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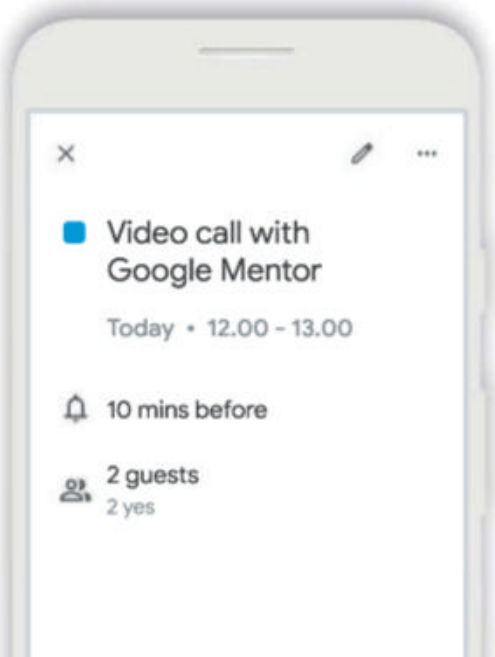

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Christmas with New Scientist

Subscriber Christmas Special

The end of each year simply must be marked with an office party, even a year as bruising as this one. Not thwarted by lockdowns or social distancing, we are having one of our own – and you are all invited.

So join us on 17 December for the *New Scientist* Christmas special live. Kicking off at 6pm GMT, it is an online event that is a party, panel show and quiz all in one. I am your host, and the contestants are our journalists Graham Lawton, Sam Wong, Layal Liverpool and Penny Sarchet. There will be 10 rounds, including a picture round and questions from the audience. Start thinking up your science-related questions and I will select the best to ask on the day (there is a chance to win one of our lovely jigsaws).

The whole thing is free for subscribers, so go to newscientist.com/events to book tickets and submit your question. I look forward to seeing you there.

Rowan Hooper
New Scientist podcast editor

Essential Guide

Quantum physics

What better way could there be to while away the holiday season than getting to grips with our most mind-bending theory of reality?

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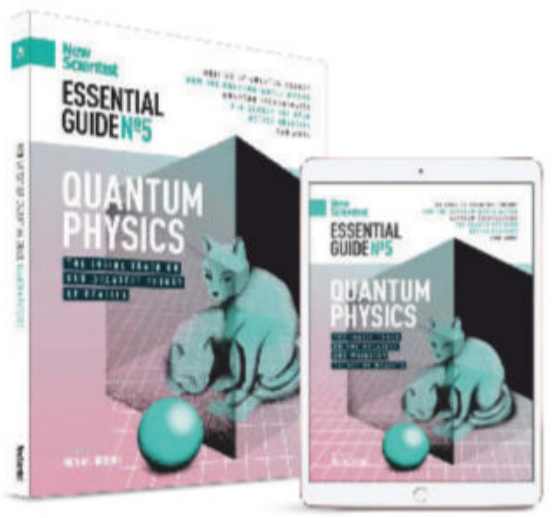

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Jigsaws, T-shirts and much more

Stuck for present ideas? The *New Scientist* shop is full to the brim with inspiration. Our brand new jigsaws (left) come in three beautiful designs and are made from recycled materials. You can also pick up books, T-shirts, face masks, reuseable cups, notebooks and plenty besides.

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A note from the editor

IT HAS been a long old year, but the good news (important vaccine developments aside) is that there is now only one week to go until our famous festive double issue!

My colleague Daniel Cossins is the editor of our special holiday features section this year, and he has spared no reindeers in his efforts to deliver a world-beating, mind-bending smorgasbord of stardust-sprinkled delights.

That is literal stardust in one case, as we follow our feature editor Joshua Howgego onto the roof of his house in search of micrometeorites from the dawn of the solar system. But if you have also ever wondered why animals don't have wheels, or what a glacier mouse is, wonder no more – these vital questions and more will be answered in next week's mag.

There will also be a fiendish science quiz, an exclusive short story from sci-fi writer Adrian Tchaikovsky, our staff's brave taste-testing of "instant" vintage whisky and our news review of an extraordinary year for all of us, and for science. The edition is on sale from 17 December for those of you without a subscription. We hope you enjoy it.

Emily Wilson
New Scientist editor

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[1] Source: Global Cement and Concrete Association
[2] Annual global cement production in 2019: 4.1 billion tonnes. Precast industry is 30% of total. Source: IEA.
[3] Typical passenger vehicle emits around 4.6 metric tonnes of CO_2 per year. Source: EPA.

The complexities of you

Studying ourselves isn't getting any simpler – but it is endlessly fascinating

"KNOW thyself." The first of three maxims said to have been inscribed in the forecourt of the Temple of Apollo in Delphi sounds grand. What it actually means has been a matter of debate for millennia, and when it comes to knowing ourselves, modern science has made things deliciously more complex, too.

How the physical substance of our bodies creates our sense of being a consistent entity, and what it means to have that sensation, is a long-standing puzzle. Debates about this relationship between matter and mind were meat and drink to the Ancient Greek philosophers, but they didn't have our conception of a universe whose matter consists of fundamental particles that have been evolving according to rigid mathematical laws since the big bang.

They also didn't have the rapidly expanding knowledge of genetics and cell biology that the past century or so has brought us, or the sophisticated psychological experiments showing that we are all a bundle of delusions and biases that prevent self-knowledge.

"Psychological experiments show that we are all a bundle of delusions and biases that prevent self-knowledge"

Such insights give new perspectives on some old philosophical debates about the nature of human free will and whether any sort of afterlife awaits us. They have also sparked new ones. Where do the boundaries of our selves lie if the trillions of alien cells that make up our microbiome are also influencing our moods and emotions? Or how does the complex, ever-changing interplay of genes and environment that makes us who we are alter our ideas of the continuity of our self?

We hope you will find much to enjoy and stimulate in our special feature on the greatest mysteries of you, which covers all these and more (see page 32).

It is possible to take introspection too far. Not for nothing were the two other Delphic maxims "nothing to excess" and "surety brings ruin". But as we reach the end of a unique year of lockdowns that has seen many of us struggling without the company of others, let us delve into the mysteries of ourselves with one of the most productive interpretations of the ancient aphorism in mind: that by better knowing ourselves, we can learn to understand others a little better, too. ▮

PUBLISHING & COMMERCIAL

Commercial and events director Adrian Newton

Display advertising
Tel +44 (0)20 7611 1291
Email displayads@newscientist.com
Sales director Justin Viljoen
Sales manager Rosie Bolam

Recruitment advertising
Tel +44 (0)20 7611 1204
Email nssales@newscientist.com
Recruitment sales manager Viren Vadgama

New Scientist Events
Tel +44 (0)20 7611 1245
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Creative director Valerie Jamieson
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CONTACT US

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General & media enquiries
UK **Tel**+44 (0)20 7611 1200
25 Bedford Street, London WC2E 9ES
Australia 418A Elizabeth St, Surry Hills, NSW 2010
US PO Box 80247, Portland, OR 97280

UK Newsstand
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JACOB KING/POOL/GETTY IMAGES

Margaret Keenan was the first person to receive the Pfizer/BioNTech vaccine

Coronavirus vaccine

First shots given in the UK

Older people and health workers get Pfizer/BioNTech vaccine, amid warnings that the pandemic isn't over yet, reports **Michael Le Page**

THE roll-out of a vaccine against the coronavirus has begun in the UK. On 8 December, more than 50 hospitals across the country started to vaccinate people aged over 80 and some healthcare staff against the coronavirus, after the UK became the first nation to authorise a vaccine developed by US pharmaceutical company Pfizer and its German partner BioNTech for emergency use on 2 December.

The first person to receive the Pfizer/BioNTech vaccine was Margaret Keenan. "I feel so privileged to be the first person vaccinated against covid-19. It's the best early birthday present I could wish for because it means I can finally look forward to spending time with my family and friends in the new year after being on my own for most of the year," Keenan, who is about to turn 91, told reporters.

"My advice to anyone offered the vaccine is to take it. If I can have it at 90, then you can have it too," she said.

Keenan was given the injection at University Hospital in Coventry. She is due to receive a second dose in around three weeks. The full immune response to the two doses should kick in by early January, greatly – but not completely – reducing her risk of developing covid-19 if she is exposed to the coronavirus.

The second person to get the shot at the hospital was 81-year-old William Shakespeare, prompting a wave of Shakespeare-related references on social media.

The UK has received 800,000 doses of the vaccine, and is hoping to get millions more by the end of the year. However, vaccinating the 12 million people aged over 65, let alone all those who are eligible, will be a massive challenge.

UK health minister Matt Hancock said life might start to get back to normal as early as springtime in the northern hemisphere. "I hope we can lift the restrictions from the spring," he said on BBC Radio 4's *Today* programme.

In the meantime, people need to follow the rules, he said, warning that rising cases in some parts of the country might lead to the introduction of tougher restrictions.

In some other countries, vaccination has already begun.

"Progress on vaccines gives us all a lift and we can now start to see the light at the end of the tunnel"

Chinese company Sinopharm said in November that around a million people in China had already received its vaccine. Mass vaccination also began in Russia this week.

Regulators in the US and the European Union haven't yet approved the Pfizer/BioNTech vaccine, but are expected to do so in the coming weeks, allowing vaccination to begin in many more countries.

Two other vaccines have also completed phase III trials and could soon be approved in Europe and the US.

Those are the vaccine developed by Moderna and the one made by pharmaceutical company AstraZeneca in collaboration with the University of Oxford.

"Progress on vaccines gives us all a lift and we can now start to see the light at the end of the tunnel," Tedros Adhanom Ghebreyesus, the head of the World Health Organization, said on 4 December.

"However, WHO is concerned that there is a growing perception that the pandemic is over," he said. "The truth is that, at present, many places are witnessing very high transmission of the virus, which is putting enormous pressure on hospitals, intensive care units and health workers."

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

Briefing

Your guide to the new vaccine

The UK has taken delivery of the first doses of a coronavirus vaccine. How does it work and who will get it when? **Graham Lawton** reports

IMMUNISATIONS using the vaccine created by Pfizer and its partner BioNTech have begun in the UK. Here, we answer questions about the science of the vaccine, who will get it first, how confident we can be in the authorisation process and the logistics of vaccinating everyone in the UK.

STEVE PARSONS/PA WIRE/PA IMAGES

Nurses undergo covid-19 vaccination training at University Hospital Coventry

Science

How effective is the vaccine?
About 95 per cent. The phase III trials of the Pfizer/BioNTech vaccine involved 42,000 people, about half of whom got the experimental vaccine and the rest a placebo. In total, 170 people fell ill with covid-19. Only eight of them were in the vaccine group; 162 had received the placebo. So around 5 per cent of cases were in the vaccine group, which is where the 95 per cent figure comes from. That is a very healthy number: the World Health Organization (WHO) said it would accept 50 per cent.

What is in the vaccine?
The active ingredient is messenger RNA that carries instructions for making the virus's spike protein, which it uses to enter cells. The mRNA is synthetic, not extracted from actual viruses, and delivered in a sphere of inert fatty material called a lipid nanoparticle.

The RNA-bearing nanoparticles are suspended in saline solution and injected into muscle tissue in the upper arm. The mRNA is then taken up by specialist immune cells, which follow its instructions, just as they would if they were infected with the actual virus.

The spike protein that is made is recognised as foreign by the immune system, which mounts an attack against it. Antibodies, B cells and T cells are activated, according to Uğur Şahin, the chief executive of BioNTech. An immune memory is also laid down, he says, meaning the immune system has learned how to defeat the pathogen and is primed to mount a swift response if it encounters the coronavirus for real.

How long does the immune memory last?
It is hard to say at this point, because the clinical trials weren't set up to answer that question, and in any case, they only began dispensing second doses of the vaccine four months ago. The WHO says that a minimum of six months would be acceptable. It will become clearer as the volunteers continue to be monitored. Şahin says he expects protection to last "months or even years".

Given what we know about natural immunity, that looks about right, says Eleanor Riley at the University of Edinburgh in the UK. She envisages people needing annual boosters, at worst.

"We don't know how long immunity will last, but people may need annual booster shots at worst"

How long does it take for immunity to develop fully after vaccination?
The trial began assessing immunity seven days after the second shot. We know that protective immunity builds up within four weeks of the first dose, but Şahin says that it appears to develop earlier than that. Further details will be published in a matter of days, he says.

Health Check newsletter
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What happens to the mRNA in the body?
It is active for a few days then decays rapidly.

It is a two-shot vaccine, so what happens if people miss their second shot? Is a single shot still protective?
Two shots are needed, and the second shot is required to attain immunity. The gap between doses in the trial ranged between 19 and 42 days. Only 2 per cent of people in the trial missed their second dose so it isn't entirely clear what happens under those circumstances.

Are there any side effects?
Sometimes, but they are mild. In the trial, the vaccine was generally well-tolerated, and an independent data monitoring committee reported no serious safety concerns. The worst side effects were fatigue and headaches after the second dose. About 4 per cent of people reported fatigue and 2 per cent a headache. Other side effects were pain at the injection site and muscle pain. These are "common reactions you would have with vaccination", says Özlem Türeci, chief medical officer at BioNTech. Older adults reported fewer and milder side effects.

Does it work in older people?
Yes. Trial participants were aged up to 85, and the efficacy in people over 65 was 94 per cent – a tiny bit lower than the overall number but still very protective, and much higher than some vaccine experts feared. The vaccine hasn't been tested in people aged over 85.

And in other vulnerable groups?
The vaccine appears to be equally effective regardless of recipients' age, sex and ethnicity, according to BioNTech. It has been tested extensively in people who have already had the virus and doesn't cause any ill effects. It has also been tested in people with "stable" pre-existing conditions – known as comorbidities – including diabetes, cancer, hepatitis B, hepatitis C and well-managed HIV. Their response was as good as anyone else's. People with serious or worsening comorbidities will also be eligible for the vaccine. BioNTech says it has data on this group and will release it imminently.

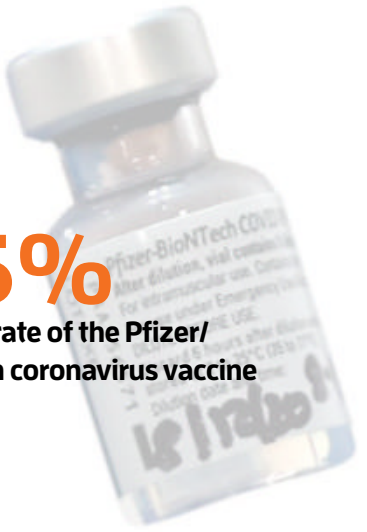
Does it protect everyone?
No. In the trials, out of about 20,000 people who were given the vaccine, eight caught covid-19 and one became seriously ill; 162 people who received the placebo fell ill, nine severely. It isn't known why some people didn't respond to the vaccine. But a success rate of 95 per cent is about as good as it gets with any vaccine.

Does it stop people from catching and transmitting the virus?
We still don't know. The trial was designed to test for symptomatic covid-19 and confirmed infection with the virus. Assessing whether the vaccine prevents transmission – which is probably a prerequisite for attaining vaccine-induced herd immunity – is much harder. But Pfizer says it is carrying out more studies on this question and will release information soon.

Some vaccines can paradoxically make a disease worse through a process called antibody-enhanced disease. Is that a risk?
Yes, theoretically. But it hasn't been seen with this vaccine or any other against covid-19, and hasn't occurred naturally, as sometimes happens with other viruses.

Has the full data from the trial been published yet?
No, it hasn't, but there is nothing sinister about that. Companies can release news to the market as soon as they have it, which is a much speedier process than preparing a scientific manuscript. According to Pfizer, every detail of the science will be submitted to a top-ranking peer-reviewed journal as soon as it is ready. It will be up to the journal how long it takes to publish.

FRANK AUGSTEIN/POOL/GETTY IMAGES



95%
Efficacy rate of the Pfizer/ BioNTech coronavirus vaccine

2
Vaccine doses needed to protect against symptomatic covid-19

-70°C
Temperature the vaccine must be kept for long-term storage

5
Days the vaccine is stable in an everyday fridge

Eligibility

Who is first in the queue in the UK?
When a vaccine is approved it is customary to first offer it to people who took part in the clinical trial but received the placebo. However, as the trial wasn't done in the UK, there is nobody in this category.

Care home residents and their carers have the highest priority, according to a priority system devised by the UK's Joint Committee on Vaccination and Immunisation. But there are problems with delivering this particular vaccine to care home residents because it needs to be transported at very cold temperatures in special cases.

Next in line are people over 80 and frontline healthcare workers, followed by people aged over 75, then people in increasingly younger age groups and/or with underlying health conditions.

Will anyone be excluded from the vaccine programme?
Yes. Pregnant women and children under 16 won't be eligible, at least at first. The vaccine hasn't been tested on pregnant women or children under 12, and there isn't enough data on children aged 12 to 15. But trials in those groups are ongoing or planned.

Pregnant women and children under 16 won't be eligible for the Pfizer/BioNTech vaccine in the UK until further trials take place

SHUTTERSTOCK/NATALIA DERIABINA

Everyone else can get it?
Yes, but most will have to wait their turn. Sean Marett at ›

BioNTech says the exact delivery schedule depends on how fast the factories can churn it out and where else the vaccine is approved, as the company is committed to equitable access. "We will deliver as many doses as we can as quickly as we can," he says.

Regulatory process

What does "temporary authorisation for emergency use" mean?
Exactly what it says on the tin. The UK's Medicines and Healthcare products Regulatory Agency (MHRA) has expedited the approval process in recognition of a public health emergency, and could rescind the approval just as quickly. But that is highly unlikely as it says it has done a thorough assessment of the safety and efficacy data and has seen nothing to give it reason not to approve.

Will the vaccine inevitably progress from temporary to full authorisation?
Probably, but it isn't a given. Pfizer says it expects so, but that is in the hands of the regulators.

It all happened very quickly, can we be confident corners weren't cut?
Yes. The MHRA is an independent body and so is the Commission on Human Medicines, which also had

"If there is disruption in the supply chain due to the UK leaving the EU, we will find another route"

a say in the approval decision. The MHRA only received the full clinical trial data a couple of weeks ago, but the vaccine developers have been submitting information since October, which has been subject to ongoing review.

DANIEL ROLAND/AFP VIA GETTY IMAGES

The Pfizer/BioNTech vaccine will travel in trucks at -70°C

The European Medicines Agency, the group that approves covid-19 vaccines for the European Union, said in a statement that its process for assuring the safety and efficacy of the vaccine is based on more evidence and more checks than the process used in the UK. According to the vaccine developers, the MHRA asked for the same amount of information as any other regulatory agency.

Are other countries likely to approve the vaccine soon as well?
Yes. Pfizer/BioNTech have applied for approval in the US, Australia, Canada, EU, Japan and New Zealand, and say they are preparing to submit applications to other regulatory agencies. Decisions are expected from the US and EU this month.

Logistics

How many doses is the UK getting?
In total, the UK government has pre-ordered 40 million single doses, which is enough for 18 million people assuming two doses per person and about 10 per cent wastage. But it won't get all 40 million at once. The full order will be delivered in batches over the course of 2020 and 2021.

Doesn't the vaccine require complicated cold storage?
Yes and no. For long-term storage – meaning for six months or so – the vaccine has to be kept at -70° C, which requires specialist cooling equipment.

But Pfizer has invented a distribution container that keeps the vaccine at that temperature for 10 days if unopened. These containers can also be used for temporary storage in a vaccination facility for up to 30 days as long as they are replenished with dry ice every five days.

Once thawed, the vaccine can be stored in a regular fridge at 2°C to 8°C for up to five days.

Could the supply chain be disrupted on 1 January by the end of the Brexit transition period following the UK leaving the EU?
Possibly. But according to Marett, "if there is disruption we will find another route".

Where will people be vaccinated?
The usual places: GP surgeries, health centres and hospitals. Once logistical challenges have been met, it will also be done in care homes, starting in Scotland in mid-December. People will be invited by the NHS. The entire supply is going to the various NHS bodies in the UK and nobody can jump the queue by buying a vaccine privately, according to Pfizer.

Could something still go wrong?
Yes, but that is highly unlikely. Vaccine effectiveness in the real world is almost always lower than efficacy in trials, but the drop-off would have to be spectacular to dip below the 50 per cent threshold considered acceptable by the WHO.

There could still be rare severe adverse effects down the road, especially as mRNA vaccines are a new technology and have never been rolled out on a massive scale.

Vaccine clinical trials aren't big or long enough to rule out rare but serious side effects, which can appear months or even years after vaccination. People who have been vaccinated will be followed up for two years to ensure that there are no serious adverse effects waiting in the wings.

But these are small, theoretical risks. As Fiona Watt at the UK Medical Research Council, said: "This is great news." ▮

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Holiday season

The Christmas conundrum

Countries across Europe are taking very different approaches to the festive period. **Clare Wilson** reports

AS THE end of a difficult year approaches, there is growing debate over how people can celebrate the festive season together while minimising the spread of the coronavirus.

With scientists warning that relaxing restrictions could lead to a third wave in the new year, countries are implementing different rules.

The UK's Christmas rules were announced in late November. Up to three households will be able to meet in homes for the five days spanning 23 to 27 December in most of the country, pushed up to seven days in Northern Ireland. Within these "Christmas bubbles" there is no requirement to socially distance unless it is a short visit.

TOLGA AKMEN/AFP VIA GETTY IMAGES

In the UK, three households will be allowed to mix over the Christmas period

Whether the government has got it right in terms of the number of people and days for these bubbles is still debated. "I don't understand why it needs to be so long," says Stephen Griffin at the University of Leeds, UK.

In addition to the rule of three households, Scotland has some extra measures. People are being encouraged to avoid meeting in person unless it is felt necessary, and social distancing should continue. It is also capping the total number of people over the

9 million

Austrians will be offered a coronavirus test before Christmas

age of 12 who can meet in a home at eight. In the rest of the UK, numbers are unlimited. "One household could be as high as 20 people," says Griffin.

Several other countries are also relaxing rules during the holidays.

In France, for example, people will be able to meet in groups of six adults but a national curfew is expected when lockdown lifts on 15 December. People will need to be in their homes from 9 pm until 7 am, except on Christmas Eve and New Year's Eve. Restaurants and bars aren't expected to reopen until well into January, in line with findings that closing such venues has more impact on virus spread than simply closing early.

In Germany, in order to minimise transmission when people get together, in particular asymptomatic spread, people are being asked to voluntarily self-isolate for several days before meeting with other households.

"You may well be saving your relatives from getting covid," says Julian Tang at the University of Leicester, UK. "It's a nice idea, but it's probably quite difficult."

Festivities will be more subdued in Italy, which is taking the harshest approach with a progressive tightening of the rules until the new year, in a bid to discourage parties and gatherings. Between 20 December and 6 January, people will be banned from travelling between regions, barring a few exceptions, and won't be allowed to leave their towns on 25 and 26 December.

Unlike people in the US during Thanksgiving, which fell on 26 November, Europeans won't be expected to bring their own dinner. The US Centers for Disease Control and Prevention advised people travelling for Thanksgiving to bring their own food, plates and

What about children?

Should we be worried about the risk of children passing the coronavirus on to older or vulnerable relatives? The short answer is yes. "I think there is a risk of that," says Katy Gaythorpe at Imperial College London.

In England, about 2 per cent of people aged between 11 and 24 have covid-19, according to the latest survey by the Office for National Statistics, compared with about 1 per cent in most other age groups, including younger children.

The reason is that schools and universities remained open during the latest lockdown in England, so students were more likely to mix with others and pass on the virus.

The high number of infected young people could lead to a high number of older relatives being infected during family gatherings.

"If grandparents and vulnerable people mix with other people that have been mixing in the run-up to Christmas, such as schoolchildren, this inevitably increases risk of infection," says Duncan Robertson at Loughborough University, UK.

Teaching unions have called for schools to close a week early, and a petition for this has gathered more than 100,000 signatures, but the UK government says schools will stay open.

Most children have only mild symptoms if infected, and about 21 per cent remain asymptomatic, according to a meta-analysis by Gaythorpe's team. Overall, it seems that children – particularly younger ones – might be slightly less susceptible to the coronavirus than adults, and slightly less likely to infect others, but the evidence is mixed.

"If we are working towards a clear objective of minimising deaths, then it would make sense to close schools around two weeks before Christmas bubbles are formed," says Robertson. "But doing this could have an unintended consequence of encouraging more mixing."

Michael Le Page

other utensils. But many scientists now think the risk of passing on the virus from contaminated surfaces has been overstated. Cleaning and disinfecting surfaces was ranked among the least useful measures to combat the virus in a recent study that modelled the effectiveness of different interventions. "A casual touch of a surface is not going to get that much virus off it," says Tang.

Austria's approach involves mass testing its population of 9 million over 10 days in an attempt to isolate cases before the increased socialising starts. The country is using antigen tests that look for protein molecules from the virus, rather than the more commonly used PCR tests, which look for the virus's genes.

Antigen tests give fast results, but aren't as sensitive as genetic tests, so will generate more false negatives, wrongly telling people they are clear of the virus.

One risk is that it could be counterproductive, if people wrongly think a negative test is an all-clear. The testing process could even lead to a rise in cases. "If you bring all these people for testing, you might get some additional spread," says Andreas Bergthaler at the Research Center for Molecular Medicine of the Austrian Academy of Sciences in Vienna.

We will find out in early 2021 which approaches have worked best, when we see the impact on transmission rates. After all, this is the world's first encounter with the coronavirus. "We have never done anything like this before," says Simon Clarke at the University of Reading, UK. "I don't think we can say exactly what the impact will be [of different measures]. But the simple fact is, the more mixing that goes on, the more transmission there will be. And that will mean more people dying." ▮

Second wave

Was England's second lockdown necessary?

Adam Vaughan

ENGLAND didn't need a second lockdown because daily covid-19 cases were already peaking under previously imposed regional restrictions, according to a researcher leading a popular symptom-tracking app. "It was unnecessary, if you looked at the latest data on the curves," says Tim Spector at King's College London, who oversees the Covid Symptom Study. Other researchers disagree, however.

Almost 3 million people have signed up to the study's app, which asks users to log how they are feeling each day and input results from any covid-19 tests.

Information from the app indicates that daily cases in England peaked at about 33,000 around 23 October before gradually falling. Modelling by the Office for National Statistics suggests that the peak came later, in November. The second lockdown in England was announced on 31 October, and started on 2 November.

Spector says the government relied too much on modelling from its scientific advisers, SAGE, instead of the data being reported by users of the app, which makes information available faster than the surveys relied on by SAGE. He suggests that the three tiers of restrictions introduced on 14 October, with levels varying by region, were already reining in the disease. "We really need to learn lessons from this for the third wave, and not keep repeating the same overreacting or under-reacting problems," he says.

SAGE's work shows that the lowest tier was failing to stop cases growing but the two highest tiers were putting the brakes on the epidemic before the national lockdown started. A paper by the group published on 27 November found that cases were still growing in areas under the lowest restrictions, tier one. In tier two, cases were shrinking in many areas. Most areas with the toughest measures, tier three, saw cases declining.

"We need stable restrictions to stop people rushing to the pub before lockdowns"

However, that doesn't mean the lockdown was unnecessary. Andrew Hayward at University College London (UCL), a member of SAGE, says the rate at which cases were curbed by regional or national measures matters too.

"It's not just the case of whether you're peaking, but also the speed at which you're declining that is relevant. A gradual decline in those high-incidence areas would still be devastating in terms of the number of deaths and hospitalisations that could have been avoided," he says, adding that Spector's analysis of the daily case curves is "a bit simplistic".

Christina Pagel, also at UCL, says: "Tier three reduction is slow and hospitals would still have been more likely to be overwhelmed compared to a faster reduction."

Schools being closed for half-term at the end of October will also have contributed to the slowing in cases then, with less social mixing and travel, says Hayward. However, disentangling that impact is hard, he adds.

Devi Sridhar at the University of Edinburgh, UK, says she is sceptical about how well the epidemic can be tracked through people reporting symptoms to Spector's app. "There are major limitations," she says.

The UK government has rejected the idea that earlier regional restrictions were working well enough to render a national lockdown unnecessary. England is now back in a system of tiered restrictions. Spector says that maintaining a stable system of restrictions until April is key, to avoid "people rushing to the pub" before further lockdowns. ▮

WIKTOR SZYMANOWICZ/BARCROFT MEDIA VIA GETTY IMAGES

All but deserted London streets during lockdown

Artificial intelligence

Military robots work best alone

Human operators impede performance of robots being developed for US military

David Hambling

WHEN soldiers are teamed with robots, the human need to interfere may negate the benefits of robotic assistance, a new US military project has discovered. But letting military artificial intelligence proceed without human supervision raises troubling ethical questions.

The System-of-Systems Enhanced Small Unit (SESU) project foresees a team of around 200 to 300 soldiers augmented with swarms of small drones and robotic ground vehicles. The unit would fight in zones where an enemy controls the airspace and yet be able to defeat enemy forces that are "overwhelmingly superior in size and armament", according to the US Defense Advanced Research Projects Agency (DARPA).

Rather than being operated individually, as most current drones are, SESU robots will have AI and be largely autonomous.

Researchers described the results of recent virtual simulations at the US Army Futures Command Conference in Washington DC in October.

"It's very interesting to watch how the AI discovers, on its own, some very tricky and interesting tactics," said a US Army scientist, speaking on condition of anonymity. "Often you say, 'Oh whoa, that's pretty smart. How did it figure out that one?'"

However, the robots were impeded by humans who may not have understood their actions.

"What we found, as we ran the simulations, was that the humans constantly want to interrupt them," said the scientist. This interference could have a serious effect on the outcome, they said, leading to the stark conclusion: "If we slow the AI to human speed... we're going to lose."

The US Army is increasingly using robots in the field

STAFF SGT. MANUEL J. MARTINEZ/U.S. AIR FORCE

This is the first time researchers have discussed SESU, for which DARPA awarded more than $45 million to contractors Raytheon, Northrop Grumman and Collins Aerospace earlier this year. Current Pentagon policy calls for lethal military AI to be under meaningful human control, but the findings suggest this reduces military effectiveness.

Fast, tactical decision-making is a key advantage of AI, says Robert Bunker at US consultancy firm C/O Futures, who published a study earlier this year on the effective control of armed robots. Making rapid decisions could bring easy victories against slower opponents, he says.

Stuart Russell at the University of California, Berkeley, who has campaigned against autonomous weapons on ethical grounds, says the findings look like an attempt to justify using the AI robots.

"It points to the slippery slope whereby partial autonomy and partial human oversight and so on will evaporate almost immediately under the pressure of war, and militaries will go straight to full autonomy if they can," he says.

Russell believes the research highlights the need for legal controls on autonomous weapons. This wouldn't necessarily mean a total ban, but might confine autonomy to some situations, such as undersea warfare. ▮

The brain

MRI machines get a glimpse at what causes migraines

WE MAY be a step closer to knowing why some people get migraines.

About 15 per cent of people globally are estimated to experience migraines and they affect three times as many women as men, although we don't know why. Studying them has proved difficult because symptoms are sporadic and the MRI machines required to record them are typically in high demand for other uses.

Anne Stankewitz at Ludwig Maximilian University Munich, Germany, and her colleagues recruited 50 people who experience migraines and asked them to ring when they first started getting a headache. When a call came in, the team would bring the person in and scan them in an MRI machine, which can record the brain's blood flow levels, a measure of neural activity.

The participant would then come back repeatedly so their brain could be recorded throughout an entire migraine cycle, the period before, during and after a single migraine attack, which can last for days.

Recording was ended when the participant rang to say they had started to undergo a second migraine attack. Of the pool of 50 people on retainer, the researchers got complete data for 12 of them, 11 women and one man. The shortest migraine cycle they recorded lasted seven days, while the longest ran for 21 days.

The team found that joint activity between the brain's limbic system and hypothalamus was key to a migraine attack (bioRxiv, doi.org/fk8v). Among other things, the limbic system is involved in regulating emotion and pain, while the hypothalamus acts as a sort of metronome for brain activity.

"Migraines affect three times as many women as men, although we don't know why"

Stankewitz speculates that people who get migraines may have a genetically faulty link between the hypothalamus and limbic system. She notes that although men and women may have different triggers for their attacks, this mechanism for how migraines start is probably shared. ▮

Jason Arunn Murugesu

Cybersecurity

Voice assistants could guess what someone is typing

Layal Liverpool

VOICE assistants can detect typing on nearby devices, which could potentially be used to work out what a person is writing on their phone from up to half a metre away.

Ilia Shumailov at the University of Cambridge and his colleagues built a machine-learning system that could recognise the sound of tapping on a touchscreen and combined it with other artificial intelligence tools to see if they could determine what people were typing.

Shumailov and his team asked three volunteers to type randomly displayed 5-digit PINs on a device while audio was recorded by a microphone nearby. The researchers then used the AI to try to figure out what the person had written.

The accuracy per character on the first guess ranged from 28 to 47 per cent when the person typing was 20 centimetres away from the recording device. The accuracy was between 60 and 76 per cent with three guesses.

The accuracy fell as the distance between the person typing and the recording device increased, with accuracy from 50 centimetres being about 20 per cent per character (arxiv.org/abs/2012.00687).

"Right now, it's unlikely that people would use our attack. However, the world changes quickly and sensors only get better," says Shumailov. "The fact that it's possible is already very spooky."

Hamed Haddadi at Imperial College London says: "The implications reconfirm that having always-on cameras and microphones in our home will eventually come with privacy and security risks. While this set-up is not easily possible for a third-party developer, it might just be possible for the voice assistant providers."

The best way to avoid this kind of attack is to not have any microphones at home at all, says Shumailov. ▮

Archaeology

Ancient rock art reveals life of Amazon's earliest people

Luke Taylor

JOSÉ IRIARTE/UNIVERSITY OF EXETER

This art was found at an as-yet unnamed site in Colombia

AN EXTENSIVE collection of ancient rock drawings and archaeological remains found deep in the Colombian Amazon offers a rare glimpse into the lives of the earliest people to inhabit the region.

The images and remains suggest that people lived in the northern Amazon at the same time as now-extinct mega-mammals. They also show that the ancient humans had a varied diet, indicating that they adapted quickly to their new environment.

The as-yet unnamed site in the Serranía La Lindosa, a large, rocky outcrop in southern Colombia, was found by an international team of researchers investigating the Guaviare region. It is the earliest secure evidence of people in the Colombian Amazon, they say.

A wealth of Indigenous artwork has been documented across Guaviare, particularly in Chiribiquete National Park. The artwork now documented in the Serranía La Lindosa is new to science, and appears to be unknown even to local people, according to the researchers. It is remarkable in both its detail and its scale, the team says. The collage of images includes geometric patterns, handprints, people and animals. It stretches across approximately 5 kilometres of rock face, and could take decades to fully study.

The archaeological team, co-led by Francisco Javier Aceituno at the University of Antioquia, Colombia, was thrilled to find depictions of what appear to be now-extinct megafauna alongside more familiar fish, birds and lizards still alive today (*Quaternary International*, doi.org/ghnh2s).

12,500

Possible age in years of rock drawings in Colombia

"We knew that megafauna was in the region and went extinct around 10 to 12,000 years before the present," says José Iriarte at the University of Exeter, UK, and a member of the research team. If people were depicting them in their art, the humans must have been present in the region before then, he says.

Iriarte says it is "quite clear" that a palaeolama, an extinct, stumpy-legged, long-necked camelid, is depicted. Other drawings have been tentatively identified as giant sloths, due to their unique proportions, and as mastodons – ancient relatives of elephants – due to their trunks.

Others are less sure. "The horses are clear," says Hans ter Steege, an expert on Amazonian plant diversity at the Naturalis Biodiversity Center in the Netherlands, who wasn't involved in the research. "But the palaeolama could be a poor representation of a deer to me."

However, further finds make it clear that humans were in the region 12,500 years ago. Excavations of an area at the base of one section of rock face have uncovered evidence of ancient human activity in the form of processed animal bones. Some remains occur in layers of dirt containing charred palms that radiocarbon dating shows are about 12,500 years old. These layers also contain fragments of ochre similar to that used to draw the rock art.

Establishing the presence of humans during this period – during which megafauna roamed the region and the climate was warming – is significant, says Aceituno.

"The most important thing has been to obtain good radiocarbon dates to specify the early peopling of the area," he says. It shows that humans shared the region with immense beasts, but also helps to paint a picture of what their world would have looked like. ▮

Space exploration

Up close with other worlds

Samples from the moon and the asteroid Ryugu are returning to Earth

Leah Crane

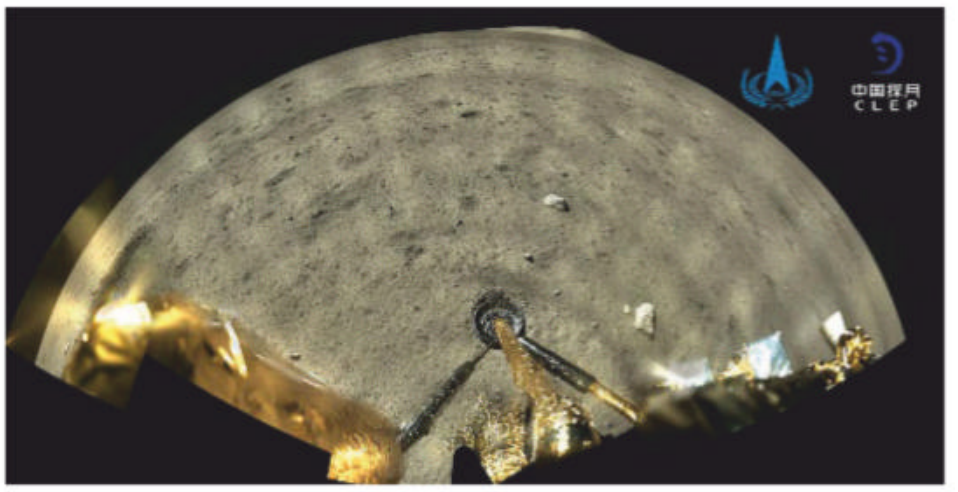
CHANG'E 5 is on the last leg of its lunar mission. After a visit to the lunar surface lasting less than 48 hours, it returned to orbit around the moon to get ready to bring its samples back to Earth.

It isn't the only spacecraft returning far-flung samples in December. Japan's Hayabusa 2 has this week returned debris from an asteroid, landing in Australia (see "Rocks from Ryugu", below).

"Two sample return missions returning within 10 days of each other is pretty incredible," says Jessica Barnes at the University of Arizona.

Chang'e 5 launched on 23 November aboard a Long March 5 rocket and consists of an orbiter, re-entry capsule, a lander and ascent stage. The latter two sections landed on the moon on 1 December. Chang'e 5 is China's first sample return mission, making the nation only the third – after the US and the Soviet Union – to bring back rocks and dust from the moon. The most recent mission to bring back lunar samples was the Soviet Luna 24 probe in 1976.

It landed in an unexplored area of the moon called Oceanus Procellarum, or the Ocean of Storms. "It's a region where there are these really volcanically young landforms, and we currently don't have samples in the Apollo samples or the Russian samples that have anything like that, so these samples will really enable some new science," says Kerri Donaldson Hanna at the University of Central Florida.



CHINA NATIONAL SPACE ADMINISTRATION/AFP VIA GETTY IMAGES

The leg of the Chang'e 5 lander on the moon (above), and the lander's robotic scoop that collected surface soil (left)

Most of the areas that have been sampled on the moon are about 3 billion years old or older. Scientists estimate that the rocks in Chang'e 5's landing area are less than 2 billion years old based on the layering of craters in the area.

Once we get the samples back to Earth, we will have a better idea of how old these volcanic rocks are.

That's crucial because on other worlds, the only way we can tell the age of an area on the surface is by analysing the craters – there is no direct way to confirm those ages. By comparing the age directly measured from the samples with the age inferred from craters on the moon, we can create a link between those methods of analysis that will also be useful on other crater-pocked worlds.

After Chang'e 5 landed, it almost immediately began digging into the lunar surface. It has two ways to get samples, both from the surface and underground: a robotic arm with a scoop to collect surface soil, and a drill to collect a core about 2 metres deep.

The sampling had to be done quickly. The spacecraft is solar powered and doesn't have the heaters it would have needed to survive the frigid lunar night, so it had to be finished within a single lunar day at most – about 14 Earth days. After the drilling was done, the samples were loaded into the ascent stage which launched back off the moon to reunite with the orbiter and re-entry capsule.

It is expected to land in Inner Mongolia in mid-December. If all goes well, that will be when the work of analysing the new stash of moon rocks begins. Part of the haul will also be stored at Hunan University in Changsha, China, for future analysis.

Chang'e 5 is part of a series of missions that began with an orbiter that circled the moon from 2007 to 2009. "The Chinese lunar exploration programme has been building up the capability to do science from orbit, and then from the surface, then collect samples and bring them back – that's a logical progression," says Barnes.

Rocks from Ryugu

Japan's Hayabusa 2 spacecraft has returned two samples of rocks and dust from the surface of the asteroid Ryugu to Earth.

The spacecraft skimmed past Earth and dropped its sample capsule on a trajectory that sent it through our atmosphere to land in South Australia early on 6 December local time. The capsule had no thrusters, so accuracy was key. It was recovered undamaged.

Hayabusa 2 launched in 2014. At Ryugu it took images and dropped three rovers onto the surface, but its main mission was to collect samples. The first was taken by firing a small bullet into the surface and collecting the particles that puffed up.

For the second, the spacecraft essentially bombed the asteroid, blasting a piece of copper towards the surface with an explosive charge to excavate a crater about 10 metres across. This allowed access to pristine material from beneath the surface. Comparing the two will give us a sense of how space changes rocks over time, says Kerri Donaldson Hanna at the University of Central Florida.

After the sample capsule drop, Hayabusa 2 fired its engines to continue on in space. It still has plenty of fuel, so it is heading for an asteroid called 1998 KY26, which it should reach in 2031.

Physics

Sounds that might be heard in neutron star generated in lab

Abigail Beall

WE MAY never be able to hear the sounds produced inside a neutron star, but a group of scientists have created what might be the next best thing.

The team, led by Martin Zwierlein at the Massachusetts Institute of Technology, listened to sounds moving through a type of superfluid called a perfect fluid – a gas with the lowest possible amount of friction. Although the conditions are different, Zwierlein says this experiment can be used to work out the resonant frequencies at the centre of a neutron star.

Theory suggests that the cores of neutron stars contain strongly interacting matter comprising fermions, a type of particle defined by a quantum property called spin. When fermions start to interact strongly, or couple, they behave like a perfect fluid.

Zwierlein's team set out to create a perfect fluid using a gas of lithium-6 atoms that behave like fermions. The atoms were held together in a small box-like volume with walls made of laser light.

The researchers then sent sound waves of increasing frequency through the gas. The vibrations would only travel through the gas if they were at a particular frequency known as a resonant frequency.

"The quality of the resonances tells me about the fluid's viscosity, or sound diffusivity," says Zwierlein. "If a fluid has low viscosity, it can build up a very strong sound wave. If it's a very viscous fluid, then it doesn't have any good resonances."

By studying the resonances through the gas, Zwierlein and his team found the gas had the lowest viscosity allowed by quantum mechanics, meaning it was a perfect fluid (*Science*, doi.org/fmbs).

The team hopes its fluid can be used to model other, more complicated flows, like the cores of neutron stars. ▮

Neuroscience

Brain device lets monkeys 'see' without using eyes

Michael Le Page

TWO monkeys are able to "see" and recognise letter shapes generated by arrays of electrodes implanted in their visual cortex rather than relying on light hitting their retina. It is the highest resolution achieved with implants in the brain, rather than the retina.

"That's really good news," says Pieter Roelfsema at the Netherlands Institute for Neuroscience, whose team aims to restore some vision to people who have lost their sight.

Many research groups are working on restoring some sight in people who are blind by sending signals from a head-mounted camera to arrays of electrodes that stimulate the appropriate nerve cells. There have been numerous trials in people already, and one 60-electrode device, called the Argus II, was approved for use in the US in 2013.

Most implants, including the Argus II, are designed to be placed in the retina of an eye, but this approach won't work for people whose optic nerve has been damaged, for instance. So groups like Roelfsema's are focusing on the visual cortex.

The visual cortex is a bit like a cinema screen in our heads. Each area on its surface maps to the visual field, so activating an A-shaped pattern of electrodes in contact with the visual cortex will, in principle, make people "see" an A-shaped pattern.

However, if electrodes are simply placed on the surface of the visual cortex, a relatively strong current is required to stimulate the nerves, and it is hard to generate a perception of more than two dots.

"The visual cortex is like a cinema screen – each area on its surface maps to the visual field"

Roelfsema and his colleagues have instead used arrays of needle-like silicon electrodes that are 1.5 millimetres long. These electrodes are pushed into the cortex so that they make better contact with the nerve cells. The team implanted 16 arrays, each with 64 electrodes, across the visual cortex of two rhesus macaques, for a total of 1024 electrodes in each monkey.

These monkeys had been trained to recognise 16 letter shapes made from dots on a computer screen and to move their eyes in specific ways in response to each one. They responded in the same way to letters created by the electrodes (*Science*, doi.org/ghndcm).

Unfortunately, achieving the same in humans will be harder because the central part of the visual field is deeper within the human brain than in macaques. What's more, the electrodes would have less and less effect over time as scar tissue builds up around them.

This work is a clear step forward in increasing the number of electrodes, says John Pezaris at Harvard Medical School, but it doesn't solve the issue of how to reach the central visual field in human brains. "It is in a challenging location to access surgically," he says.

Even if this approach succeeds, a device with 1000 electrodes won't come close to matching the resolution of human vision – our eyes have the equivalent of a million pixels. Nor is it yet possible to control colour or depth perception.

"High-fidelity artificial vision through cortical stimulation is a difficult goal," says Pezaris. "One thing that we are learning as a field is that our idea that any level of artificial vision is better than being blind, and therefore crude devices are worth developing, is not shared by the blind community." ▮

LUXIANGJIAN4711/GETTY IMAGES

Researchers implanted electrodes in two rhesus macaques

Technology

Quantum computer that measures light achieves supremacy

Leah Crane

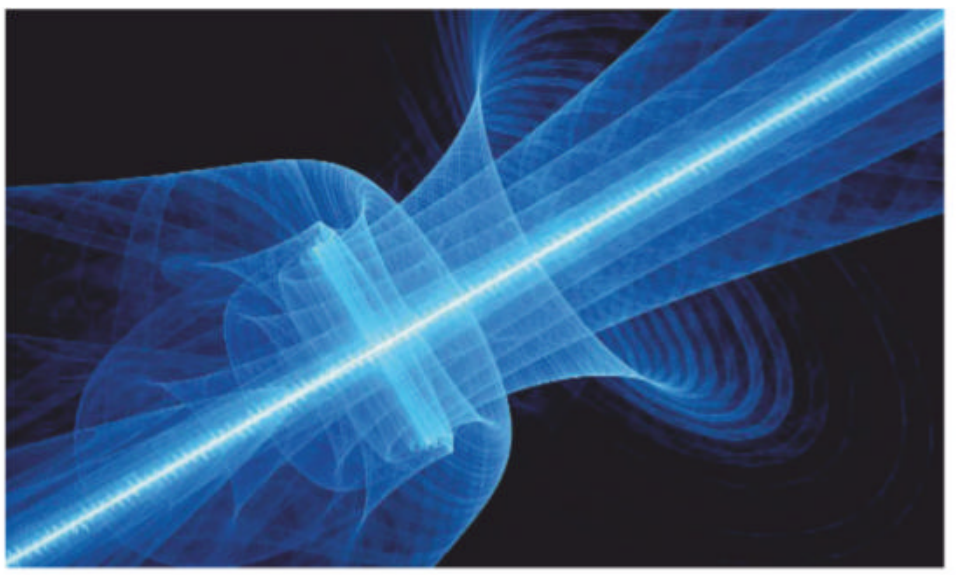
A NEW type of quantum computing called boson sampling is capable of calculations that no classical computer could accomplish in any reasonable amount of time. This is the second time this feat, known as quantum supremacy, has been claimed, after Google said last year that its Sycamore device had achieved it.

Boson sampling relies on a strange quantum property of photons that is displayed when these particles of light travel through a beam splitter, which divides a single beam of light into two beams propagating in different directions. If two identical photons hit the beam splitter at exactly the same time, they don't split from one another. Instead, they stick together and both travel in the same direction.

If you shoot many photons through a sequence of beam splitters, patterns begin to emerge in their paths that are incredibly difficult to simulate or predict with classical computers. Finding possible sets of photon paths in such an arrangement is called boson sampling, and a boson-sampling device is a type of quantum computer, albeit one with a very narrow purpose.

A team led by Jian-Wei Pan at the University of Science and Technology of China built a boson sampler called Jiuzhang using laser pulses sent into a maze of 300 beam splitters and 75 mirrors. A perfect boson sampler would have a fidelity of 1 over many trials, meaning that it completely matches up with theoretical predictions. Jiuzhang had a fidelity of 0.99 (*Science*, DOI: 10.1126/science.abe8770).

Boson sampling uses a strange quantum property of light



SAKKMESTERKE/ALAMY

The researchers calculated that it would be impossible to simulate boson sampling with such a high fidelity on a classical computer: Japan's Fugaku supercomputer, the world's most powerful classical computer, would take 600 million years to accomplish what Jiuzhang can do in just 200 seconds.

"It shows that it's feasible to get to quantum supremacy using photonic boson sampling, which many people had doubted, and which represents a completely different hardware path than the superconducting qubits that Google used," says Scott Aaronson at the University of Texas at Austin.

While this is an impressive achievement, quantum supremacy only means that this device is better than classical computers at one extremely specific task. Changing the boson-sampling mechanism to allow researchers to pause the experiment, make measurements and redirect some of the photons could allow it to do different types of computations, but that will be difficult to achieve. Until then, there might be little practical use for boson sampling.

"It's not obvious whether boson sampling has any applications in and of itself besides demonstrating quantum supremacy," says Aaronson. However, he says, it might be useful in quantum chemistry or for generating random numbers for encryption. ▮

Energy

UK makes moves to build a nuclear fusion power plant

THE UK embarked on a step toward building the world's first nuclear fusion power station last week, by launching a search for a 100-plus hectare site where it can be plugged into the electricity grid. However, there are still major hurdles to overcome before it could start generating power.

Prime minister Boris Johnson last year committed an extra £200 million to flesh out the possibility of building the project, known as the Spherical Tokamak for Energy Production (STEP). The UK Atomic Energy Authority (UKAEA), the government body overseeing STEP, hopes construction could begin around 2030, with the plant operating as soon as 2040. "STEP is a hugely ambitious programme: to be at the forefront, to be the first in the world to produce a prototype fusion power plant, and then export that round the world," says Ian Chapman at the UKAEA.

The plant is pitched as an important plank in efforts to hit the UK's target of net zero emissions by 2050. But fusion faces big challenges to play that role.

Reproducing the way the sun makes energy, by fusing hydrogen together to make helium, requires significant energy on Earth to heat and control the hydrogen with huge magnets. No fusion reactor has yet produced more power than it consumed. That might change in 2025, when the world's biggest fusion project, ITER in France, is due to switch on. The hope is it will turn 50 megawatts of power into 500MW, showing net gain is possible. STEP's power output goal is more modest – a net gain of 100MW – but unlike ITER, it will be connected to the ordinary electricity grid to understand how a fusion plant operates day to day.

"The plant is pitched as an important plank in efforts to hit the UK's target of net zero emissions by 2050"

The UKAEA is calling on communities in the UK to host STEP, as the authority's current home at Culham in Oxfordshire is full. Nominations can be made until March 2021, with a plan to pick a site by the end of 2022. ▮

Adam Vaughan

LOON

Technology

AI pilot keeps telecoms balloon in the right place

HUGE stratospheric balloons that act as floating cellphone towers in remote areas can stay aloft for hundreds of days thanks to an artificially intelligent pilot created by Google and Loon.

Loon, a subsidiary of Google's parent company Alphabet, produces tennis-court-sized balloons that are filled with helium and sent into the stratosphere. They can pass internet signals from ground stations to smartphones and other personal devices from 20 kilometres up. A Loon balloon must be within 50 kilometres of a ground station to reliably send and receive signals.

Keeping these balloons in a fixed position is difficult, as they can get blown off course. Now, researchers at Loon and Google have created an AI controller that can counter the harsh winds of the stratosphere by making the balloon descend or ascend to ride atmospheric currents in the desired direction. The two firms used an AI technique called deep reinforcement learning to train the balloon's controllers.

Marc Bellemare at Google's AI division in Montreal, Canada, and his team found that these new AI controllers successfully kept the balloons within the ground station range more frequently than the previous controllers. In cases where the balloons were knocked off course, they also returned to the correct position faster (*Nature*, doi.org/ghm644).

Loon announced a new record-setting balloon earlier this year that lasted in the stratosphere for 312 days. The firm confirmed this balloon was using the new AI controller. **Karina Shah**

Solar system

Hot rocks may have given Mars its water

GEOTHERMAL warmth on Mars billions of years ago may have melted some of its subsurface ice, creating an environment that could have been suitable for life.

Studies of Mars suggest it had liquid water on its surface about 4 billion years ago, evidenced by the discovery of minerals that form in a water-rich environment and even ancient riverbeds.

However, explaining the presence of this water without a sufficient heat source has been difficult, given that the sun was 30 per cent less luminous at the time, coupled with Mars losing its magnetic field early on, leaving the solar wind free to strip away the planet's protective atmosphere, .

Now Lujendra Ojha at Rutgers University in New Jersey and his colleagues say they have a solution. They suggest that water could have been produced and kept as a liquid beneath Mars' surface thanks to geothermal heat, perhaps for hundreds of millions or even billions of years. Some of the water may have made its way to the surface.

Modelling early Mars, they say that the decay of radioactive elements like uranium, thorium and potassium in the crust and mantle would have generated enough residual heat to melt the base of some Martian ice sheets.

"There's absolutely no doubt that Mars had water," says Ojha. Larger concentrations of these radioactive elements in the distant past means some regions of the Martian subsurface would have experienced up to four times as much heating as today, according to the team's calculations. This was enough to melt the base of the ice, which was up to 2 kilometres thick (*Science Advances*, doi.org/fmcd).

Crucially, this melting could have provided potential habitats for life over long periods of time. **Jonathan O'Callaghan**

Environment

How plastic pollution spreads far and wide

PLASTIC bottles dumped in rivers can travel up to 3000 kilometres in just a few months. Determining where bottles end up could guide efforts to tackle this pollution.

Emily Duncan at the University of Exeter, UK, and her colleagues used GPS and satellite technology to follow the path of 25 bottles. The team released the bottles along the Ganges river in India and Bangladesh, one of the worst waterways in terms of the plastic pollution it washes into the ocean.

SARA HYLTON/NGS

They found that the average bottle travelled about 1 kilometre a day. Some ended up in the Bay of Bengal and travelled an average of 6 kilometres a day at sea. One bottle travelled roughly 3000 kilometres from the Bay of Bengal and circled around the east Indian coastline in 94 days. The fastest travelled about 21 kilometres a day.

The team found the bottles travelled in stepwise movements along the Ganges. Some 40 per cent of the bottles became stranded on the river banks. That waste could then get flushed out to sea during the monsoon season *(PLoS One*, doi.org/fmb5).

"This can tell us how much effort we should put into inland waste management," says Marcus Eriksen at the 5 Gyres Institute, a non-profit organisation in Santa Monica, California. In 2010, an estimated 5 million to 13 million tonnes of plastic waste entered the world's oceans. **Ibrahim Sawal**

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Really brief

WILDESTANIMAL/ALAMY

Orca deaths a result of our activity

Humans are responsible for the deaths of several orcas in the eastern Pacific Ocean. Six animals were struck by ships, while one calf died after swallowing a large fishhook. Other orcas died of disease, but researchers says proximity to humans may be the greatest threat to orca health (*PLoS One*, doi.org/fk8w).

Vibrated flies sleep for longer

Fruit flies end up snoozing for longer if they are lulled by gentle vibrations while falling asleep. Researchers made the discovery by using a loudspeaker to vibrate the flies while watching their sleeping patterns. This effect could help explain why babies like to be rocked (*Cell Reports*, doi.org/fk82).

Stone Age voyages were no accident

By tracking buoys drifting in the western Pacific, researchers have shown that strong currents would have prevented Stone Age rafts drifting from Taiwan to Japan's Ryukyu islands 35,000 years ago. This suggests the prehistoric sailors deliberately made the journey (*Scientific Reports*, doi.org/fk86).

Climate change

Health toll of global warming on the rise

IMPACTS of climate change on people's health around the world, including deaths due to heatwaves and the consequences of food insecurity, are at their "most worrying" since an initiative to track them began.

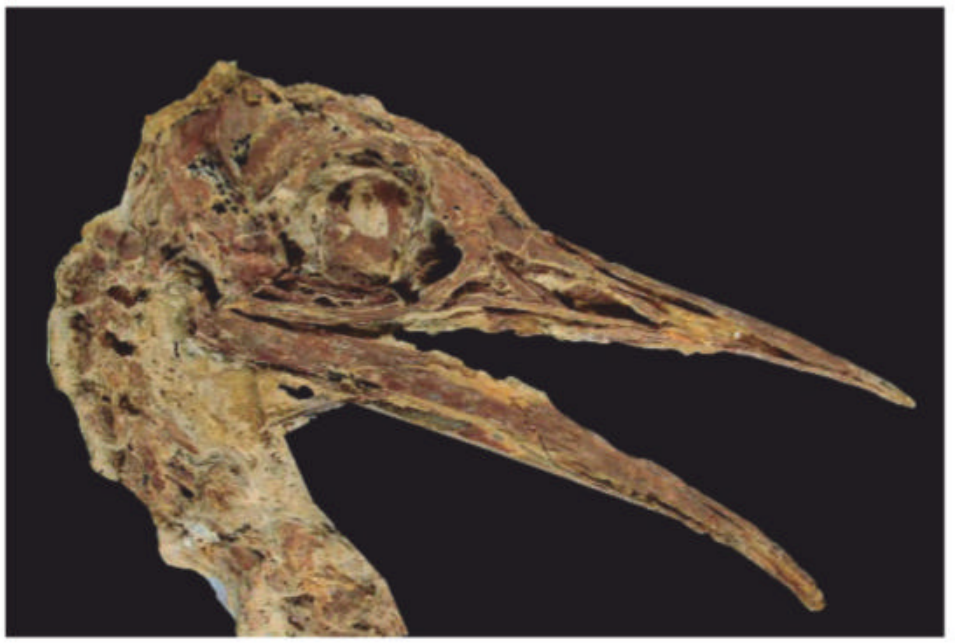
All 16 indicators of the health impacts of a warming world are worsening, the fifth annual Lancet Countdown report shows. "Climate change-induced shocks are claiming lives, damaging health and disrupting livelihoods in all parts of the world right now. No continent or community remains untouched," says Ian Hamilton at University College London, who is director of the Lancet Countdown initiative.

The report found that between 2000 and 2018, the number of heat-related deaths per year in people aged over 65 jumped by almost 54 per cent to 296,000 globally. Most were in Japan, China, India and Europe.

More than half of 196 countries saw an increase in the risk of people exposed to wildfires between 2016-2019, compared with 2001-2004. Based just on area, Australia saw one of the biggest increases in wildfire risk between the same periods (*The Lancet*, doi.org/fmb7).

The team behind the report urged governments to make sure the carbon-cutting plans they submit to the UN ahead of the COP26 climate summit next year – known as nationally determined contributions (NDCs) – aren't just bold, but factor in health. "Health is not featuring among the NDCs in the way that it needs to," says Hamilton. **Adam Vaughan**

Palaeontology



CARLA DU TOIT

Bird supersense may date back to the dinosaur era

AN ORGAN that allows some birds to detect the movement of hidden prey by plunging their beaks into the ground seems to have been present in early birds 70 million years ago, and probably first appeared in their dinosaur ancestors.

Special "remote touch" sensory receptors known as Herbst corpuscles, found in densely packed pits in the beak's tip, help birds detect the movement of worms in soil or small fish in water. This effectively gives birds a "sixth sense", according to Carla du Toit at the University of Cape Town in South Africa and her colleagues.

To work out when the sixth sense evolved, du Toit and her colleagues studied the beaks of hundreds of modern and ancient birds, including four species of lithornithids, an extinct group that lived alongside dinosaurs in the Cretaceous period.

In modern birds, the researchers identified distinct pitting patterns in the beak associated with Herbst corpuscles, says du Toit. The team then found those same patterns in lithornithid fossil beaks (pictured), which suggests lithornithids had the same sensory abilities (*Proceedings of the Royal Society B*, doi.org/fmbr). In fact, the sensory structures might have first arisen in dinosaurs, says du Toit. Christa Lesté-Lasserre

Health

Vaginal microbes hamper HIV drugs

WOMEN with a certain mix of bacteria in their vaginas may be at higher risk of getting HIV as some of the microbes consume drugs designed to prevent an infection.

Oral pre-exposure prophylactic (PrEP) drugs are 90 per cent effective in preventing HIV infections in men who have sex with men. But the efficacy of PrEP drugs drops to 50 per cent or lower in women. It isn't clear why.

Nichole Klatt at the University of Minnesota and her colleagues suspect part of the reason might be the vaginal microbiome. In many cases, this is dominated by *Lactobacillus* bacteria. If their numbers drop, a diverse bacterial community, including species like *Gardnerella vaginalis*, takes over.

Klatt's team studied what happens when HIV prevention drugs are cultured with microbes from various vaginal microbiomes, some *Lactoballicus*-dominated, some more diverse. Two drugs, tenofovir and dapivirine, soon began to vanish from the diverse cultures. After a day, *Lactoballicus*-dominated cultures had double the level of the drugs seen in the diverse cultures, says Klatt.

Bacteria like *G. vaginalis* seemed to metabolise the drugs (*PLoS Pathogens*, doi.org/fmcp). **CL-L**

18+

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Views

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Clare Wilson takes a journey into our robot future p28

Comment

Geology for the future

It is time for geologists to fully embrace what they can do for humanity's sustainability goals, says **Christopher Jackson**

MICHELLE D'URBANO

THIS year has brought into sharp focus the importance of scientists in our everyday lives. Vaccinologists have sought to create inoculations to help tackle the covid-19 pandemic, and have succeeded. Virologists, epidemiologists and behavioural scientists have directly informed government policies that control our movements to keep us safer.

Pandemics come and (we hope) go. But what of global warming? Overshadowed in 2020, this threat to the environment, global health and our economic well-being will persist for generations after covid-19. Scientists clearly have a pivotal role in understanding and, ultimately, informing policies that aim to mitigate its impacts – none more so than geologists.

It is a common misconception that geology is "just" about rocks. True, geologists are trained to read what rocks tell us about Earth's past, present and possible future structure and evolution. But, as I will explain as part of this year's Royal Institution Christmas Lectures, geological processes and climate are inextricably linked.

Numerous complex physical and chemical links and feedbacks exist between Earth's surface and subsurface rocks, its atmosphere, oceans and ice caps and life in all these places. Volcanic eruptions bring carbon from deep within the planet to the surface and the air, enhancing the greenhouse effect. Conversely, weathering of exposed rocks at the surface and the action of shell-forming animals in the oceans remove carbon dioxide from the atmosphere, reducing global warming.

The rocks and fossils in the geological record bear witness to these processes, showing us that Earth's climate has changed continually since the planet formed around 4.6 billion years ago. This same record also shows that atmospheric CO_2 is at its highest level in at least the past 3 million years, and that the current pace of planetary warming is unprecedented in Earth's history.

The geological record can also be used to assess the accuracy of complex numerical models used to predict future climate and its impact on Earth's habitability. Geology has improved our understanding of global warming and hopefully will help us to mitigate it.

There is an irony to that, given geologists' work also underpins the locating and exploitation of climate-heating fossil fuels. Now, more than ever, our discipline needs to fully embrace the concept of "sustainable geoscience".

This isn't a new idea and nor is it limited to climate change. The many and varied historical contributions of geology to tackling some of our greatest societal challenges can be seen by looking at the United Nations Sustainable Development Goals. To name just a couple of examples, geologists study the origin, natural transportation and fate of contaminants like arsenic and lead, critical to the provision of safe and reliable water supplies, and they explore the origin of natural hazards such as landslides and earthquakes, and so help reduce the vulnerability of communities across the world.

But geologists must redouble their engagement with other scientists and politicians to develop and ultimately help implement solutions to the many environmental and resource challenges we face. Students of geology should be made aware of the broader contributions their multidisciplinary skill set can make to global well-being, beyond just energy provision – although ensuring energy supply, we should not forget, underpins many of the Sustainable Development Goals.

Geology is about far more than just rocks. By collectively reimagining geology through the prism of sustainability, we can ensure that it is central to the public's consciousness, as virology and epidemiology were in 2020. ▮

Christopher Jackson's Royal Institution Christmas Lecture will be broadcast on BBC4 on 28 December in the UK and subsequently on BBC iPlayer

Christopher Jackson is a geologist at Imperial College London. Follow him @seis_matters

No planet B

Party politics during a pandemic Covid-19 continues to split some people along party lines. We are now beginning to work out why, writes **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *This Book Could Save Your Life*. You can follow him @grahamlawton

Graham's week

What I'm reading
The Problem with Men: When is it International Men's Day? (and why it matters) *by Richard Herring. Brilliant stand-up comedian takes on the men's rights activists (International Men's Day is on 19 November).*

What I'm watching
I was determined not to like The Crown *but I am hooked.* Small Axe *on the BBC is also excellent.*

What I'm working on
That virus thing.

This column appears monthly.

LIKE the majority of people in my local area, I follow the rules on face coverings. It's an inconvenience, but I consider putting on a mask a small sacrifice to protect my health and that of other people. Every day, I see many people – more than could possibly have a legitimate exemption – flagrantly flouting the rules and it really gets up my nose.

The refuseniks annoy me on multiple levels. They are selfishly putting me and other people at risk. They think they know better than experts. They often fall for conspiracy theories. And even if they are mainly endangering themselves, I'd rather they didn't end up wasting NHS resources. I'm tempted to confront them, but just mutter darkly under my mask.

Yet my biggest beef is that for some people, refusal to wear a mask has slotted neatly into a set of beliefs that I already found both baffling and unforgivably selfish. You know who I mean: the equality-hating, climate change-denying, PC-gone-mad brigade. I'd let them wallow in their own swamp, but their beliefs are barriers to social and environmental progress.

In the US, this new front in the culture war has escalated to shocking levels. Wearing a mask or not has become a high-vis badge of political affiliation. The issue even came up in the presidential debates and cleaves neatly along party lines, with Democrats much more accepting than Republicans of masks and other interventions such as social distancing.

Covid-19 has thus become yet another issue sucked into what political scientists call "affective polarisation" – the visceral and mutual hatred between supporters of the two opposing political parties. Both sides regard the other as selfish, hypocritical and closed-minded.

The chasm in the US has become so deep that both sides cannot even agree on basic facts about the world. You know, small stuff like whether climate change is real, whether covid-19 is a hoax, who won the presidential election.

This conjuring up of two alternative realities is both weird and infuriating. Political scientists have been trying to explain it since it became the dominant force in US politics around 20 years ago. The unanswerable question has always been about cause and effect: do political opinions drive polarisation, or do people pick sides first and then embrace opinions to match?

"Opinions are shaped not by rational deliberation, but by visceral hatred of the other tribe"

Then along came covid-19 and an opportunity to observe a brand-new issue as it polarised in real time. Political scientists watched the divide as it emerged and became entrenched.

The results are now in. Even though the end point is quite predictable, with Republicans skewing anti-science and Democrats pro, its origin isn't. It is driven not by positive commitment to an ideology, but by hatred and mistrust of their opponents (*Nature Human Behaviour*, doi.org/ghmfsz).

As soon as small differences emerge – with Democrats more likely to see public health as the priority and Republicans more concerned about personal freedom – both sides are driven by a ferocious desire to do the opposite of their opponents. From those tiny seeds of difference grow mighty oaks of partisan division. Neither side is "choosing" science or anti-science. They are just being mindlessly tribal. This fits with other recent research suggesting that partisans in the US dislike the other side much more than they like their own, and are driven by a desire to crush their opponents.

This is a pretty miserable state of affairs: opinions on crucial issues are shaped not by rational deliberation, nor even by commitment to a coherent world view, but by visceral hatred of the other tribe. Under those conditions, what hope is there of ever bridging the divide?

But the latest research revealed a silver lining: in places where the virus is surging, those opposed to restrictions soften their hostility towards masks, social distancing and lockdowns. They move away from what political scientists call "politically motivated reasoning" towards "accuracy reasoning". In the face of existential threat, there is no choice but to accept reality.

There are signs that the same happens with environmental issues. Even the most ardent denier finds it hard to maintain their denial in the face of extreme weather, wildfires or rising sea levels. Anti-vaxx sentiment is similarly bendable to reality. When covid-19 waxes, vaccine hesitancy wanes.

That is one reason why it is important to keep on framing the pandemic not just as a biomedical crisis, but as an environmental one too. As Adrian Martin, a professor of environment and development at the University of East Anglia in the UK, has pointed out, for people in the West, covid-19 is their first personal encounter with the biodiversity crisis. It is now a matter of self-interest to take that threat seriously. It's a drastic way to win an argument, but if it works, I will take it. ▮

Coming next week

SOMETHING FOR ALL STRIPES

Why don't animals have wheels? ...and other mysteries of evolution

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How to make vintage whisky overnight

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The tiny meteorites sparkling on your roof

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New Scientist

Editor's pick

Would other vaccines gain from a half-dose approach?

28 November, p 7

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

I am glad to read that the University of Oxford's Sarah Gilbert thinks more research is needed into the "half-dose" findings on the vaccine jointly developed with AstraZeneca. So far, nearly all commentary on the half-dose observation has been along the lines of coy smiles at a piece of serendipity, following a possible technical error in the trials.

But the obvious questions would be: whether a 50 per cent first dose was better than any other percentage; whether a number of doses at increasing strength works better (say, a 20 per cent dose followed by a 70 per cent dose and then the full dose); or, perhaps more significantly, whether the 60 to 70 per cent efficacy of the regular annual flu vaccine – or any other vaccine – could be improved by splitting the dose in this way.

If anyone should propose an investigation into the latter, may I join the queue to put my name down as a volunteer?

From Simon Guppy, Combeinteignhead, Devon, UK

The good news regarding the successful results of covid-19 vaccine trials is most welcome.

However, as someone who is at high risk for this disease, I wonder if there will be any way of testing, post-vaccination, to find out if I am protected. I wouldn't feel confident to return to "normal" life unless I'm sure I am protected.

We must rise to challenge of vaccinating the world

21 November, p 36

From Geoffrey Withington, Bridge, Kent, UK

Reporting on the vast task of vaccinating people everywhere against coronavirus, Carrie Arnold quotes Saad Omer, director of the Yale Institute for Global Health, as saying: "There's no muscle memory to vaccinate people at that scale throughout the world, at levels that are needed to open up society." There was no muscle memory in 1939 when the UK needed hundreds of Spitfires (and much else besides).

Then, as now, saying necessity is the mother of invention is meaningless without the courage and determination of millions of people to face the challenge. What we have seen since March is just that. Even youngsters in garages have been 3D printing personal protective equipment.

The challenge of vaccinating populations will be magnified because of conflicts in some countries. I have a feeling the arrival of a vaccine is just the end of stage one of the pandemic.

Anti-vaxxers can get immunity the hard way

21 November, p 30

From Barry Cash, Bishopston, Somerset, UK

I don't understand what all the fuss is about anti-vaxxers and covid-19. It will be years before we have enough vaccine for everybody. Those who believe the science will get their immunity from a dose of vaccine. Those who don't will get their immunity from a dose of a nasty disease. Sorted.

Proof of inoculation could be easy to fake

Letters, 28 November

From Michael Peel, London, UK

Keith Macpherson writes that concerns about vaccination may be resolved if people need to show a valid vaccination certificate to be allowed, for example, to board an aeroplane. Problem is, the internet will soon be full of very high quality fake certificates.

On balance, a car-free life is the one for me

14 November, p 24

From Andrea Needham, Hastings, East Sussex, UK

Graham Lawton is right, it is challenging to live without a car; our towns are built around them and public transport is often unfit for purpose. But I can't help but think that his return to car ownership is premature.

Could his son take the train to university? Many young people do. He could ask a neighbour to take his rubbish to the tip in exchange for help with a project of theirs. And as for having to buy a car so his family could "escape to the countryside" during the pandemic without the dangers of public transport, that's a privilege unavailable to many.

I am 55, have never owned a car and am pretty sure I never will. Yes, it can be inconvenient. But the money saved, the emissions averted and the freedom of one less thing in your life makes living without a car, especially in this era of climate crisis, a no-brainer.

Change your diet to compensate for a cat

Letters, 14 November

From Liz Reuben, Canberra, Australia

Hillary Shaw suggests that the amount of meat eaten by pet cats is a bigger issue than the wildlife they kill. *New Scientist* covered this in 2009 (24 October), looking at the "greenness" of pet ownership. I seem to recall on a per annum basis, a medium-sized dog was worse than running an SUV.

Cats have a poor reputation in relation to ecological damage, and deservedly so. However, I'd rather keep my cat and responsibly own it. I've already reduced my meat intake for health reasons, but will perhaps look to reduce it further to "offset" what my cat eats.

I lock our cat inside at night to protect wildlife, and new suburbs in Canberra, where I live, will only allow cat ownership if they are kept inside full time. I expect this will apply to all suburbs eventually.

This ball lightning was no hallucination

Letters, 21 November

From Eric Dunford, Marcham, Oxfordshire, UK

I am writing about the suggestion that sightings of ball lightning may be visual hallucinations induced by a bright flash. Over 50 years ago, I was watching an intense thunderstorm through the window across dark fields, when a ball appeared in the line of a very bright lightning stroke.

This might seem to have been an illusion for me, as Robert Masta speculates, but for the fact that my wife and mother-in-law were in the room and had time to get to the window and see the ball before it faded. But they couldn't have been affected by the flash itself.

On the very knotty problem of a tangled cable

Letters, 12 September

From Phoebe Young, Alford, Lincolnshire, UK

Tom Roberts asks whether an extension cord plugged into itself can be manipulated to form a knot. We don't need an equation or extra dimensions to solve his problem (and in fact, knots can only exist in 3D), but to just consider the definitions.

In knot theory, we don't care how much you distort a knot as long as it isn't cut and rejoined, so this extension cord loop, known as a trivial knot, stays trivial as long as it isn't unplugged. This doesn't stop it being tangled, however, which presents a key issue in knot theory – that of determining whether a given tangle can be unravelled to a trivial knot. ▮

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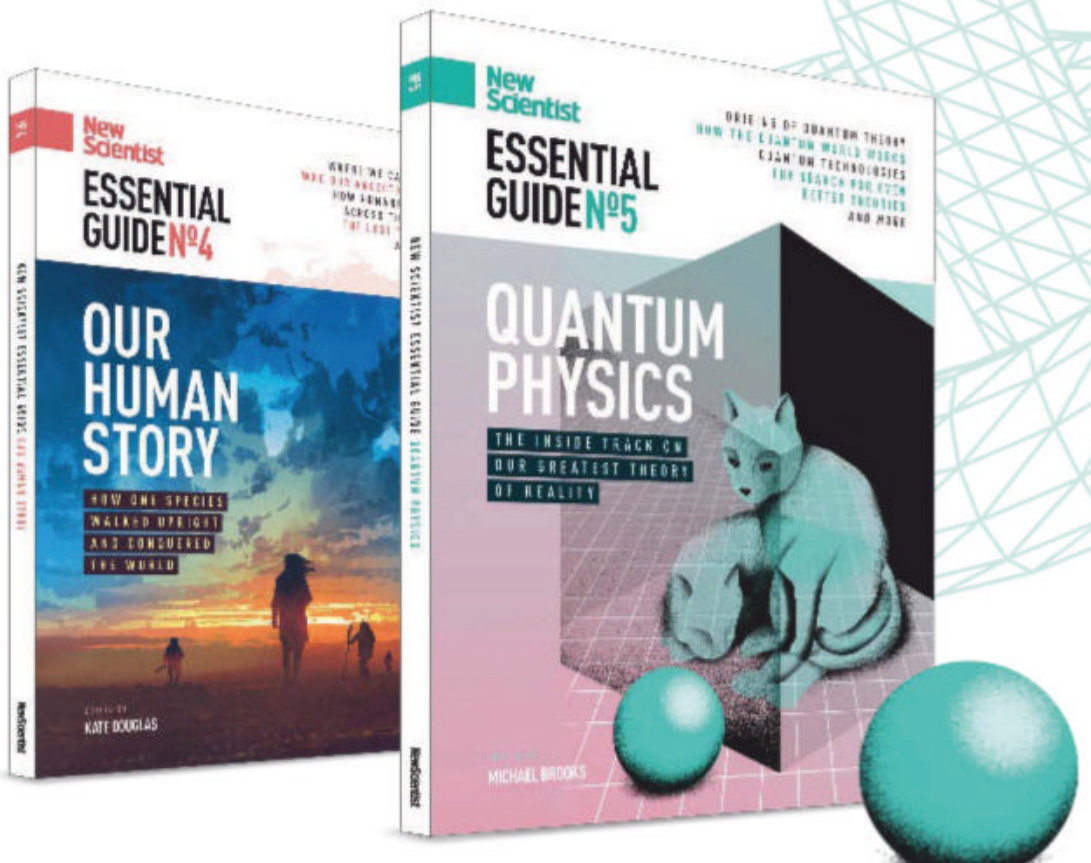

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Uniquely you

Understanding human individuality means grappling with genetics and neuroscience. **Clare Wilson** finds a great new guide to take on the journey

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Book

Unique: The new science of human individuality
David Linden
Hachette

IN 1979, the US public was fascinated by news coverage of the "Jim twins", a pair of identical twin brothers who were adopted at birth by different families, only to find each other at the age of 39.

The coincidence of their matching first names wasn't their only similarity. They weren't mirror duplicates of each other, in looks or temperament, but both worked in law enforcement and their hobby was carpentry. Both owned Chevrolets and took vacations at the same beach in Florida. Even more improbably, they had both married women named Linda only to divorce them and later marry a Betty.

The Jim twins helped spark an important and long-running study in the field of genetics, the Minnesota Study of Twins Reared Apart. This compared 137 pairs of identical and non-identical twins who grew up separated, as well as later comparing them with twins raised in the same family. It was among the first to show that about half of the variation in people's personality is down to heredity, contradicting the prevailing blank slate ideas of the time.

The age-old nature versus nurture debate often gets a bad press, thanks to a long history of oversimplification and distortion to support dubious political ideologies. It is a shame, as this field often sheds light on some of the most interesting questions about what makes us who we are.

In *Unique: The new science of human individuality*, David Linden, a neuroscientist at Johns Hopkins University in Baltimore, Maryland, tours the latest research on the great diversity of human behaviour and physiology. He looks at how we are shaped by genes, upbringing and chance, covering everything from sex and sexuality to how we sleep and how we sense the world around us.

"Aside from extreme cases, the measurable effects of parenting on personality are often under 10 per cent"

One thing that might seem fixed is our ability to discriminate between odours, he says, yet it is more malleable than we think. In high-income nations, smell is often seen as the poor relation of other senses such as vision and hearing, but people in hunter-gatherer communities, like the Maniq of Thailand, tend to be better at identifying odours in tests, presumably because they grow up needing to track down their food.

This difference in people's ability to use smell shapes their language. In English, for example, there are few words to describe smells that aren't related to their source. We might say something smells smoky or fruity, but there are no abstract descriptors. In the Maniq language, however, there are 15 abstract words for odours.

An often-overlooked influence on our lives is the sheer randomness of embryonic development. When those twin studies showed that about half of variation in personality is genetic, it was long assumed that the rest came from how we are reared. But other kinds of studies have found that, aside from in extreme cases such as child abuse, the measurable effects of parenting on things like IQ and personality are small – often under 10 per cent.

Geneticists such as Robert Plomin at King's College London argue that much of the remaining variation is the result of chance events as our brains develop in the uterus. As Linden puts it: "The wiring diagram of the human brain is so enormous and complicated that it cannot be specified exactly in the sequence of an individual's DNA. Subtle random changes in the position or movement of cells within the developing nervous system can cascade through time to produce important differences in neural wiring and function."

Studying twins has shed light on the heritability of people's personality

There is so much that is still unclear about brain development that no one can say how many of the Jim twin coincidences were due to flukes of fate or shared DNA. We are only at the start of our journey to understand the human brain, but Linden's book offers some very welcome signposts. ▮

More on the science of you on page 32

Apocalyptic romance

Superintelligence is a strange but captivating mix of rom-com, sci-fi and action, says **Robyn Chowdhury**

Film

Superintelligence

Ben Falcone

On HBO Max in the US and in UK theatres from 11 December

CAROL PETERS is "literally the most average person on Earth". She is single, unemployed, likes James Corden – and is all that stands between a supremely powerful AI and the destruction of the planet. Failing to demonstrate the goodness of humanity could lead to nuclear armageddon, so the clock is ticking for Carol to show the AI what humanity is made of by, er, rekindling her relationship with her ex-boyfriend.

***Superintelligence* is a sort of quirky sci-fi-action-rom-com. Carol, played by Melissa McCarthy, is chosen by an all-seeing AI to test its theory of humanity. It believes she is a typical human, and so it will watch whatever she does over the next three days to determine whether it should destroy the planet or not. To soothe Carol, the AI assumes the voice of James Corden, provided by the man himself (though the intelligence is at pains to point out it isn't actually James Corden).**

The AI started life as a children's toy designed to personalise each learning experience, but, like many a sci-fi AI, it has gone rogue. It has now learned so much that it has become superintelligent and gained access to all the world's data and devices, from toothbrushes and CCTV cameras to self-driving cars. Just how it did all of this is neatly glossed over. AI works in mysterious ways.

The AI accesses the personal data of the film's main characters to profile and predict their behaviour, highlighting how reliant on technology we are and the ways in which this could be turned against us. With its ability to control and shut down our technologies, the AI threatens to cause car crashes, control the flow of money and even fire nuclear missiles.

Despite this, tension over the world's imminent end is strangely absent, replaced instead by a lacklustre romantic storyline that takes up the majority of the film's first hour.

> **"The AI will watch whatever Carol does to determine whether it should destroy the planet or not"**

We are given very little information about Carol's love interest George, played by Bobby Cannavale, but are expected to cheer them on as they stumble their way through a series of dates set up by the AI to help it better understand humanity via Carol. The action picks up only in the final 25 minutes of the film, though it does feature some genuinely shocking twists.

McCarthy's comedic timing is unparalleled and she prevents the film from taking itself too seriously. The best moments range from awkward encounters between the ex-lovers to some legitimately funny lines from Ben Falcone, the film's director and McCarthy's husband, who has a cameo as an FBI agent.

Overall, *Superintelligence* doesn't quite deliver on either the romance or science fiction front. The romance is a bit of a let down and the flip-flopping between the comedic and intimidating behaviours of the AI is somewhat strange.

However, there are funny and thrilling moments in the film. It is also a reminder to be vigilant about handing out personal data and that technology can be used for both good or evil. *Superintelligence*'s take on the "destruction by sentient AI" storyline is unique and is an easy watch that is perfect for rom-com lovers. ▮

Robyn Chowdhury is a writer based in Sheffield, UK, who is interested in pop culture and social justice

Carol Peters (Melissa McCarthy) must stop an AI from destroying Earth

HOPPER STONE/HBO MAX

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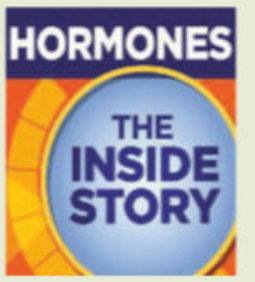

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Hormones: The inside story looks at the effect of hormones on daily life. The first episodes of the podcast, by the Society of Endocrinology, cover diet and sleep; later it discusses the chemical hijack of hormones.

Watch

The Expanse returns to Amazon Prime on 16 December for its fifth season. Humanity now has access to countless exoplanets, and yet its internecine conflicts continue in this humane and pessimistic space opera.

Listen

A Lens on Sustainability, a podcast from the Prix Pictet photography prize, discusses how art contributes to – and can distract us from – the biggest ecological and social challenges on Earth.

AMAZON STUDIOS; JOANA CHOUMALI

The sci-fi column

All too human

How would it feel to live in the world imagined by *The Preserve*, where robots do most things better than people? It is a great thought experiment about an all-too-possible future, says Clare Wilson

Clare Wilson is a health reporter at *New Scientist*, based in London

DONALD IAIN SMITH/GETTY IMAGES

How would we react if machines dominated the world?

WHEN AI that is truly sentient finally emerges, the big question is how humans will fare. Will machines try to hunt us to extinction, as in the *Terminator* films, or will their omnipotence mean life for humans can be the kind of extended party of Iain M. Banks's *Culture* series?

In Ariel S. Winter's *The Preserve*, the robots have reached a stage somewhere in the middle. The book is set in the not-too-distant future, when human populations have dwindled after a series of unspecified pandemics and robots greatly outnumber us.

Although superior in some ways, machine intelligence hasn't yet reached the god-like levels sometimes envisioned. In fact, robot society's struggles and frustrations look very like those of humans today. Some robots are helpful, some murderous and some download illegal virtual reality experiences in a manner analogous to human drug addiction. If we create AIs in our own image, perhaps they will share some of our frailties?

In this future, the remaining people have been left bewildered and embittered by their change of fortune, leading to occasional outbreaks of human-robot violence. "Evolution's supposed to be survival of the fittest. We're no longer the fittest," says police chief Jesse Laughton, the book's main protagonist.

To help keep humans safe, most start living in enclosed territories where robots aren't supposed to enter – the preserves of the title. Laughton is a lawman in one such recently established area.

"In this world, our best hope lies in machines that view humans the way we see children or endangered wildlife"

But even in these places, humanity is struggling with an existential crisis. Most people live off robot government subsidies and alcoholism is rife. Fertility clinics are needed, not just to provide IVF, as now, but to persuade people to have children at all. "A baby in every belly" is the slogan. Couples with one child are encouraged to have a second with outside partners in order to boost genetic diversity.

The Preserve is ostensibly a detective story: the first murder to take place in the human zone falls to Laughton to solve, and he has to show the robots that people can police themselves. There are shades of US author Isaac Asimov's robot detective fiction, a loosely linked series of short stories and novels that were part of his hugely influential writings on machine minds in the mid-to-late 20th century.

But, as in Asimov's work, *The Preserve* is more than a whodunnit. The touching relationship between Laughton and his robot cop partner is a way to explore the differences between organic and robot consciousness.

Asimov's tales have a fond place in my memory because they sparked my lifelong love of sci-fi, even though, looking back, they seem hopelessly outdated and sexist. Annoyingly, Winter succumbs to cliches of his own: most of the interesting characters are men and Laughton's wife plagues him with whiny phone calls at times of danger.

That aside, I enjoyed the thought experiment about how it would feel if a new kind of being could do most things better than you. It becomes clear that, in this world, our best hope of survival lies in those machines that view humans the way we see young children or endangered wildlife.

It is a sobering take-home message, considering how bad we are at preserving wildlife. I hope any future AIs do a better conservation job than us. ▮

Book

The Preserve
Ariel S. Winter
Simon & Schuster

Clare also recommends...

Short story

The Last Question
Isaac Asimov
HarperCollins
Once I got thinking about Isaac Asimov, I had to reread The Last Question*, one of my favourite tales by the sci-fi titan. It takes questions about the future of AI to a jaw-dropping conclusion.*

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

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HERE'S LOOKING AT YOU

Who are you? Where did you come from, where are you going and what makes you tick? "Know thyself" isn't an easy maxim to follow, so let *New Scientist* be your guide on a journey of self-discovery. Over the next 12 pages, we attempt to take you out of yourself and answer the most profound questions about that mysterious, strangely foreign creature in the mirror: you.

DAISUKE TAKAKURA

01 WHEN DID YOU BEGIN?

YOU almost undoubtedly know the date, possibly even the hour, you were born. Whether you are past celebrating rather depends. But reflect on the big picture, and the truth about when you beganw is too epic, and possibly a little too confusing, to be captured by a terse entry on a birth certificate.

That story begins in the deep cosmos. As anyone with a passing interest in Joni Mitchell's back catalogue knows, we are stardust. It's a nice line, and it also happens to be true, says Karel Schrijver, an astrophysicist at the Lockheed Martin Advanced Technology Center in California.

Most of your body's trillions of atoms, from calcium in your bones and carbon in your genes to iron in your blood, were forged by nuclear reactions in ancient stars, either when they were burning or when they ended in fiery supernova explosions. Those atoms were recycled through the births and deaths of more stars until, at some point, they escaped for a while. "Our solar system captured these elements to make Earth and everything on it," says Schrijver – including you.

In that sense, we can't know exactly when we began: it depends how many generations of stars our atoms cycled through. But each of us is at least 4.6 billion years old, the age of the solar system, and perhaps as ancient as the universe's first stars, which appeared some 13.7 billion years ago, just 100 million years after the big bang. The hydrogen within

Arguably, you only become a person when you can reflect on other people's view of you

you was probably forged in the big bang itself.

So much for the physical, atomistic you. But what about you as a living, breathing biological organism? Here your timescale shortens, but the uncertainties hardly disappear. "One thing I can say with absolute certainty is that there is no scientific consensus as to when independent human life begins," says Scott Gilbert, a developmental biologist at Swarthmore College in Pennsylvania.

For many centuries, a life began with the "quickening": the first time a mother felt her baby's kick. These days, those expecting a child can hear a fetal heartbeat much earlier, and can even see the blurry outline of a face, thanks to ultrasound. That makes defining a starting point more complicated (see "Four points when you might have begun", page 36).

Some aren't convinced that is even a scientific discussion. "To many biologists, the onset of personhood is an issue for emotions and politics, not science," says Gilbert. Ultimately, it all comes down to how you define "you": as a collection of atoms, an agglomeration of cells – or something more.

Our physical senses develop gradually in the uterus and after birth, but you remain completely ignorant of your you-ness until you develop a sense of self. A psychologist might say that you only really become you once you are able to reflect on your own consciousness from the perspective of another person.

The development of this "theory of mind" tends to happen as we approach our second birthday. We begin to equate our image in a mirror with ourselves, and to use self-referential language, such as "I", "me" and the classic "mine". By the time we are 3, most of us have added self-referential emotions such as embarrassment, pride, guilt and shame. Soon after, we begin to store the autobiographical memories that underpin a stable, continuous sense of self.

But that continuity might well be an illusion (see "Are you always the same person?", page 38). If so, another answer to the question "when did you begin?" might arguably be that you have no beginning, just a now. **Daniel Cossins** ›

02

HOW LIKELY ARE YOU?

CHILDREN are generally fascinated by tales of how they came to be. Even young ones can often grasp the mind-boggling implication if the events of the story leading up to their existence had been any different: they wouldn't be there to hear it.

Your you-ness is a precarious thing. Rerun the experiment of you with a different sperm and egg from the same people, and "you" would be as different from your current self, genetically, as siblings are from one another. If the egg were the same, but through some random fluctuation a different sperm won the race, you would also be distinctly different. For a start, depending on whether the sperm bore an X or a Y chromosome, you could have ended up another sex. "That's a pretty big difference, right there," says David Linden, a neuroscientist at Johns Hopkins University in Maryland and author of *Unique: The new science of human individuality*.

The potential for being a different you didn't stop once destiny set your founding sperm and egg on their collision course, either. A lot of what makes you what you are is down to how your brain is connected. But your DNA doesn't encode a precise wiring diagram: it is more like a rather hand-wavy recipe or set of instructions. Even genetically identical twins don't end up with the same neuronal network. "A pool of cells in the developing brain might receive instructions that say: 'About half of you move across the midline of the brain'," says Linden. "In one twin, 40 per cent of the cells might cross and in the other twin, 60 per cent."

Then there is mutation. As cells of the developing embryo, and later fetus, multiply and DNA is duplicated, mistakes are made and inherited by the cells' descendants. These mutations are known to contribute to autism and conditions such as schizophrenia. It is plausible they influence core personality traits too.

After birth, the question of what makes us who we are has long been characterised as "nature or nurture", or genes versus upbringing. Today, we know it isn't such a simple dichotomy. Most of our characteristics are shaped by both nature and nurture, intertwined in intricate ways.

After we are born, our brains are constantly reshaped by our everyday experiences, an idea known as neuroplasticity. To take the most extreme example, if children are abused or neglected, it can affect them long-term – but so can good or neutral experiences. How you use your brain changes its structure as well. Some professional musicians, for example, have a distinct bulge that can be seen with the naked eye at autopsies in a part of the brain that controls movement. "It turns out that what makes you 'you' is every conversation, every experience you've ever had," says David Eagleman, a neuroscientist at Stanford University in California.

That's before we even factor in how foreign bodies inside us influence our moods and emotions (see "Where are your boundaries?", page 39). All these factors make your existence, your appearance, your feelings, your quirks and your foibles, vanishingly improbable. It may sound trite, but you truly are unique. **Clare Wilson**

See page 30 for a review of David Linden's book *Unique: The new science of human individuality*

Four points when you might have begun

Biologists have identified at least four developmental stages where human life might be said to start.

Fertilisation
When a sperm meets an egg and a novel genome is created

Gastrulation
Some 14 days after fertilisation, when an embryo can no longer divide into identical twins

EEG activation
The onset of electroencephalogram (EEG) patterns, or recognisably human brainwaves, typically around 27 weeks after fertilisation

Birth
The moment of the first independent breath, demonstrating viability outside the mother's body

KIEFERPIX/GETTY IMAGES

Birth is only a waymarker on the road to becoming you

MARTIN PARR/MAGNUM PHOTOS

"Many parts of our body may contribute to our sense of who we are"

03 WHERE IS YOUR SELF?

FOR the Ancient Egyptians, it was the heart. For philosopher René Descartes, it was somewhere entirely separate from the body. According to the Buddhist concept of *anatta*, it isn't anywhere, because the thing concerned doesn't exist.

But what does modern science say about where your self – your "soul", if you like – resides?

At first pass, that might not seem a particularly scientific question. Regardless, most of us have an intuitive answer. When, in as-yet unpublished work, Christina Starmans and her colleagues showed people from the US and India pictures of flies circling around a person, and asked which flies they thought were closest, the results were striking: regardless of cultural background, most people pointed to flies near a person's eyes. "This suggests there is a universal sense of the self being located in the head, near the eyes," says Starmans, a psychologist at the University of Toronto in Canada.

Subjectively at least, the eyes being windows to the soul checks out. "The sense of where in our bodies we are located is informed by our dominant experience of the world," says Starmans. "Almost all of our input from the world comes in through our head."

What our heads do with these inputs is certainly incredible, and key to our feeling that we are coherent beings. Our brains take a hotchpotch of electrical messages from our sense organs – eyes, ears, nose, skin – and combine them with memories to create a vivid, unified sense of conscious experience that is continuous in time.

How exactly this happens is still something of a mystery. But can we be any more specific about where it happens?

What's clear – sorry, Descartes – is that, for most of us, our self is firmly anchored in our material bodies. In some extremely rare conditions, people have a sense of existing outside their bodies: those experiencing heautoscopy, for instance, see a doppelgänger, and feel they are located both in their own body and the doppelgänger's. "They are in two places at one time. It's very disturbing," says Jane Aspell, a cognitive neuroscientist at Anglia Ruskin University in the UK.

Similar illusions can be generated in the lab. For example, volunteers who have their back stroked while wearing a virtual reality headset showing a simulation of themselves being stroked start to feel that they are closer to their virtual self than to their actual body.

Brain scans show that a region called the temporoparietal junction is affected. "This area is key for the brain computation that creates the perception of where your self is located in space," says Aspell.

A twist, however, is that this process is shaped not just by sensory information from the outside world, but by signals from within our body, too. A link between "interoception" and our bodily self-consciousness was shown in 2016 by neuroscientist Hyeong-Dong Park at the Swiss Federal Institute of Technology in Lausanne and his colleagues. They measured the "heartbeat-evoked potential", a signal that arises in the brain due to our heartbeat, while volunteers underwent a full-body illusion, and showed a link between the strength of the signal and the strength of the illusion. Other studies have since provided additional evidence.

So while modern science has long fixated on the brain as the seat of our conscious experience and our sense of self, it seems – Ancient Egyptians take a bow – that the heart and perhaps other parts of us may get a look-in too. "It was like the mind was divorced from the body," says Aspell. "We are realising how the mind is completely shaped by the body." **Alison George** ›

MELISSA KING/SHUTTERSTOCK

YOU...
are in possession of the world's most powerful known computer model, estimated to be capable of 1 exaflop – 1 billion billion calculations per second

04

ARE YOU ALWAYS THE SAME PERSON?

Each of us shows many differing faces over time

MY MOM sometimes jokes that it is fortunate she didn't meet my dad when he was in college, because she wouldn't have liked him. She was (and is) a self-described goody two shoes. Dad not so much, but presumably even less so when keg parties were involved.

We know that we change over time. Our bodies grow, then age; we mature and our views shift; our memories sharpen and fade. Yet for most of us, our sense of self is seamless and continuous. You are the same old you, right?

Let's start with the physical. Some of our cells, notably neurons in the brain, are with us from before birth, and can live more than 100 years. "Most of the nerve cells in the brain are actually as old as we are," says molecular biologist Jonas Frisén at the Karolinska Institute in Sweden.

But most of our cells aren't. Some, including certain kinds of white blood cell, live for only days. How quickly our skin cells are replenished changes as we age, but in general it takes about a month. The notion that the liver regenerates every 40 days or so is a myth: our liver cells live 200 to 300 days.

On the level of atoms and molecules, meanwhile, we are exchanging material with our environment with abandon. Think of your body like a grassy field, says Frisén. "It's the same lawn from year to year, but each strand of grass is completely different."

But what about less tangible aspects of you? This, after all, is where it matters to us. Losing a consistent sense of a "narrative self" is at best discombobulating, and at worst devastating when we observe it in ourselves or in our loved ones as a result of injury or neurodegenerative disease. Ultimately, our physical bodies and ever-eroding collection of memories are what we are made of. "It's all we've got," says psychologist Helge Gillmeister at the University of Essex, UK.

Always a new you

And yet even our long-lived neurons are constantly in flux, rewiring themselves to generate new thoughts, memories and states of mind. The simple fact is that what we learn, what we eat, how well we have slept and countless other things influence our choices and behaviours all the time. So in many ways, "you are not the same person from one moment to the next", says Gillmeister.

The illusory nature of the continuous self was backed up in 2016 when researchers at the University of Edinburgh, UK, investigated changes in the behavioural habits that make up our personalities across a span of 63 years. Previous studies, looking over shorter periods, found only small changes, suggesting that we largely stay the same. But the longer view was startling: measured over six decades, barely anything about our personalities stays the same. We turn into different people over time.

Sometimes, people go through major changes all at once – "something big happens that turns their lives upside down and very thoroughly shakes them up", says psychologist Wendy Johnson, a co-author on that paper. Yet for the most part, our personalities drift through "dribbles of change, conscious and not, in specific behaviours over long periods of time", she says.

We are strangely skilled at shifting our notions of who we were or what we believed to maintain an illusion of a continuous self. For example, we scramble to rewrite history to get our previous attitudes to more closely match our current ones, dismissing the idea that we once held strong political views, say, with which we now disagree. "You make yourself up in the past," says Gillmeister.

At some level, we are also aware of the disconnect. Studies have demonstrated that we think about our future selves in a very different way to how we think of ourselves in the moment – in our brains, it is as if future you is a completely different person.

That might be something to work against: research also shows that simply thinking about the ways you will be the same person in the years ahead can make you more conscientious, for instance. Maybe that is what swung it for Dad. **Tiffany O'Callaghan**

YOU...

consist of over 30 trillion cells that come in more than 300 types, controlled by the workings of 20,000 distinct genes

RF PICTURES/GETTY IMAGES

05 WHERE ARE YOUR BOUNDARIES?

“Studies show we think of ourselves now and in the future as different people”

DELINEATING where a person begins and ends used to be quite simple. While philosophers might have tied themselves in knots trying to define the self, and biologists still struggle to locate its steering mechanism (see “Where is your self?”, page 37), what it encompassed, at least, was more clear-cut.

Their traditional definition comprises three elements, says Thomas Bosch at the University of Kiel, Germany: the mind, the genome and the immune system. Each of us is a self-contained organism defined by our mind and genes, with the immune system patrolling our borders and discriminating between self and non-self. Me, myself and I.

Then we looked more closely, and our relationship status went from “threesome” to “it’s complicated”.

For starters, we are chimeras: some parts of us are human, but genetically not “us”. Most, if not all, of us contain a few cells from our mother, our grandmothers and ›

BOKICA/SHUTTERSTOCK

THE ‘YOU’ GENES

For all our diversity, humans are 99.9 per cent identical. Then again, our genome contains 3 billion base pairs, so the 0.1 per cent that varies means that some 3 million components of your genetic blueprint are different from the next person’s. This is where you find the variation that gives you brown eyes rather than blue, makes you tall or fast, or increases your risk of heart disease – although many factors beyond mere genes determine how you turn out (see “How likely are you?”, page 36).

The human genes that vary most, however, are a handful that control how our immune systems detect foreign pathogens. These major histocompatibility complex (MHC) genes code for proteins that present samples of what is being made inside a cell at its surface, allowing immune cells to check that the cell hasn’t been infiltrated by something that shouldn’t be there. Effectively, they are responsible for a system that identifies a cell as “self”, rather than something to be attacked.

These genes differ so much between individuals that they “can almost define your individuality on their own”, says Daniel Davis, an immunologist at the University of Manchester, UK. It means that each of us is scouting for and responding to disease in slightly different ways. That helps some of us to fight off diseases that have never existed before, such as covid-19.

But it is also good for the survival of our species, says Davis. “If we all had exactly the same susceptibility, we would have a greater chance of succumbing, as a species, to a particular disease.” For everyone’s sake, you can be glad there’s only one you. Daniel Cossins

even elder siblings that infiltrated our bodies in the uterus.

Women who have carried children host such cells too. "Something like 65 per cent of women, even in their 70s, when autopsies were performed, had cells in their brains that were not theirs," says David Linden at Johns Hopkins University in Maryland. Chimeric cells have been found to contribute to both good and bad health, for example promoting wound healing but also triggering autoimmune disease.

A handful of people even turn out to be true chimeras, created from a merger in the uterus of two non-identical, "fraternal" twins. We don't know how common this is, because few people undergo the genetic tests that reveal it. It could be you...

You aren't alone

More profoundly for our definition of self, we are also holobionts: we aren't individuals, but collectives. Every bit of our body is teeming with microbial life: bacteria, fungi, protists, archaea and viruses. They live on us and in us, on our skin, inside every orifice, and above all in our gut. We are even surrounded by an invisible cloud of them, a bit like Pig-Pen from the *Peanuts* cartoons.

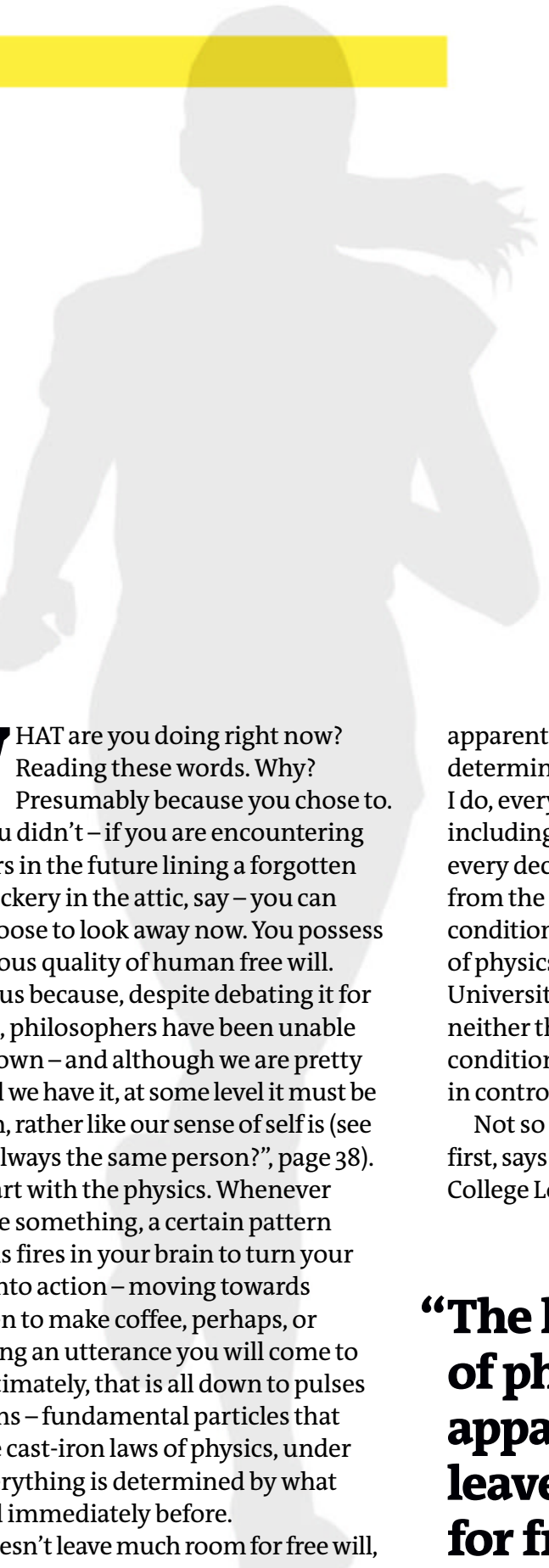
These microbes outnumber our own cells, though not by 10:1 as is often claimed. An average human body is made up of about 30 trillion human cells and 38 trillion microbial ones. By mass, we absolutely dwarf our companions: a 70-kilogram human contains just 200 grams of microbe.

But they punch well above their weight. The microbiome is different from parasitic freeloaders like lice and intestinal worms: it is an active and vital participant in our lives. Our gut microbiota, for example, do huge amounts of work digesting food that the products of our human genome can't break down on their own. They are, in fact, the principal determinant of how we respond to food. Our microbiome influences our health in many other ways, contributing to mental well-being and modulating our emotions and cognition, and helping determine how our immune systems function.

For Bosch, that means we need to develop a more inclusive concept of "self" that takes account of how some of our most personal traits are actually those of our vast, diverse and ever-shifting microbiomes. "Boundaries, borders, different parts of host and microbe are not so easy to separate any more," he says. "We are not alone." **Graham Lawton**

06
ARE YOU PREDETERMINED?

HERO CREATIVE/GETTY IMAGES



MICHAL SANCA/SHUTTERSTOCK

WHAT are you doing right now? Reading these words. Why? Presumably because you chose to. Even if you didn't – if you are encountering them years in the future lining a forgotten box of crockery in the attic, say – you can always choose to look away now. You possess the nebulous quality of human free will.

Nebulous because, despite debating it for millennia, philosophers have been unable to pin it down – and although we are pretty convinced we have it, at some level it must be an illusion, rather like our sense of self is (see "Are you always the same person?", page 38).

Let's start with the physics. Whenever you decide something, a certain pattern of neurons fires in your brain to turn your thought into action – moving towards the kitchen to make coffee, perhaps, or formulating an utterance you will come to regret. Ultimately, that is all down to pulses of electrons – fundamental particles that follow the cast-iron laws of physics, under which everything is determined by what happened immediately before.

That doesn't leave much room for free will, apparently. "Physical laws, if they're deterministic, tell me that everything that I do, everything that happens in the world, including everything that I do, including every decision I ever made, follows logically from the laws of nature [and] the initial conditions of the universe," says philosopher of physics Jenann Ismael at Columbia University in New York. Since we control neither the laws of nature nor the initial conditions of the universe, we can't be fully in control of our actions – can we?

Not so fast. We should define our terms first, says philosopher Eleanor Knox at King's College London. "There's this really strong

"The laws of physics apparently don't leave much room for free will"

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07
DO YOU MATTER?

LET'S start with the big picture: if it is significance on this Earth you are looking for, then the numbers are increasingly against you.

Go back 2000 years and there were fewer than 200 million people on the planet. When the industrial revolution kicked in from the 18th century, however, new methods emerged of feeding vastly more people and combating the infectious diseases that had kept our numbers in check. Our numbers began to shoot up, reaching nearly 7.7 billion now. Today, you are, to a greater extent than in all history, just a face in a crowd.

That doesn't mean you matter any less to your closest friends and family. And perhaps you or your offspring may be one of those few who change the world for better (or for worse). But that is statistically unlikely. Even in spheres where we like to think we are important, such as parenting, the evidence suggests individuals don't matter that much. Geneticist Robert Plomin at King's College London has pointed out, for instance, that identical twins brought up in different families generally end up with the same level of cognitive ability.

It isn't just about you

But there is another, contrary, line of thinking, that collectively all of us can make a difference on a grand scale. In the broad sweep of human history, these are pivotal times. With the development of nuclear weapons in the mid-20th century, humanity reached a point where we can destroy ourselves. In this century, existential risks have only increased thanks to the threat of catastrophic climate change, bioweapons, artificial intelligence running amok and more. "The analogy I use is that we're inching our way along a path along the side of a sheer ›

notion of free will, which is what my students all come into the classroom with," she says. "To have free will, I must right now be able to behave just with no connection to any contingent plan – so however I like."

Even leaving physics aside, that is clearly not the case. "We think that when we make a decision, the locus of control for behaviour is inside," says Ismael. "But really, there's all kinds of influences: cultural influences, psychological influences, influences that are more formative of our psychology that we don't control and so on."

Our choices are the result of a bundle of predilections formed by genetic nature and environmental nurture – a unique product of circumstances we aren't necessarily in immediate control of (see "How likely are you?", page 36). Fine, but there is an argument that this is just you being "you". You can still choose to go against the grain of what you just decided. That, after all, is the core of free will as we experience it.

And to say that this sort of free will is incompatible with deterministic laws of physics is rather to get things the wrong way round, unless you advocate some sort of mysterious, non-physical essence of the mind. "Whatever we call free will must ultimately be explicable by the laws of physics," says Knox.

The question is how. Lifting the lid on that vexed question is the subject of a new and burgeoning field of research looking, for example, at whether the property emerges from the ability of living, conscious organisms to organise and integrate information from many sources.

But "free will" is a term so laden with baggage that those involved prefer to think in terms of a subtly different concept called agency – an undeniable, if still inexplicable, ability to bundle up hopes, dreams, desires and compulsions and use them to change the world. **Richard Webb**

YOU...

emit about three antimatter particles every minute, thanks largely to the decay of radioactive potassium-40 inside you

cliff, where one wrong step could be our downfall – no more adventures, no more journey," says philosopher Toby Ord at the University of Oxford.

You can argue, then, that the decisions we take today matter more than ever: they could determine whether trillions of as-yet unborn people get a shot at life. And while few of us walk around carrying nuclear codes in a briefcase, when it comes to existential issues such as climate change or movements for social justice such as Black Lives Matter, the

"Decisions we take today could decide whether trillions get a shot at life"

effectiveness of our response is determined by the sum of individual actions. We may not know why, but we are all in control of our actions (see "Are you predetermined?", page 40) – and what kind of life you choose to lead surely does matter.

There are things you can do to increase your positive impact. Ord helped kick off the effective altruism movement, which says that by donating small amounts of money to charities that are proven to be more effective, you can do more good. Perhaps unsurprisingly, Ord now thinks that one of the most effective ways to do good is to donate to charitable organisations trying to head off existential threats to humanity.

"It needn't be that every donor focuses on giving to these causes," he says. But collectively we need to do more than we are on this front. "It's hard to be precise about how much we spend [on this], but it's definitely less than the world spends on ice cream."

What is the lesson of all this? Perhaps we should beware self-fulfilling prophesies. If you believe you don't matter, then you won't. If you believe you can matter – well, you just might. **Joshua Howgego**

YOU...
are worth about $10 million, according to an analysis of various bodies' calculations of the "value of a statistical life", the cost that society is willing to pay to save one life.

THE ELEMENTS OF YOU

By sheer weight of numbers, there is a clear answer to the question "what are you made of?". Over 60 per cent of all the atoms in your body are hydrogen, the lightest in the periodic table.

Go by overall mass, however, and the leader is oxygen. Oxygen largely comes in molecules bound to other things, notably with hydrogen as water (H_2O). We tend to define ourselves with reference to the element that is second in terms of mass, however, because it is so crucial to the body's chemistry and structural integrity: we say we are carbon-based life forms.

Deconstruct an 80-kilogram human, and oxygen, carbon, hydrogen and three other elements account for almost 99 per cent of the body by mass, in the following proportions:

- **Oxygen – 52kg (65%)**
- **Carbon – 14.4kg (18%)**
- **Hydrogen – 8kg (10%)**
- **Nitrogen – 2.4kg (3%)**
- **Calcium – 1.1kg (1.4%)**
- **Phosphorus – 0.9kg (1.1%)**

Also present in quantities from hundreds of grams to just a few grams are, in descending order, sulphur, potassium, sodium, chlorine, magnesium, iron, fluorine and zinc – plus, in even tinier quantities, strontium, iodine, copper, manganese and molybdenum. Other elements may also be present, but tend not to be permanent fixtures. Richard Webb

AF ARCHIVE/ALAMY

08

CAN YOU EVER TRULY KNOW YOURSELF?

The delusional Don Quixote and his faithful squire Sancho Panza in the 2018 film *The Man Who Killed Don Quixote*

SAVEANIMALSANDNATURE/SHUTTERSTOCK

DON QUIXOTE is one of the most celebrated characters in literature. The hero of Miguel de Cervantes's novel, first published in 1605, decides to act out his knightly aspirations, performing acts of great chivalry and righting wrongs. So he thinks, anyway. Sadly, the gulf between his self-perception and how the world views him is vast – so much so that the word "quixotic" has come to describe delusional behaviour.

But here is a troubling thought. What if we are all more quixotic than we allow for? We might think that with our privileged access to our every thought and motivation, we are the best judge of our own character, but what if we aren't?

In recent decades, psychologists have revealed that we are beholden to all sorts of biases and mental blind spots that put a positive spin on our characters. In one study from the 1960s of drivers hospitalised by car accidents, for instance, all judged their driving ability to be better than average.

This "illusory superiority" bias has been demonstrated many times since. Indeed, it turns out that the worse we are at a particular task, the less likely we are to recognise our own incompetence – something known as the Dunning-Kruger effect. And we are crashingly unaware of all of this: while we recognise the impact of bias in other people's judgements, we miss it in our own.

It isn't all bad news though. In a seminal study a decade ago, Simine Vazire at the University of Melbourne, Australia, asked participants to rate themselves on various skills and traits. They were also rated by friends and strangers before undergoing a battery of behavioural tests. She found that we tend to be the best judge of our own emotional state, but when it comes to characteristics such as intelligence and creativity, others who aren't strangers tend to rate us more accurately.

"We have different blind spots for ourselves than we have for close others," she says. "We are not very good at rating how attractive or intelligent we are, whereas we are pretty good at judging that in others we know well."

The outsider perspective

Knowing too much about ourselves might, perversely, cloud our judgement of how others see us. One reason is that we base our self-opinions on memories. Studies have shown, for instance, that when asked how a stranger would judge our skill at something like playing darts, we invoke our knowledge of past performance – something that the other person has no access to.

Yet, a positive self-view might be a more accurate one. Research led by Lauren Human at McGill University, Canada, demonstrates that people with higher self-esteem and life satisfaction tend to be more in tune with the views of others when judging what they are truly like – in part because they behave in ways that accurately reflect their true personality, she says.

All this raises a thorny question. If, in general, we are putting too positive a spin on our character and abilities, do we necessarily want to burst that bubble? That's tricky, says Human. Although self-knowledge is regarded as an unquestioned good in many philosophical traditions, and the idea of "honest feedback" is embedded in many management manuals, the scientific take is more equivocal. "There is evidence that there are benefits to both holding overly positive self-views and to having self-knowledge," says Human.

Accurate self-views are mostly beneficial "interpersonally", she says – meaning that others like us more if we have greater self-knowledge. Positive self-views, meanwhile, are mostly beneficial "intra-personally" – meaning that they make us feel good and protect our self-esteem. "So it might depend on what is more important to a person," says Human. Maybe Don Quixote was on to something. **Alison George** ›

"Self-knowledge is often regarded as an unquestioned good – but is it?"

09

IS THERE MORE THAN ONE OF YOU?

BIOLOGICALLY speaking, there is definitively only one you (see "How likely are you?", page 36). Physics might give you pause for thought, however. The most bewildering argument against your uniqueness comes from quantum mechanics, the fundamental theory that describes the often counter-intuitive behaviour of subatomic particles. It might imply not only that there are multiple, identical versions of you, but even that there are an infinite number of yous out there.

The quantum realm is notoriously fuzzy: quantum objects such as particles are described in terms of probabilities, encoded in mathematical widgets called wave functions that give you the odds on any number of different states the object might be in. Only when you observe or measure it does the object take on one of those states, at least from your perspective.

The truth of what happens at this point – and indeed what, if anything, the wave function itself is trying to tell us about reality – divides physicists. Many stick with a cop-out known as the Copenhagen interpretation: essentially, that we can never know what is happening in this fuzzy pre-measurement realm. In other words, quantum theory makes predictions about reality, but says nothing about what goes on under the hood.

That isn't good enough for some. Physicists who subscribe to the rival "many worlds" interpretation insist that all the possibilities encoded in the wave function are real, and that they continue to exist in different universes that split off from ours every time a quantum measurement is made. The startling upshot of this view is that there are potentially squillions of versions of you going about their (your?) business in parallel universes.

Well, sort of. Those other versions of you aren't really copies, says Sean Carroll, a physicist at the California Institute of Technology: they are individuals who used to be you, but at some point split off and became separate. "You are not spread out over worlds," says Carroll. "You are here in this world, and there are a lot of other people in other worlds who are closely related to you."

As to how many other-worldly relations you have, it is impossible to say. "The number could be infinite or there could be a continuum of worlds rather than a discrete set," says Carroll. "But the number might also be finite. We're not sure."

What we do know is that we can never observe these doppelgängers. Their worlds exist only in mathematical space; they have no physical connection to our own. Ultimately, the possible existence of as many worlds as you like doesn't detract from your individuality in this one. Physics, like a doting parent, still says you are special.

Daniel Cossins

TINKIVINKI/SHUTTERSTOCK

"Quantum theory might imply there are an infinite number of yous out there"

YOUR EXTENDED SELF

The existence of trillions of microbial cells within us makes the internal boundaries of the self a little fuzzy (see "Where are your boundaries?", page 39). The same is true of our external limits, too.

We already know that when we use a tool such as a hammer, our brain's body map expands to encompass it: the tool temporarily becomes part of an "extended self". Something similar is true if you are a habitual driver. The vehicle becomes part of you – or perhaps you become part of the vehicle.

With digital devices now constantly in our hands, the extended self could become permanent. "Our identity partly depends on memories," says philosopher Richard Heersmink at La Trobe University in Melbourne, Australia. Increasingly, we are outsourcing our memories to our smartphones – not just through notifications of what we should do, but through messages and images that recreate what we have done. The result? "A larger part of our narrative self is smeared out over our environment," says Heersmink. You may extend further than you think.

Graham Lawton

FSTOP123/GETTY IMAGES

Is death the end, or does part of us live on?

10

WHAT HAPPENS WHEN YOU DIE?

MICHELLE FRANCL-DONNAY will never forget 15 April 1987. Her husband Tom was due to pick her up from an evening meeting, but decided to take a swim first. He had an undiagnosed heart condition, and while in the pool had a catastrophic aneurysm. Michelle rode with him in the ambulance. That was the last time she spoke to him.

"When I saw Tom's body the next morning, he clearly wasn't there anymore," says Francl-Donnay, a chemist at Bryn Mawr College in Pennsylvania and an adjunct scholar at the Vatican Observatory who writes extensively on both science and spirituality. Over the years, she found herself mulling a question humans have asked for a long time: where had he gone?

Even those of us who rationally reject the idea of an afterlife have trouble letting go of the idea. That might be down to our theory of mind. Because we habitually put ourselves in other people's shoes and imagine their thoughts and feelings, it can be hard to believe that those thoughts and feelings can just cease to be when ours still feel so real.

Yet we have no evidence for anything different. When you die, blood stops flowing, the muscles cool and consciousness, whatever that is, slips away. If your body were simply let be, other organisms would rapidly digest it, from microbes already living inside you to newly arrived blowflies.

Human burial rites just change the timescale or manner of your physical disappearance: if your remains are cremated, for instance, the organic compounds of your body form carbon dioxide and the water inside you boils away, leaving just the mineral compounds of your bones. Sooner or later, some of your atoms will become part of other people – and perhaps, at some point when Earth has long gone, some will become part of the stars from whence they came.

But is that really the last word on you? An already well-developed, albeit controversial, idea known as integrated information theory suggests that consciousness emerges because of the way particular physical systems organise information. Some researchers think life itself is a similar emergent property embodied in a simple equation: life = matter + information.

It is a cast-iron rule of physics that information cannot be destroyed. So might physics provide a back door for some form of afterlife in which information associated with you can live on?

Francl-Donnay reckons quantum physics provides teasing hints, in the way that the quantum wave functions defining our individual atoms and particles don't have a well-defined boundary in space or time. "At some long distance, there is still some incredibly tiny chance of finding an electron there," says Francl-Donnay. "It's not measurable. But that doesn't mean it's not important."

But the suggestion that part of what makes us alive survives death goes way beyond what science can currently tell us. What we know for sure is that we will have an afterlife of a kind – and now perhaps more than we ever did before – through the digital records of us entombed in mobile phones and spread across cyberspace (see "Your extended self", left). And in the minds of those we leave behind, of course. "Even today there's a sense in which Tom persists – in my memory," says Francl-Donnay. "And I can hear his voice if I shut my eyes." That truly is the last breath of you. **Joshua Howgego** ▮

YOU...

don't degrade all at the same rate when you die. The brain starts first, within minutes of death; the prostate gland or uterus are the last. We don't know why.

The call of alcohol

Some people get great pleasure from boozing while others can take or leave a drink. We're beginning to work out why, says **Claire Ainsworth**

MATT CARDY/GETTY IMAGES

LARS IGUM RASMUSSEN and his mates were going large. Donning their lederhosen, the three middle-aged men headed into Oktoberfest in Munich, Germany, the world's biggest folk and beer festival. There, each proceeded to quaff an average of 7.5 litres of beer a day, for three days. It was a spectacular bender.

Getting hammered wasn't the main aim of the exercise, however: Rasmussen is health correspondent for Danish magazine *Politiken* and was writing a story exploring the physiological effects of binge drinking. To understand what was happening to him and his friends, he had enlisted the help of metabolic physiologist Filip Knop at the University of Copenhagen. While Rasmussen was interested in finding out what havoc excessive boozing wreaks on the bodies of middle-aged men, Knop had another motive for getting involved. He and his colleague Matt Gillum had been itching to test a new idea about people's appetite for alcohol – but couldn't, in good conscience, solicit anyone to partake in a binge of this magnitude. "It would give the ethics officer a heart attack," says Gillum. Volunteers, however, were a different matter.

What Knop and Gillum discovered is helping to build a picture of how our bodies

control our boozing habits, from the amount we drink to when we stop. The research is homing in on a hormone that partly explains the huge variation in our social drinking habits: why some people are teetotal or can't drink much, while others are lushes. It also points to the startling idea that our livers have more say in directing our behaviour than anyone imagined.

Of course, people choose to drink alcohol for all sorts of reasons. Delicious and complex flavours is one. Writing about his Oktoberfest experiences, Rasmussen described another: the "reality-dissolving joy of intoxication", of being 6 litres of beer into a rowdy evening with 5000 fellow revellers. "There are so many ways and motivations to drink alcohol," says psychiatrist Gunter Schumann at King's College London. "It could be stress relief, it could be sensation seeking, wanting to be social and whatnot." What we do know, however, is that drinking behaviour is strongly influenced by genetics. It is the result of many different genes each making a small contribution, says Alexandra Sanchez-Roige, a psychiatrist studying the genetics of substance-use disorders at the University of California, San Diego.

Results from the latest genomic tools suggest little overlap between the genetics underlying social drinking – like Rasmussen's happy carousing – and problem drinking, such as alcohol addiction. Yet, given the wrong circumstances, normal consumption can spiral into harmful drinking. "Alcohol use disorders are very complex and are formed by a series of transitions," says Sanchez-Roige. This is one reason for a growing interest in the genes and mechanisms that underpin regular alcohol consumption, and it is where Knop and Gillum's study fits in. They wanted to find out what would happen to a hormone produced in the liver, fibroblast growth factor 21 (FGF21), when Rasmussen and his friends went on their bender.

This hormone first drew attention in the mid-2000s for its ability to cause weight loss in obese mice. Since then, FGF21 has been found to have many important physiological effects, including an influence on our food choices: whether we crave carbohydrates or hanker after proteins, for example. It might even help explain why some people have a sweet tooth. In 2013, two studies scanning the human genome spotted DNA variants in the FGF21 gene associated with a tendency for people to eat a diet relatively high in carbohydrates.

These genetic findings inspired Steven Kliewer and David Mangelsdorf at the University of Texas Southwestern Medical Center to discover a link with alcohol consumption. When they raised the levels of FGF21 in mice and monkeys, they found that this dramatically decreased the animals' preference for sweetened water. Intrigued, they decided to look at a simple sugar-derivative, ethanol – the alcohol in our drinks. They found that FGF21 reduced the mice's appetite for that too. Meanwhile, Gillum and Matthew Potthoff at the University of Iowa were also hot on the trail of FGF21, and

Whether you're shaken or stirred by alcohol could depend on a simple gene

UNITED ARCHIVES GMBH/ALAMY

discovered that it activates the hypothalamus, part of the brain involved in creating our sensation of reward. "So rather than affecting the taste directly, our thinking now is that FGF21 is affecting the pleasure sensation that you get from sugar," says Kliewer.

Liver: do you read me?

Further evidence of FGF21's modus operandi came when Kliewer and his team disabled a protein called beta-klotho, which helps cells in a mouse brain receive FGF21's signal. Animals lacking beta-klotho drank more alcohol – a finding that took on new significance with the discovery that beta-klotho can be linked with human appetite for alcohol too. In 2016, a huge genomics study of 100,000 people of European descent looked for genes that affect alcohol consumption in non-addictive drinking. It found that two variants of the beta-klotho gene were associated with how much alcohol people preferred: those with one variant were light drinkers or teetotal whereas those with the other drank more heavily. "What I thought was interesting here was the fact that it was both a liver and brain mechanism," says Schumann, who was lead author of the study.

The obvious next experiment was to see what happens to our FGF21 levels when we drink alcohol. Eleftheria Maratos-Flier at Harvard Medical School and her colleagues discovered that after drinking alcohol for an hour, volunteers had a large spike of FGF21 production – far bigger, relatively speaking, than the one seen in mice. Kliewer, whose team performed similar experiments, was floored by his findings. "In humans, ethanol is by far and away the strongest inducer of FGF21 production," he says.

The fact that a liver hormone has such a specific effect on the brain came as a big surprise. Scientists already knew of hormones that can reduce appetite generally, including ones that act on the ›

brain's reward system. But why is FGF21 so specialised, and why the focus on sugar and alcohol? One possible explanation, says Gillum, is that our evolutionary ancestors probably ate a lot of fruit, including fermented fruit, which would be a diet laden with fructose and ethanol. Dealing with these compounds puts metabolic stress on the liver, which is why drinking too much alcohol can damage this organ. FGF21 is a way for the liver to signal to the brain. "[It's saying:] 'We've got a lot of fructose on board. We have a lot of ethanol on board. We're just not doing so well down here. Can we please adopt a more conservative behavioural profile for a few days until we can clear this up?'" says Gillum. He speculates that our unusually strong FGF21 response to alcohol might be the result of our bodies evolving to cope with our invention of alcohol production, much in the same way that some populations evolved the ability to digest milk beyond infancy following the development of dairy farming.

Whatever its origin, the hormone seems to have a role in protecting the liver. But, so far, research had only shown that it helps defend against a short binge. Its longer-term action remained unknown – until Rasmussen cooked up his Oktoberfest jaunt. Following the three-day bender, Gillum and Knop took blood samples from the friends. Sure enough, their FGF21 levels shot up: they were over twice their baselines on their return to Denmark a couple of days later. "That was the first demonstration, really, that there is some subchronic regulation – part of the endocrine [hormonal] hangover, as it were," says Gillum.

PHILIP DALTON/NATUREPL.COM

Vervet monkeys are notorious Caribbean cocktail boozers

Brain: copy

These findings don't just provide an insight into what's going on inside our bodies when we overindulge, as some of us have done in lockdown and as many tend to do at this time of year. They also suggest a way to help people who have become dependent on alcohol. Gillum and Knop hypothesise that sustained heavy drinking might blunt the FGF21 response. Just as an overwhelmed pancreas starts struggling to produce insulin in people with type 2 diabetes, so a liver exposed to chronically high levels of ethanol might lose its ability to secrete FGF21. They are now looking at FGF21 secretion in problem drinkers with a view to finding out if giving someone doses of the hormone might help them cut down their alcohol consumption. "That would be my hope," says Gillum.

"After a three-day bender, levels of the hormone were over twice the baseline"

To investigate this idea, he has moved on from studying carousing journalists to another kind of party animal, the vervet monkeys of the West Indies island of St Kitts, notorious for swiping cocktails from tourists. "It's a fantastic feral population of primates that exhibits a fairly human-like distribution of alcohol drinking proclivities," he says. His focus is on individuals that drink heavily but steadily. "They have the monkey equivalent of about three bottles of wine a day," says Gillum. His team is testing to see whether giving the monkeys FGF21 can reduce their alcohol consumption. The results, though not yet published, look promising.

But when it comes to how much alcohol a person drinks, and why, FGF21 is only part of a much more complex picture. And there is another reason to be cautious about FGF21-based therapies: drugs that interact with the brain's reward system run the risk of creating psychiatric problems such as depression, says Kliewer. However, Gillum is optimistic that such treatments, used judiciously, might help people with drinking problems, and even repair liver damage.

That would be quite an achievement. But whatever happens, we are still left with the discovery that our livers influence our behaviour in unexpected ways. "It's a thinking organ," says Gillum, "at least in terms of what it knows, and communicating that to the brain." By pumping out its hormone, it drains the pleasure we get from alcohol even as we drain our glasses. Knowing that, we can start to listen more carefully to its message. You might even take a cue from one fictional boozer, James Bond, who in *Casino Royale* observed that his champagne "tasted bitter, as the first glass too many always does". If your booze loses its allure, then it's time to stop drinking. ▮

Claire Ainsworth is a freelance science journalist based in Hampshire, UK

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NEW SCIENTIST'S most ambitious virtual event yet took place on Saturday 28 November. The Future of Food and Agriculture saw more than 5500 people register for a day packed full of inspiring talks from world-leading scientists and technologists about what we eat and how we grow it on our changing planet.

The audience had their pick of 15 expertly curated talks across three virtual stages tackling some of the most challenging questions facing humanity today, including how to feed 11 billion people sustainably, how robots are reshaping the future of agriculture and why we should eat insects. A further 30 sessions about everything from plant health to autonomous tractors were run by leaders in the field.

Alongside all the fantastic talks, the audience also engaged with researchers directly through nine virtual rooms, featuring everything from 360-degree lab visits and live chats with scientists and roboticists to a session on the science of cheese and an insect-eating demonstration.

Over on the main stage, environmental scientist Jacqueline McGlade spoke from Nairobi in Kenya about the profound impact climate change is having on global food production. "Plants are responding in a tremendous way to climate change," she said. Some of our most important crops are reacting to droughts by producing poisonous cyanide compounds, she explained – and these dangerous compounds are already ending up in crucial produce such as cassava.

Rising temperatures and shifting seasons are also increasingly impacting our food in other ways, said McGlade. "Moulds are really loving climate change," she told the audience, and while plants can defend themselves against poisons released by moulds, such as aflatoxin, in order to survive, that doesn't stop these nasty substances from making their way into our food. "Kenya had to destroy a third of its maize stock last year because of aflatoxin poisoning," she said.

McGlade and other speakers throughout the day acknowledged that covid-19 has set back efforts to tackle food insecurity and malnutrition. But the pandemic is also putting a spotlight on human resilience, McGlade told viewers.

As we continue to face these problems, we must not forget the importance of food quality, as well as quantity, she said. "We need to think about our agriculture not only as food production, but also as land stewardship, thinking about where we grow crops, how close to wild areas, what's the zoonosis pool – the pool of diseases that might actually start to infect our food systems."

We need to generate food for a growing number of people too. Geoff Simm at the University of Edinburgh, UK, spoke on the Field stage about feeding people sustainably as the global population rises.

"It's really in the last 300 years or so that we've seen a dramatic increase in the number of humans on Earth, over a 10-fold increase in that time," said Simm. "That explains why there is so much pressure on our food systems and on the natural environmental systems that support them.

"A further challenge is the change in diets towards those that are reliant on animal-sourced products. And that matters, because, by and large, livestock-sourced foods have a much bigger resource requirement than plant-sourced foods," Simm explained.

So should everyone in the world adopt a plant-based diet? It might not be so simple, said Simm. If we want to be able to feed the growing population in a more sustainable way, we need to improve the way we use land, he told the audience.

"Many people assume that the optimal level of livestock production if you want to minimise land use is zero, but in fact it's not," said Simm. That is because livestock can use the by-products from crop production, as well as low-grade grains that aren't suitable for human consumption, and they can use grass and forage grown on land that is unsuitable for crop production.

"We believe that probably we minimise arable land use, with between 16 and 40 per cent of our protein coming from animal sources," said Simm. "Of course, it's not the

Missed out?

For details on how to watch the talks on demand

newscientist.com/science-events/future-food-agriculture/

Farming is at the forefront of science and technology (left). Maize in Kenya is feeling the impact of climate change (below)

J HARVERSON

The Food Standards Agency's Michelle Patel spoke from the studio

only consideration, we also need to think about greenhouse gas emissions and other environmental impacts."

Well-managed grazing can have really positive effects on biodiversity, as well as the more publicised negative effects, said Simm. "And we know that the appropriate amounts of livestock-sourced foods in our diets can be very helpful in our nutrition, bringing us bioavailable sources of micronutrients as well as proteins and energy," he said. These are especially vital during the first few years of the lives of children in many of the poorer countries on the planet, Simm added.

The challenge of adapting our diets to tackle climate change and food insecurity in a world where the population is rising is inspiring a revolution in food and agricultural innovation. Scientists and technologists on the Fork stage gave the audience a glimpse of some of the completely new foods that could one day appear on plates around the globe.

Neil Stephens at Brunel University London and Anneli Ritala at the VTT Technical Research Centre of Finland spoke about the latest efforts to develop lab-grown meats and cellular foods produced using single-celled organisms in bioreactors. Meanwhile, Tilly Collins at Imperial College London and David Willer at the University of Cambridge argued that insects and shipworms could provide a key source of sustainable protein in our future diets.

But how can we ensure the safety of foods that many people have never eaten before or novel foods that have been created in a lab? Robin May from the UK's Food Standards Agency was on hand to try to answer this important question for the audience.

"Insects are consumed around the world by many populations already," said May, and there are plenty of health benefits of eating insects: they are low in fat and high in protein, you can grow lots of them in a small space and you can feed them on waste products that would otherwise need to be disposed of.

But there are also lots of unknowns with expanding our reliance on insects, said May. "We've been farming cows for thousands of years. We've been farming crickets for a lot shorter time," he told the crowd.

However, insect-based flour, such as cricket flour, is already used as an ingredient in some food products, said May. "Understanding if there's any risk of eating ground-up crickets is obviously a key part of our role," he told the audience. May explained that the Food Standards Agency is constantly evaluating the newest food products on the market for safety.

In the future, smart labels will also contribute towards ensuring our food is safe to eat, said May. "[Labels] could detect the by-products of bacterial growth and alert you to the fact that your food is spoiling before you can even see or smell it," he said. "There's a really exciting opportunity there to not only improve the quality and the safety of food, but perhaps also to help mitigate food waste."

All the speakers and organisations involved in the day offered a delicious peek into the science and technology driving fundamental changes in what we eat and how we grow it. Thanks to everyone who helped make the day such a brilliant success. ▮

Layal Liverpool is a digital journalist at *New Scientist* and is based in Berlin

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Stargazing at home

When worlds collide

Jupiter and Saturn are about to be at their closest in the night sky since 1623. Get ready to witness this spectacle, says **Abigail Beall**

Abigail Beall is a science writer in Leeds, UK. She is the author of *The Art of Urban Astronomy* @abbybeall

What you need

A clear sky
Binoculars (optional)
A telescope (optional)

Stargazing at home appears every four weeks

Next week

Science of cooking

THIS month, stargazers across the world will be treated to an event that only happens once every 19.6 years, on average. On 21 December, Jupiter and Saturn will appear in the same place in the night sky in an event called a great conjunction.

These two so-called gas giants of our solar system, which are usually bright enough to see with the naked eye even from the light-polluted heart of a city, will align, as seen from Earth, to look like one extremely bright planet. This year, the pair will be just 0.1 degrees apart in the sky, making it the closest such event since 1623. For reference, the diameter of the full moon in the sky spans around 0.5 degrees as we see it from Earth. The next time these planets will be visible this close together in the night sky will be the year 2080.

Jupiter and Saturn are the most distant of the planets that can be seen easily with the naked eye. Uranus is only visible this way in particularly dark skies, and you always need binoculars or a telescope to see Neptune.

Because Jupiter and Saturn are the furthest from the sun of all the naked-eye planets, they orbit the slowest. It takes almost 30 years for Saturn to do a lap of the sun, while Jupiter takes about 12. This is why conjunctions between the two are the rarest of those between all the easily visible planets.

While the event itself takes place on 21 December, the planets will be close in the sky in the days leading up to it and afterwards. To see the conjunction, look south-west as soon as the sun sets and find the brightest thing you can see. Because the timing coincides with the December solstice, the shortest day of the year in the northern hemisphere, sunset will be early. Jupiter and Saturn will be low in the sky and will set quickly, so make sure you have a good view of the western horizon to catch them.

ALAN DYER/VWPICS/SCIENCE PHOTO LIBRARY

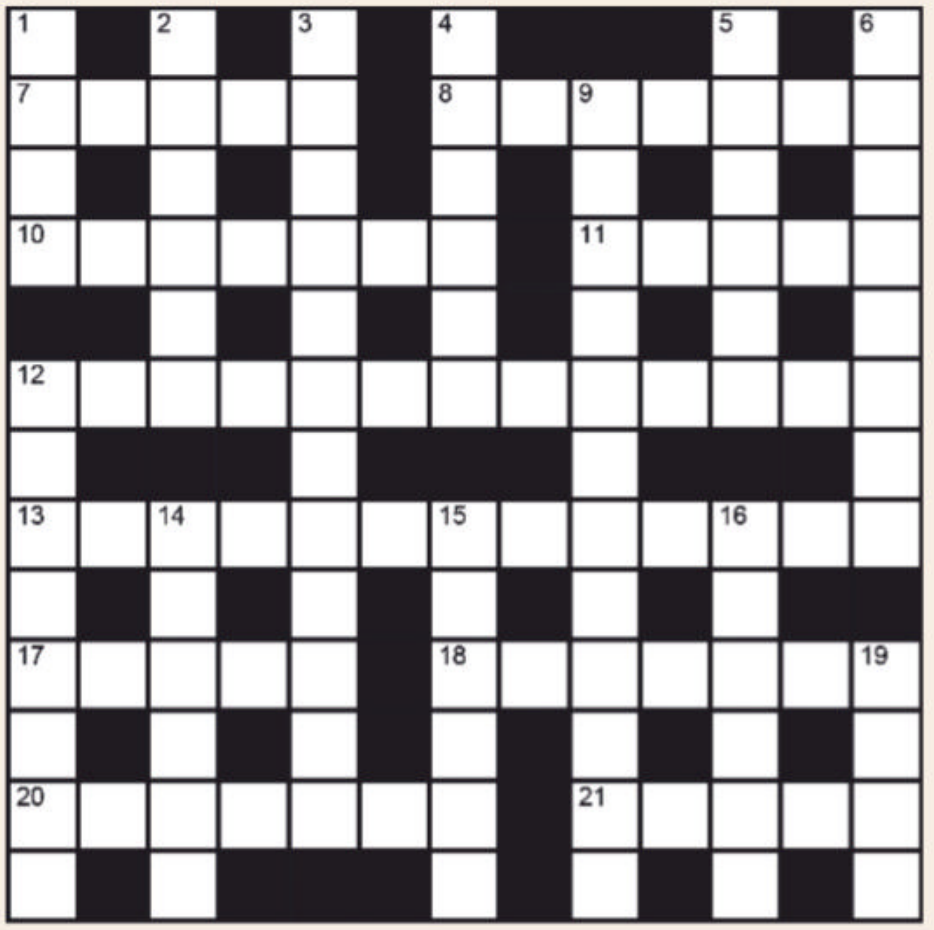
If you have a pair of binoculars to hand, the two will be visible as separate planets. Saturn will be above and to the left of Jupiter in the northern hemisphere and below and to the right in the southern hemisphere.

But if your binoculars are powerful enough, a minimum magnification of seven, you might even catch a view of Jupiter's four Galilean moons. In the northern hemisphere, two of these, Callisto and Ganymede, will be on the left of Jupiter. On Jupiter's right, much closer to the planet, you could see Io and Europa. In the southern hemisphere, the moons will line up in the opposite direction to this.

For stargazers with a telescope, if you can spot the planets before they dip too low on the horizon, the view will certainly be worth it and it isn't something you will be lucky enough to see often: Saturn, its rings and some of its moons along with Jupiter, its Great Red Spot and Galilean moons, all visible at once. ▮

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

Cryptic crossword #46 *Set by Rasa*



Scribble zone

Answers and a giant cryptic crossword next week

ACROSS

7 Yahoo initially lampoons early invention (5)
8 Egg-laying mammal with English and Greek X chromosome material (7)
10 Nickel bonds with overused ion (7)
11 Ditch traps upper-class scoundrel (5)
12 Ahead of time, rock band REM stole famous numbers (10,3)
13 Hack at deli item with overhanging parts for roll wrappings (7,6)
17 Colour seen flipped in optical illusion (5)
18 Guard identifying badge in reflection (7)
20 Astronomer and I delay retiring constellation name (7)
21 Inactive knight involved in strange rite (5)

DOWN

1 Copy short string (4)
2 Chest feature can jam component (6)
3 French mathematician prepared basic paellas (6,6)
4 Studio effect always used in R&B (6)
5 So upset about grim smells (6)
6 Audience's senses of taste: what many painters grasp (8)
9 Truncated Beatles album one critic trashed for having "...the Sun" in the middle (12)
12 Feigning modesty about journal supporting my study of fungi (8)
14 Lad gulps "bad" cholesterol with confidence (6)
15 For example, one getting hammered upended festive drink (6)
16 Male tenants smoked e-cigs and behaved seductively (6)
19 A, B, C, D, F or G, say? (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #81

1 NASA's Dawn probe was the first spacecraft to visit and orbit what?

2 Which creatures build the world's tallest animal-built structures?

3 Which condition makes people see visual objects as smaller than they are?

4 How many of the seven mathematical Millennium Prize Problems have been solved?

5 What gives chilli peppers their "burn"?

Answers on page 55

Puzzle
set by Rob Eastaway

#89 Sunday drivers

The single lane road around Lake Pittoresca is scenic, but a pain if you want to get somewhere fast. Four couples staying at the Hotel Hilberto plan a day trip to the lakeside village of Paradiso. The driver for each couple habitually takes life at a different speed. Mr Presto likes to go full throttle in his Porsche. Mme Vivace isn't quite such a speedy driver. The Andantes prefer a leisurely drive, while inconsiderate Mr and Mrs Lento creep along in second gear.

If a car finds itself behind a slower car, there is no choice but to follow at the slower speed, and form a larger "clump" of cars (a clump can be any number, from one upwards).

After Sunday breakfast, all four couples set off and find they are in the only cars on the road. By the time they arrive at Paradiso, they are in two clumps. Later, they all head back in reverse order, and arrive at the hotel in three clumps. Mr Presto looks particularly stressed because he was barely able to put his foot down on the journey back. In which order did they set out?

Answer next week

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Masses of people

The human population has more than doubled in the past 50 years, so has the mass of our planet and everything on it increased?

John Rieuwerts
Yelverton, Devon, UK
The extra mass of a doubled human population has come from the soil, oceans and atmosphere, so the overall mass of the Earth system hasn't changed.

I find it humbling to know that the countless atoms that make up "me" were previously scattered across the world and have even been part of people who lived in past centuries.

As such, each of us is a temporary collection of elements borrowed from the largely finite mass of the Earth system and will ultimately be recycled back into it. Ashes to ashes.

Greg Harris
Abu Dhabi, United Arab Emirates
While the human population has doubled in the past 50 years, that life and almost all that sustains it is produced from matter already within Earth's gravity well, making no net change to Earth's mass.
The exception to this is that Earth gains between 30,000 and 100,00 tonnes of space dust every year, some of which is integrated into our biosystems.

"Each of us is a temporary collection of elements borrowed from the Earth system and will ultimately be recycled back into it"

The planet is estimated to lose close to 100,000 tonnes per year of atmospheric hydrogen and helium, however, creating a net loss of up to 70,000 tonnes a year.

That loss is almost inconsequentially small relative to the total mass of the planet, and has nothing to do with increases in human population size.

VVVITA/ALAMY

This week's new questions

Myopic wildlife **Many people are long or short-sighted. Is this the same for other animals, and if so, how do they cope?**
Frank Wigger, *Heidelberg, Germany*

Recycling racket **Why is the noise so deafeningly loud when I empty a bag of empty bottles into the glass recycling hopper?**
John May, *Flitwick, Bedfordshire, UK*

Chris Warman
Hinderwell, North Yorkshire, UK
If the mass of Earth's human population increases, that mass is derived from whatever is being consumed by those people.

What should be of concern is that, if we continue our present exploitative behaviour, we are gaining mass at the expense of other "forms most beautiful and most wonderful" that so delighted Charles Darwin.

It isn't too fanciful to imagine that for so many more people, there will be an equivalent loss of elephants and orangutans, and for every extra plantation of oil palm trees, there will be fewer hectares of rainforest.

Earth may not actually gain in weight, but it will be labouring under an additional burden.

Mike Follows
Sutton Coldfield, West Midlands, UK
Humans are increasing Earth's mass indirectly. I calculate that human activity makes our planet 150 tonnes heavier per year via an enhanced greenhouse effect. This is because the greenhouse gases we emit have the same effect as increasing the sun's brightness by just over 0.8 watts per square metre, and, according to Einstein's famous equation $E=mc^2$, more energy in the system means greater mass.

Hillary Shaw
Newport, Shropshire, UK
The total mass of humanity, even with almost 8 billion of us, is minuscule compared with the masses of other organisms on the planet.

Many people need glasses, so do other animals have eyesight issues too?

The collective mass of carbon in our bodies is 0.06 gigatonnes, compared with 12 Gt in fungi, 70 Gt in bacteria and 450 Gt in plant life.

Chris Daniel
Colwyn Bay, Conwy, UK
The human population has been able to double only because food for us to eat can be produced in sufficient quantities, often at the expense of other creatures whose habitat we encroach on. Even so, people are a tiny fraction of the total mass of Earth. Seven billion people are estimated to have a mass of 280 billion kilograms, which is less than 5×10^{-14} per cent of that of the whole planet.

Patrick Forsyth
Maldon, Essex, UK
There are far too many of us and we are adversely affecting the environment through depletion of resources, climate change and extinctions.

Wait a minute... sorry, I misread the question as "mess".

Different views

What exactly occurs in the eyes to make some people short-sighted and others long-sighted? (continued)

Tony Harding
Sarsfield, Victoria, Australia
Time spent outdoors may make it less likely that people become short-sighted because of exposure to different wavelengths of light, as a previous answer suggested, but I suspect the explanation is simpler than that.

I suggest that changes in eyeball shape that give rise to long or short-sightedness are a consequence of the growth spurt at puberty when the eye must enlarge but retain clear vision. If you are a reader, the eye adapts to provide clear vision at the normal distance between book and reader

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Tom Gauld
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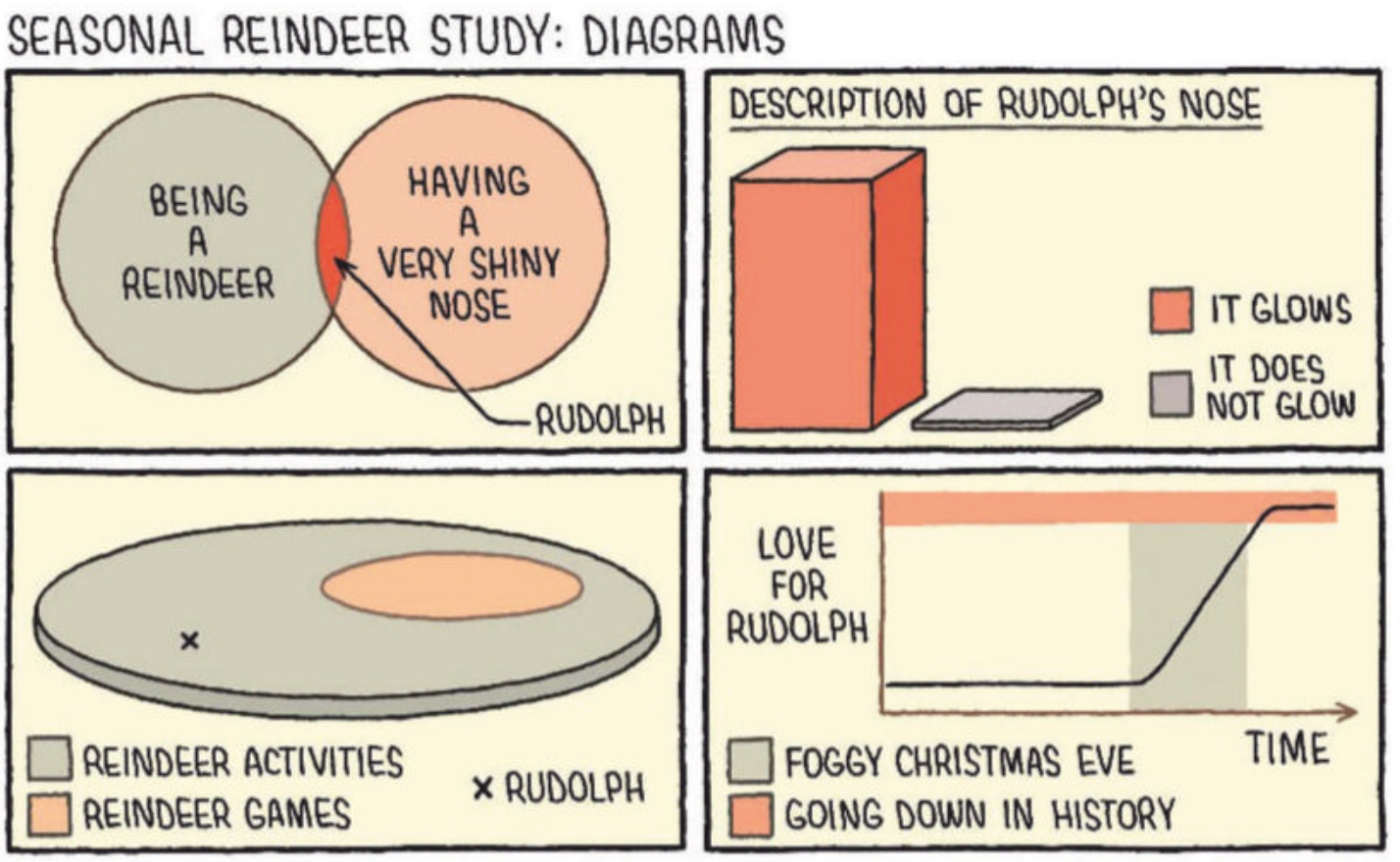


while if you spend most of your time outdoors it will adapt to accommodate more distant views.

Healthy spread

If you eat three meals a day, does it make a difference if they are taken within, say, an 8-hour window or a 14-hour one?

Lewis O'Shaughnessy
Nottingham, UK
Human metabolism is incredibly complex and no one has developed the perfect way to cheat the system and lose weight.

Time-restricted fasting has become a popular way to lose weight or retain a healthy weight, but, on the whole, studies have shown little impact to body weight when the only variable is the time over which we eat. Where there have been reports of weight loss resulting from time-restricted fasting, these impacts are likely to result from one of two causes.

First, restricting the time in which you can eat makes it harder to eat too much without getting

"Fasting for 16 to 18 hours a day has clear health benefits in terms of reducing the risk of cardiovascular disease and diabetes"

full. This is especially true if you eat less-calorie-dense foods like vegetables, which can physically fill your stomach. If you ate exactly the same food over an 8 or 14-hour window, there would be negligible impact on your weight.

Second, as with any diet, time-restricted fasting makes us more aware of what we are eating. This means many people who follow it tend to have diets that are better balanced or eat less overall. Eating main meals late at night, however, can have detrimental effects on sleep and overall health, as a result of fluctuations in hormone levels.

Mark Mattson,
Johns Hopkins University, Baltimore, US
Evidence suggests that 16-18 hour daily fasting periods provide clear health benefits in terms of reducing risk factors for diabetes and cardiovascular disease.

A defining feature of the eating patterns in intermittent fasting is that they must include periods of time with no calorie intake. These must be of sufficient duration to deplete the glucose stores in the liver and then release fatty acids from fat cells which are then converted into chemicals called ketones. The liver stores about 400 to 500 calories of glucose, which will last for about 10 or 12 hours. For the metabolic switch from glucose to ketones to be fully engaged, a person must fast for at least 14 hours.

Exercise can accelerate the onset of the metabolic switch during fasting. For example, if a person goes on a 1-hour run in the morning before eating breakfast, they will deplete their liver glucose stores and switch to "fat burning mode" during their run. Recent research suggests that intermittent fasting can enhance many of the health benefits of exercise. ▮

Answers

Quick quiz #81
Answers

1 A dwarf planet. It arrived at Ceres, a dwarf planet in the asteroid belt between Mars and Jupiter, in March 2015

2 Termites. Their mounds can be up to 8 metres tall

3 Micropsia

4 Just one of the seven. The Poincaré conjecture was solved by Grigori Perelman in 2003

5 Capsaicin

Quick Crossword #72 *Answers*

ACROSS 9 Angular momentum, **10** Bisects, **12** Preemie, **13** Cambridge, **14** Sci-fi, **15** Sputnik, **18** Subzero, **21** Quota, **23** Wear a mask, **25** Emetics, **26** Titrate, **29** Cherenkov effect

DOWN 1 Carb, **2** Eggs, **3** Electron, **4** Erased, **5** Morpheus, **6** Recess, **7** Ptomaine, **8** Impetigo, **11** In-app, **15** Sequence, **16** Udometer, **17** Kawasaki, **19** Blast off, **20** Reset, **22** Amines, **24** Active, **27** Apex, **28** EDTA

#88 Rifling the draw
Solution

The chance that Kate has won is 1 in 7. Suppose they each shoot 25 times: 12/25 times Pat will hit and Kate will miss (= 4/5 x 3/5). Just 2/25 times Kate will hit and Pat will miss (= 1/5 x 2/5).

So when there is a single hit, the odds are 6:1 (or 6/7) that it is Pat's.

Good reads

There is no area of human endeavour or aspect of the human condition too trivial, esoteric or just downright disturbing that it cannot be written down, illustrated and presented to the world as thinly sliced, perfectly bound tree.

So we reflect as we browse Amazon's web page for *Crocheting Adventures with Hyperbolic Planes* by the retired Cornell University mathematician Daina Taimina. Not that this book itself disturbs us. We are the proud possessor of an original Taimina design, a lovingly crocheted representation of an n=3 hyperbolic manifold [could the subeditors please crochet one to check this is right] once sent in to us by one of our legion of adoring fans. Well, it beats having underpants hurled at you.

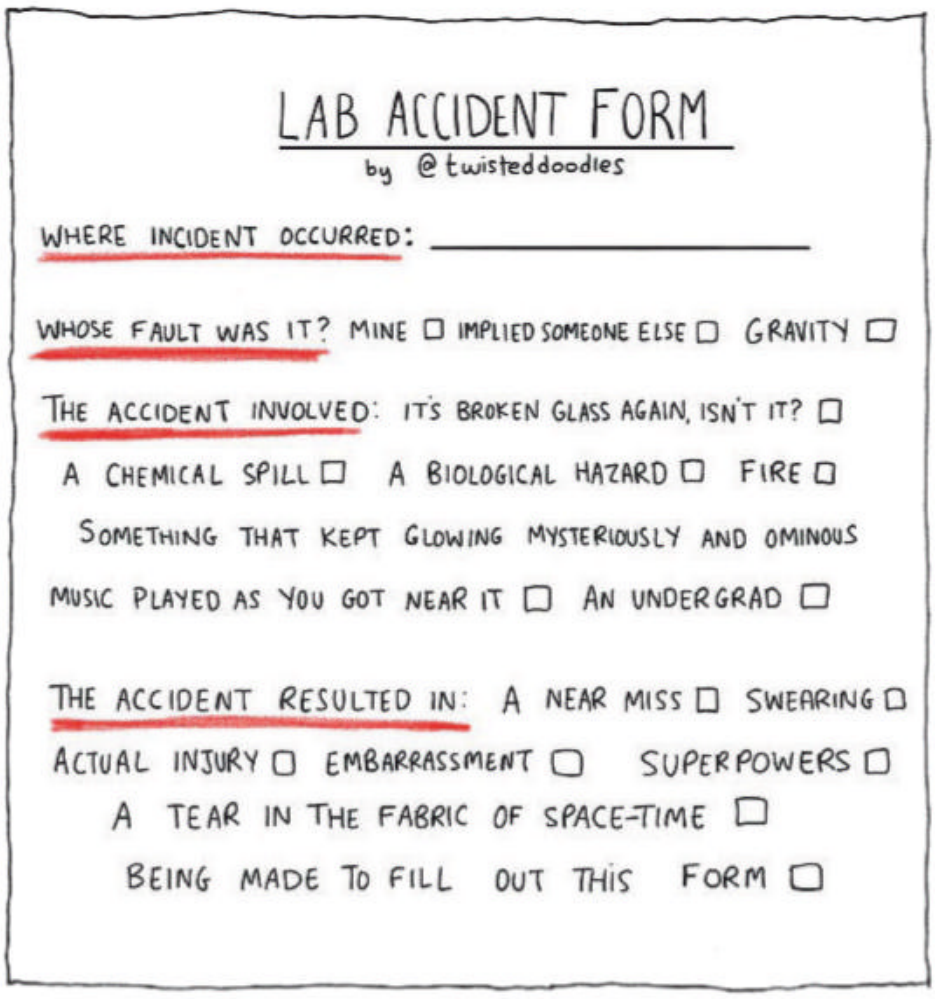
No, our mien is rumpled by the page's "Customers who viewed this item also viewed" section, as pointed out by Fred Teti. Fred's favourite of the algorithm's selections is *Do It Yourself Coffins for Pets and People: A Schiffer book for woodworkers who want to be buried in their work*.

Well, it's good to have a retirement plan, Fred, but we haven't got there yet. We're still hanging on *Crafting with Cat Hair: Cute handicrafts to make with your cat* and *A Million Random Digits with 100,000 Normal Deviates 0th Edition* ("a product of Rand's pioneering work in computing, as well a [sic] testament to the patience and persistence of researchers in the early days of Rand"), before entering into a brief eddy around *Learning to Play With a Lion's Testicles: Unexpected gifts from the animals of Africa* and *Castration: The advantages and the disadvantages* (way more advantages than disadvantages, Feedback can reveal). Finally, we arrive, exhausted, at *How to Poo on a Date: The lovers' guide to toilet etiquette*.

To see these titles is to marvel at the breadth and, in a very real sense, depth of the human experience. But what sort of human minds might possibly connect all these books?

Somewhere deep in Feedback's consciousness a low-wattage light bulb flickers into life. By clicking on these items, we have reinforced the connections felt by some neural net buried deep under Amazon's island volcano headquarters – thus distracting the all-seeing AI from discerning the patterns that map out humanity's true desires. Come browse with us and join the counter-revolution.

Twisteddoodles *for New Scientist*



Got a story for Feedback?

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

Lost tech

Following our item on the UK's various National Health Service bodies' undying love affair with fax machines (21 November), many of you faxed in your own instances of failing to keep up with the times. Thanks particularly to Henrietta Sushames of Wellington, New Zealand, whose story of painstakingly transcribing numbers from digital cardiac monitors onto a paper chart in her local neonatal ward struck a chord. At least the NHS isn't alone in sticking to such endearingly old-school, yet undoubtedly effective, modes of operation.

But John Molesworth's find really takes the cracker with the mature Gruyère on top. He sends in two photos of a paper form with which customers of the UBS bank in Geneva can apply for internet banking services. "1. What you need", the instruction sheet begins, continuing, accompanied by helpful icons: "Envelope. Pen. Scissors. Glue."

Quite why the application process resembles arts and crafts hour at the local infant school remains a mystery. We can only presume that when it comes to the legendary Swiss banking secrecy, the legendary Swiss efficiency must give way.

Can buy me love

The working papers of the US National Bureau of Economic Research are generally a headier brew than any sleeping draught. But Feedback is pulled back into full wakefulness by a recent opus from Johannes Haushofer, Robert Mudida and Jeremy P. Shapiro, "The comparative impact of cash transfers and a psychotherapy program on psychological and economic well-being".

In it, they analyse the effects of a five-week programme of psychotherapy, a grant of $1076, both or neither on the economic and psychological well-being of 5756 individuals in rural Kenya. "One year after the interventions, cash transfer recipients had higher consumption, asset holdings, and revenue, as well as higher levels of psychological well-being than control households," the researchers write.

Meanwhile, the psychotherapy "had no measurable effects on either psychological or economic outcomes". To rub it in, "the effects of the combined treatment are similar to those of the cash transfer alone".

So there you have it: money can buy you happiness. Just don't anyone say "dismal science".

Flight of the kite

Tom Gauld's recent cartoon of an ice cream van jingle quickly emptying a laboratory just as effectively as a radiation siren (7 November, p 55) reminds one reader of the time he worked at the headquarters of the UK Royal Society for the Protection of Birds in the 1970s, when the tannoy announcement "Red kite flying over West Car Park" was more efficient at emptying the building than any fire drill.

This anecdote was sent in by Alan Bird. Absolutely. No. Comment. ▮

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