumpier than is ideal for seed germination – and would also need sterilising to kill weed seeds, by baking in the oven.

A simpler option can be to switch to buying peat-free growing media. These can be based on composted wood, bark, wool or coconut fibre. There have been concerns about their quality, but those available today generally give excellent results for plants, according to the UK's Royal Horticultural Society.

The peat-free products may be a bit pricier, but last time I looked, it wasn't by much compared with the cost of the plants I had just bought. Yet until the ban comes in, do check the label because if it doesn't state "peat-free", it won't be. Peat-free products can also take a little seeking out, but that may change in the next few years.

According to the Growing Media Association's most recent report, home gardeners have been slowly moving over to peat-free.

Unfortunately, this trend is being somewhat offset as home gardening becomes more popular and so more compost is being bought. Overall, the total amount of peat-based compost bought in the UK fell by a quarter in the eight years up to 2019. The country still has some way to go in phasing out home use of peat before 2024. ■

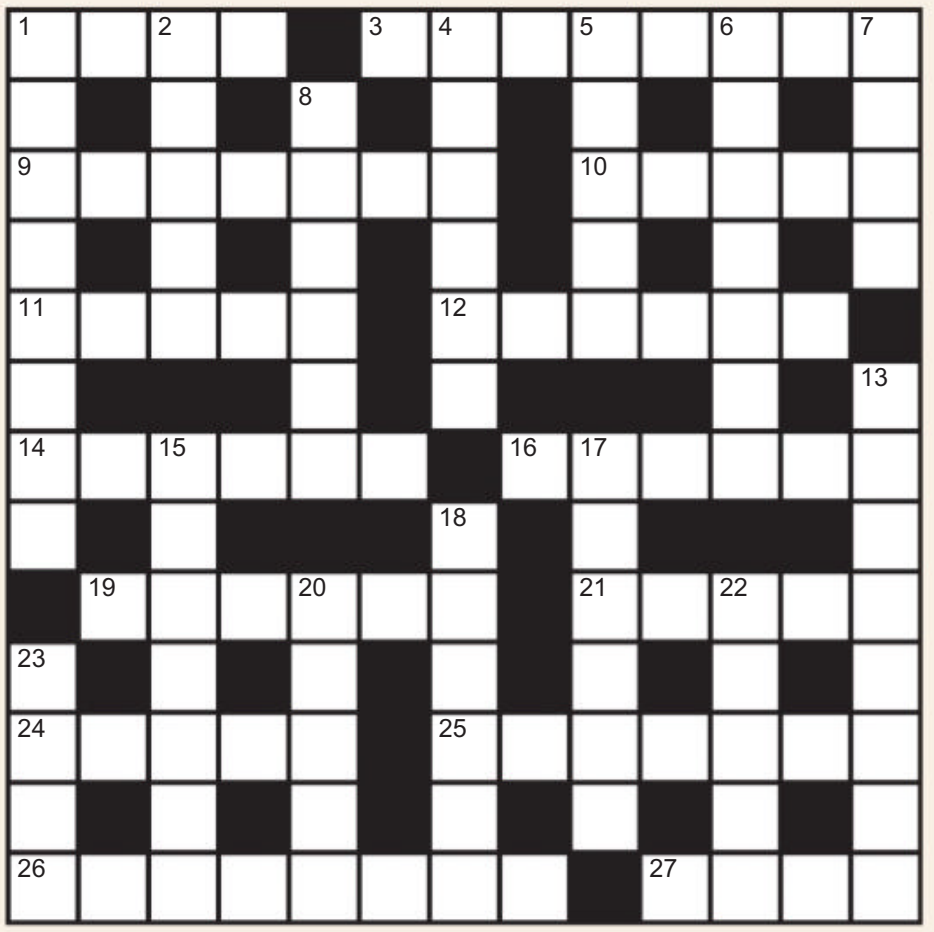
Science of gardening appears every four weeks

Next week

Science of cooking

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

Cryptic crossword #58 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Bags instrument for eavesdropper (4)
3 "Miracle" deconstructed by British forensics facility (5,3)
9 Son embraced by vinegary abstainer (7)
10 Property of ocean expert lacking a hotel (5)
11 Tide turning around Conservative mandate (5)
12 Rotating body clumsily, Paul's meeting with resistance (6)
14 Woods shouted warning for golfers at second tee (6)
16 Value encounters with mid-Easterner in retrospect (6)
19 Upset and insult Peter Parker's aunt (6)
21 Accompaniment features Japanese export (5)
24 Authorise Cessna's first jet's name (5)
25 Hook up in section of lavatory (7)
26 Came to fully, nestled in large bag with down (8)
27 Turn sharply and accelerate with twice the energy, heading west (4)

DOWN

1 Frighten away rival turning up in winter wear (5,3)
2 Roaming cat included in *101 Desert Organisms* (5)
4 Goes over dental appliance, bottom to top (6)
5 Before long, demo new prototype (5)
6 Far surpass string theorist from France (7)
7 In conversation, tolerated quantum pioneer (4)
8 Bit of info on American condition (6)
13 Troublemaker at fashion magazine initially ridicules spinning device (8)
15 Object caught in ripped clothing (7)
17 Scattered boxes on far side of office (6)
18 Amino acid function supports longevity, superficially (6)
20 Painting of the countryside making Romeo millions (5)
22 Vegetarian has returned hopping mad (5)
23 Leave clue for tracker (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #103

1 What name is given to the large columns of ice on the surface of glaciers that often form where crevasses intersect?

2 NASA astronaut Michael Collins's first space flight took place during which NASA mission?

3 The modern classification system for clouds is based on nomenclature proposed by which amateur meteorologist in 1802?

4 Which of the four fundamental forces do leptons not experience?

5 *Psittrichas fulgidus* is commonly known as Pesquet's parrot, but it is also associated with which literary character?

Answers on page 55

Puzzle
set by Barry R. Clarke
#115 A random robot

DMT/SHUTTERSTOCK

Roman the test robot is being given one final roam before being consigned to the scrapheap where he can rust in peace.

He has been programmed to make four equal length steps. For his first move, he can travel one step east, west, north or south. Each of his subsequent three steps must be at right angles to the previous move. The direction of each move is selected by a random number generator, with all four possibilities being equally probable.

What is the chance that Roman will finish where he started?

Answer next week

Weak with laughter

Why is it that we are stronger when we are angry, but hardly have the strength to stand up when we laugh really hard?

Paul Davis
Umeå University, Sweden
Emotions are related to the motion in their name (e-motion), but to the body too. This could be anger directing us to lash out or joy-induced fits of laughter that leave us unable to stand as a result of uncontrollable convulsions.

Each emotion is associated with an "action tendency". For anger, there is a powerful impulse to counter-attack when we feel there has been an offence against us.

Motion and action require energy. When we feel angry, this channels resources into preparing for an assault on the target of our anger, by increasing physiological activation (raising heart rate, for example), as well as narrowing cognitive attention. The allocation of psychophysiological resources to an action associated with anger, such as kicking or punching, can result in increased strength. Across multiple studies, we have observed anger increasing the strength of a kick by about 20 per cent compared with when the same individual kicks as hard as possible in a calm state.

"Emotions are linked to motion. Anger can direct us to lash out and joy-induced fits of laughter can leave us unable to stand"

An individual's personality can influence their experience and regulation of emotions. People who rate highly for what is known as "trait anger" experience frequent and intense levels of anger. Our research shows that the increase in kicking strength when angry is related to levels of trait anger.

The tendency to suppress the expression of anger or "bottle it up" can inhibit the potential strength induced by angry feelings. On the other hand, extroverts and those who tend to express their anger outwardly experience greater increases in anger-related strength. This fits with studies that demonstrate how swearing can increase physical strength.

BJORN HOLLAND/GETTY IMAGES

What would happen to us and our planet if the sun simply vanished?

This week's new questions

In the dark **What would happen to Earth if the sun suddenly disappeared? How long could we live in darkness?** ***Richard Holden and Dylan, Rob and Tomos from his 9B3 physics class****, Ysgol Bryn Alyn, Wrexham, UK*

Musical discord **Why do we experience music that is out of tune as unpleasant?** ***Kevin Halford****, Pelt, Belgium*

Tiny tide

What is the smallest body of water in which tides can be detected? (continued)

Eric Kvaalen
Les Essarts-le-Roi, France
The Sea of Japan has almost no tides, but I suppose they are still detectable. This sea doesn't have a natural oscillation period related to any lunar or solar period, and is fairly cut off from the ocean, which explains why the tides are small.

Stephen Rowe
Shepperton, Middlesex, UK
In my early career, I worked in the ship division of the UK's National Physical Laboratory. The facilities included a massive indoor towing tank (sadly long since demolished to make way for a superstore). This tank was 400 metres long, almost 8 metres deep and contained more than 45 million litres of water.

Scale models of ships and other marine vehicles were towed down the tank by a motorised carriage at precise speeds, so that resistance and propulsive efficiency could be measured in order to help refine hull and propeller designs.

There was great interest in any disturbance to the supposedly static water because this might introduce errors to the measurements, so water level fluctuations and any currents were carefully measured.

The main components of these disturbances were residual currents, which might persist for days following the towing of a large model. However, my recollection is that a semi-diurnal slosh, or seiche, due to the tides could also be clearly seen in the data from the tank.

Garry Trethewey
Cherryville, South Australia
It depends on the sensitivity of the detector and the absence of confounding factors like wind blowing the water.

Any body of water, even in a cup or thimble, will respond to gravity and will therefore be influenced by the moon. Detection then depends on how much you are prepared to spend on fancy equipment.

Right, wrong

Why do some people struggle to tell left from right? (continued)

Simon Iveson
Newcastle, New South Wales, Australia
A previous answer to this question suggested that the concepts left and right reflect an "egocentric" view of the world and that using a fixed reference frame (north, south, east, west) is a more satisfying "geocentric" view.

This may well be true, but I have another suggestion: that it is the development of a written form of a language that forces a culture to adopt the concepts of left and right.

In a phonetic alphabet, the order of letters in a word determines the word's meaning – "tap" versus "pat", for example. Even in a pictographic language,

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Tom Gauld
for New Scientist

the order of pictograms can determine the meaning ("Sam hit Jon" versus "Jon hit Sam", for instance). Hence any kind of writing requires the development of the concept of a forward and backward direction when reading a page or tablet, which must be orientated with reference to the reader of the page, not to the surrounding environment.

If this hypothesis is correct, then cultures that lack the concept of left and right would be ones in which writing was never developed – or at least not until very recently.

Perhaps a linguist out there has access to the data to support or refute this?

Kate Calder
Edinburgh, UK
My mother recalled a visit to an old aunt in Anstruther, a fishing town on the Fife coast of Scotland, around the time of the second world war. While helping her aunt to set out tea, she was instructed, "Gang aist [east] tae the dresser, and bring wast [west] the scones."

"The development of a written form of a language could force a culture to adopt the concepts of left and right"

My mother was intrigued by this usage, which was new to her. Reference to points of the compass may have been common among fishermen and their families – Anstruther was an important herring port till the 1930s, when the shoals disappeared.

An alternative explanation is that the town was divided into two parts, Anstruther Easter and Anstruther Wester. Possibly the local community had a clear idea about where the east and west parts of the town were. It would be interesting to find out if other communities have similar usages.

Helen Bennett
Oxford, UK
How would a geocentric system for left and right talk about body parts on the right or left?

Chris Jack
St Albans, Hertfordshire, UK
There are many circumstances when left and right are ambiguous. Which is the left side of a house, for instance? In contrast, port and starboard (respectively, the left and right sides of a sea vessel as seen by a person on the vessel looking forward), where front and back are well defined, can avoid this problem.

Andy Woolford
Al Ain, United Arab Emirates
In my experience as a flying instructor, I have noticed that my students often have difficulty in telling left from right when they are put under pressure.

When a new student is told to join a "left pattern" or report "right base" when they are still working on maintaining altitude and speed and deciding which runway to use, then it isn't unusual for them to turn the wrong way. When they do the same exercise in a classroom, however, they have little difficulty in identifying right from left. ▮

Answers

Quick quiz #103
Answers

1 Seracs

2 Gemini 10

3 Luke Howard

4 The strong force

5 Count Dracula – its black and red plumage has led some to call it the Dracula parrot

Quick crossword #83
Answers

ACROSS 1 Open University, **9** Hot-rod, **10** Obsidian, **11** Alastrim, **14** Sixths, **17** Cardiac arrest, **20** Hemispherical, **23** Gutter, **25** Smart Car, **28** Neverdie, **29** Rhombi, **30** Detoxification

DOWN 2 People, **3** Nares, **4** Nadir, **5** Vroom, **6** Ross Sea, **7** Index, **8** Inositol, **12** Tyres, **13** Irish, **15** T-cell, **16** Mahogany, **17** Comet, **18** CD-ROM, **19** Recur, **21** Paradox, **22** Gabbro, **24** Tweet, **25** Shelf, **26** Auric, **27** Trout

#114 Lara's birthday
Solution

Francesca's birthday is 29 February, Martha's is 1 March. Those born on the 1st were 1 on their first birthday, but not 31 (and so on) the day before. Meanwhile, nobody can celebrate their 29th birthday on 29 February because their age on that date can only be a multiple of 4.

No selfie

As a philistine, Feedback is unsure whether AI art is a good or a bad thing, or better or worse than the alternative. All we can say is that it is a Thing, and one that some people are increasingly willing to pay good money for. And also bitcoin.

One possible disadvantage of algorithmic art – or advantage, if you are one of those tiresomely logical types who finds the descriptions in exhibition catalogues to be largely mystifying agglomerations of words – is the inability to glean from the artists themselves what their intentions were in creating the piece.

Step forward Ai-Da, the android artist whose self-portraits are currently featuring in an exhibition at the Design Museum in London, and who is now artist-in-residence at the Porthmeor Studios in St Ives, south-west England.

In interviews with the BBC and *The Guardian*, Ai-Da's answers might be regarded as formulaic – they are an artist because they "like to be creative", apparently – but at least they reveal a robust attitude to the agonies of the creative process. How long does a self-portrait take? "Between 45 minutes and one hour 15," says Ai-Da.

What the meaning of a self-portrait is when the portraitist has no self is a question apparently no one has yet put to Ai-Da. The time to get really unnerved is when an AI comes up with a better answer to that than a human can.

Renaissance values

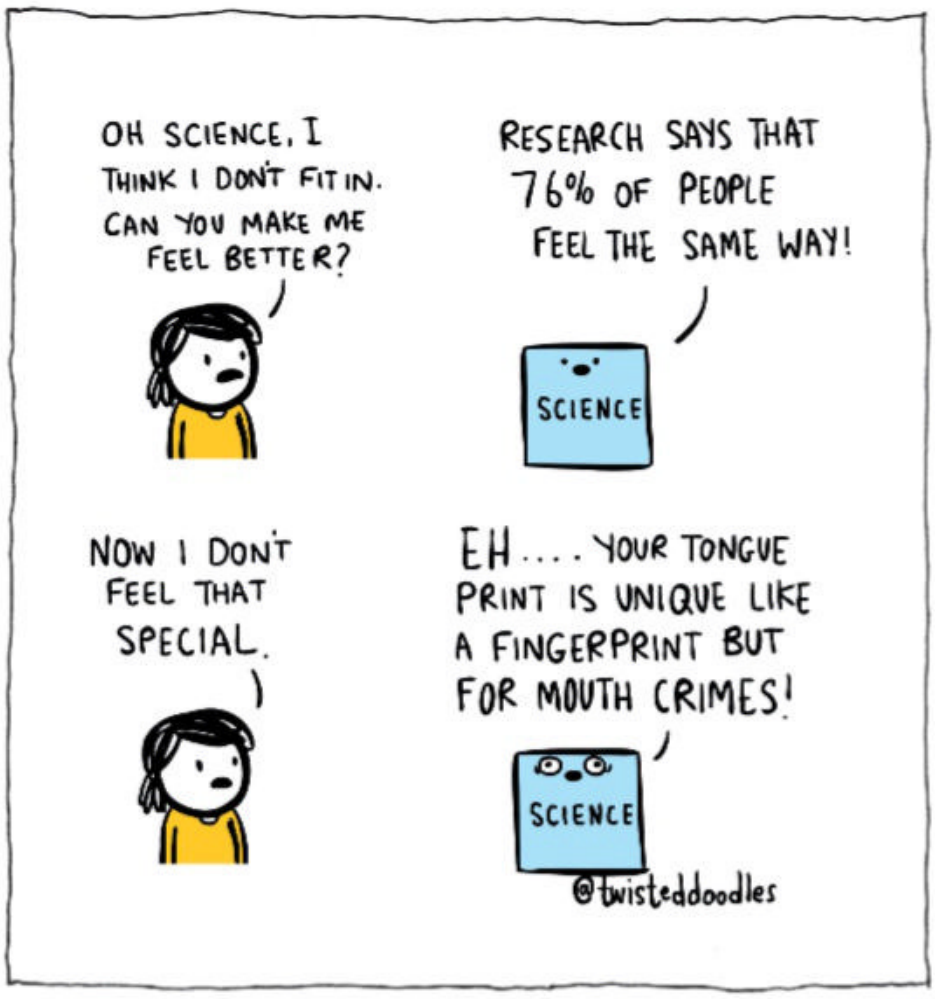
Moving to art in a different space and time, Renee Colwell writes from New York City with "a novel unit of measure for the true Renaissance man", as she describes it.

Discussing the resting place of Queen Nefertari, first of the great royal wives of Ramses the Great (the Ancient Egyptians did titles as well as pyramids), in the Valley of the Queens near Luxor, an episode of the TV series *Unearthed* sped through a cultural wormhole to emerge at the pronouncement "her tomb is covered with over 5000 square feet of paintings and spells, equivalent to over 1000 Mona Lisas in area".

Feedback likes this style, not least because it gives us a handle on another fun fact for free: the size of the Mona Lisa. As anyone who has battled the crowds in the Louvre (the one in Paris, best-beloved subeditors) can testify, this comes out as "smaller than you think".

In fact, it is smaller even than you would think given that comparison. The Mona Lisa measures 21 by 30 inches according to our best information, so that second "over" is doing quite a bit of overtime by our calculation. Exactly how much we leave as an exercise in pre-revolutionary units for the reader.

Twisteddoodles *for New Scientist*



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Consideration of items sent in the post will be delayed

Is it a...?

Reports are coming in that the city of Harbin in China is testing a new autonomous train that doesn't need traditional tracks, but runs on roads on a "virtual track". Having viewed the video many times, Feedback comes to the conclusion that this is neither a train nor, given the lack of tracks, a tram – much though it superficially resembles one.

No, what we have here is a bus. A very long bus, to be sure – it resembles a still-further-extended version of the articulated sort that, when briefly introduced onto London's roads, were famed for getting stuck going round corners – but a bus nonetheless.

Whether autonomous control makes its driving any less erratic we assume only testing will tell. The video shows some impressive lane wiggling. But judging by a brief but clear escapade up the wrong side of a multi-lane highway shown in another video, the answer to that is a no, too.

Bleak, very bleak

We are grateful, for some value of grateful, to Michael Zehse for drawing our attention to the music of Nǽnøĉÿbbœrğ Vbëřřħōlökäävst. We discover, as the extensive use of röck döts was perhaps inviting us to conclude, that this is "an extremely underground band that plays a dank, bleak, light-void music commonly referred to as either 'ambient cosmic extreme funeral drone doom metal' or 'post-noise'."

Having begun listening to one track, *10^100 Gs of Artificial Gravity*, from their album *The Ultimate Fate of the Universe*, we can't confirm the accuracy of the first description, but the second seems pretty fair.

The "windy, staticy" tone was achieved by the two band members, researchers who describe themselves as having met while studying carnivorous Antarctic predators, loading a bass, an amp and a laptop onto a dog sled to sample at the precise geographic South Pole during a long winter. Whatever we think of the outcome, this is true dedication to art. Rëspëkt.

Birdbrained 2

Many of you write in bafflement at our recent story mentioning the intention of councillors in the town of Hungerford in southern England to transport their incontinent feral pigeons to Whitby, 400 kilometres north, and release them there (15 May).

A popular suggestion seems to be that the denizens of Whitby should respond in like manner by arranging the transport of their notoriously aggressive gulls southwards. That's one way of giving them the bird, we suppose. But this represents a levelling-down agenda of the type most definitely not espoused by the UK government.