

New Scientist

WEEKLY 10 July 2021

SPECIAL ISSUE

CONSCIOUSNESS

The 10 biggest questions about the greatest mystery in the universe

TOO LITTLE TOO SOON?
England to scrap covid-19 restrictions despite surge in cases

EXTREME HEAT
North America's extraordinary new temperature highs

PROBLEM PAVEMENTS
Why it's time to reinvent the sidewalk

What is consciousness?

When did consciousness evolve?

Does consciousness create reality?

What is consciousness for?

Is the universe conscious?

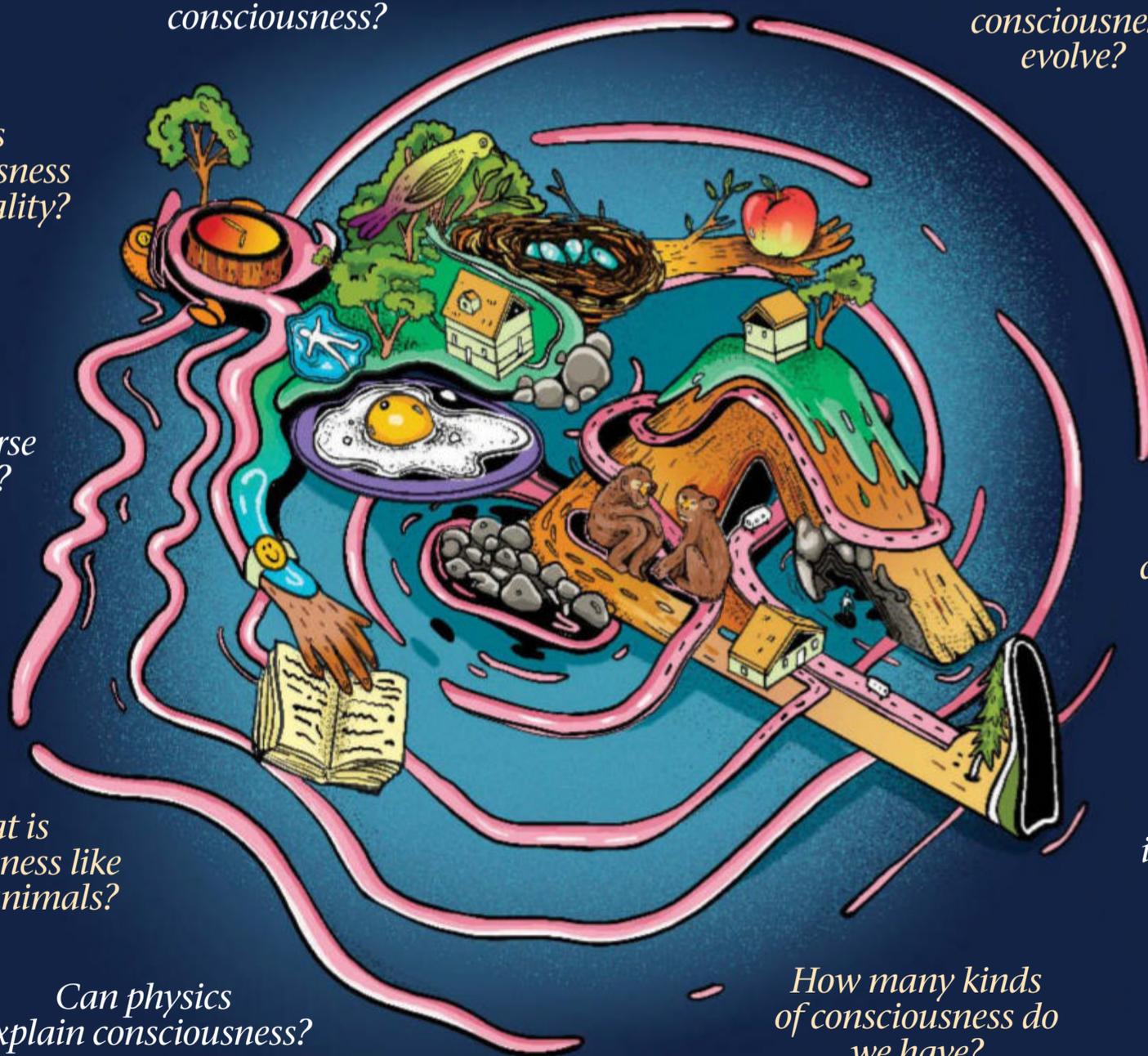
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Can we know if a machine is conscious?

Can physics explain consciousness?

How many kinds of consciousness do we have?



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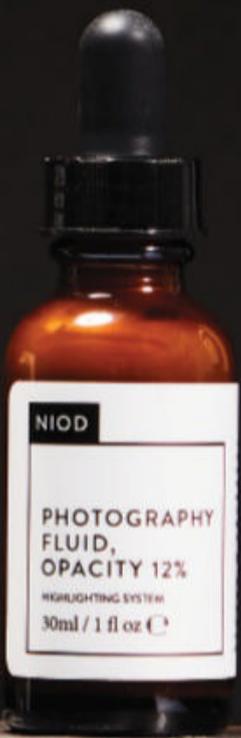


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STEVE TREWHELLA/NATURE PHOTOGRAPHERS LTD/ALAMY

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We are missing the first billion years from the timeline of the universe – the period when the very first stars burst into life and darkness gave way to light. Hundreds of times the size of the sun and a million times brighter, these stars died in powerful explosions that seeded the universe with the heavier elements that we are made of. In this talk, Emma Chapman at Imperial College London explains how astronomers are coming together to look further back in time. Join us at 6pm BST on Thursday 22 July. Tickets are available now.

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Daytime naps Sharks in French Polynesia relax by floating on updrafts

LAURENT BALLESTA

Podcasts

Weekly

The team asks whether an ancient skull discovered in China belongs to a new species of humans, explores how covid-19 affects the brain and discusses several other stories.

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Video

Surfing sharks

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Commercial and events director Adrian Newton

Display advertising

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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 Email live@newscientist.com

Creative director Valerie Jamieson

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Human resources

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CONTACT US

newscientist.com/contact

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

Marketforce UK Ltd Tel +44 (0)33 0390 6555

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Tribune Content Agency Tel +44 (0)20 7588 7588

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Tel +44 (0)330 333 9470

Email subscriptions@newscientist.com

Post New Scientist, Rockwood House, Perrymount Road, Haywards Heath, West Sussex RH16 3DH

EDITORIAL

Editor Emily Wilson

Executive editor Richard Webb

Creative director Craig Mackie

News

News editor Penny Sarchet

Editors Jacob Aron, Helen Thomson, Chelsea Whyte

Reporters (UK) Jessica Hamzelou, Michael Le Page,

Layal Liverpool, Matthew Sparkes,

Adam Vaughan, Clare Wilson

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Intern Krista Charles

Digital

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Kate Douglas, Alison George, Joshua Howgego

Feature writer Graham Lawton

Culture and Community

Comment and culture editor Timothy Revell

Liz Else

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Chris Simms, Jon White

Design

Art editor Julia Lee

Joe Hetzel, Ryan Wills

Picture desk

Picture editor Helen Benians

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Production

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Robin Burton



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High-stakes gamble

The world will be watching what happens after England's covid-19 restrictions are lifted

SOME call it a calculated risk, others a reckless gamble. Earlier this week, UK prime minister Boris Johnson announced that almost all remaining covid-19 restrictions in England are set to be lifted on 19 July, now called, by some, “freedom day”. This may be good politics, but is it good public health policy?

Scientific opinion is divided. The UK's vaccination programmes are hitting one of their goals: to decouple infection from severe disease and reduce the need for masks and distancing. Even in the face of the highly transmissible delta variant, cases are rising but hospitalisations aren't going up too much. That is good, given that the new UK health secretary, Sajid Javid, says cases could hit 100,000 a day as a result of easing restrictions (see page 9).

There is also the stark reality that countries must probably go through some sort of “exit wave” before returning to normality. The delta variant means that herd immunity is probably out of reach. Meanwhile, no country is likely to get to 100 per cent vaccination. To get over the



STEPHEN CHUNG/ALAMY

line, at some point a partly vaccinated country has to decide to let the virus run through the population, despite the inevitable deaths, leaving the survivors largely immune, although a proportion will have long covid. That requires a difficult conversation about how many deaths and chronic cases are acceptable

to a society. It also requires judicious decision-making about when and how quickly it is allowed to happen.

Some modelling suggests that dropping restrictions going into summer is better than waiting until autumn. But it doesn't have to be a binary choice between now or later. Removing restrictions one at a time is indisputably a more responsible approach. It would also help individuals and employers navigate a world in which, with the government stepping back, they are now effectively responsible for public health. That is a grave responsibility indeed. So far, workers who couldn't stay at home have been protected at work by masks, distancing and barriers, for example. What happens when those protections are dropped and people get sick? What lawsuits will we see?

And where does a new restriction-free landscape leave individuals, particularly those who are vulnerable to the virus? What is certain is that England is taking a big gamble. The world will be watching to see how the chips fall. ■

In the line of fire

The North American heatwave scenes must make plain the costs of climate inaction

ON 29 June, the village of Lytton in British Columbia recorded a temperature of 49.6°C, smashing Canadian records. The following day, fire swept through it, razing much of it to the ground.

Last week's deadly heatwave in North America (see page 10) is far from the first extreme weather event to shake the world. Apocalyptic blazes hit California last year and Australia in late 2019.

Climate attribution studies show that both earlier events were made more likely by climate change. We hardly need the verdict on the North American heatwave to tell us the risks of continued inaction.

Yet that it is what we are getting. Despite the damage and loss of life, Australia's fires

barely shifted the political dial for national action on carbon emissions. It seems unlikely that Lytton's destruction will lead Canada to rethink the emissions plan promised in April, which is still deemed inadequate to meet the goals of the Paris Agreement and limit climate change to liveable levels.

Every failure to act now comes with a human cost. A recent leaked draft of a 2022 Intergovernmental Panel on Climate Change report said, baldly: “Life on Earth can recover from a drastic climate shift by evolving into new species and creating new ecosystems. Humans cannot.”

Each failure also comes with economic costs, as we need to spend more adapting

to a warmer world as well as mitigating the emissions driving it. As our columnist Annalee Newitz points out on page 25, we are only just starting to confront how we rebuild infrastructure and social systems to cope with the damage already wrought.

Hope that we can avoid the worst effects comes from the bottom up – in the youth movements calling for change, the sinking cost of wind and solar power, the firms jockeying to create the best net-zero plans and in court judgments wringing action from recalcitrant governments and firms.

But governments must empower all those movements from the top down, too, if we are to ensure sepia-tinged hellscape don't become a norm. ■



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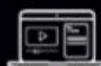
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Mini organs

Stem-cell heart can beat like the real thing **p13**

Farmer violence

Shift to agriculture sparked conflict in Chile **p16**

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Fish with tooth-like scales could explain mystery **p17**

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Newly discovered strange plant already endangered **p19**

Walk on the wild side

Beetle traverses the underside of water's surface **p19**



REUTERS/HENRY NICHOLLS

Commuters wearing face masks on the London Underground

contact for around 15 minutes.

In the Netherlands, meanwhile, at least 165 of the 600 or so people who went to a night club on 26 June were infected, despite everyone having to show evidence of a negative test or full vaccination before entering. It isn't clear how many were infected at the night club or who may have been infected on arrival.

This higher transmissibility is why delta is causing surges in cases in many places. Indonesia is battling its biggest outbreak since the pandemic began. More than 60 people died in a single hospital on 3 and 4 July after it ran out of oxygen.

Vaccines are also less effective against delta infections. In Israel, health ministry data suggests that the Pfizer/BioNTech vaccine is just 64 per cent effective at preventing symptomatic illness after two doses, compared with 94 per cent against older variants. However, low case numbers may mean this figure isn't accurate.

According to a UK study, Pfizer/BioNTech is 96 per cent effective at preventing hospitalisation due to delta, with the Oxford/AstraZeneca vaccine 92 per cent effective. That is one of the reasons why hospitalisations in England aren't increasing as rapidly as they did during previous covid-19 waves, which played a big part in the government's decision to end restrictions.

One of the risks of easing restrictions and allowing cases to increase is that it could lead to the evolution of even more dangerous variants. The more the virus replicates, the more chances there are for it to change. In countries where many people have been vaccinated, there will be strong selection for any variants that can evade vaccine immunity. ■

Coronavirus

Delta on the rise globally

Restrictions in England are coming to an end as many countries are struggling to control cases of the variant, reports **Michael Le Page**

THE highly infectious delta coronavirus variant is continuing to spread around the world, causing rising case numbers even in countries with high vaccination rates. Some countries that kept previous variants under control are struggling to contain delta, such as Thailand and Vietnam.

Some nations are imposing fresh restrictions to curb delta's spread, including Iran and Indonesia. But others are relaxing restrictions. Despite soaring case numbers, England is set to end almost all restrictions on 19 July. The health secretary, Sajid Javid, warned on 5 July that case numbers could reach 100,000 per day as a result, but wouldn't say how many deaths the

government expected.

The decision to end almost all restrictions at once – including the legal requirement to wear face coverings on public transport – has been criticised. It is a “huge gamble”, tweeted Nisreen Alwan, at the University of Southampton, UK, as many young people will be infected and the long-term consequences of that remain unknown.

A poll by YouGov showed that 71 per cent of people thought masks should continue to be mandatory on public transport, with just 21 per cent opposed.

Delta has now been detected in 96 countries, according to Maria Van Kerkhove of the World Health Organization. Increased social mixing and travel, and the relaxation of restrictions in many countries, are contributing to its spread, Van Kerkhove said on 5 July. “The world remains largely susceptible to infection.”

Delta spreads more readily than other variants. In Sydney, one person became infected after just walking past another. With older variants, local health officials said, it was thought infection could happen only with sustained



Daily coronavirus news round-up

Online every weekday at 6pm BST
[newscientist.com/coronavirus-latest](https://www.newscientist.com/coronavirus-latest)

Climate change

The heat is on out west

A devastating heatwave in the western US and Canada highlights how urgently we must adapt to long-standing droughts and worsening wildfires, reports **Adam Vaughan**

THERE is no question that the drought and recent heat across the western US is bad. Unseasonably high temperatures baked Washington and Oregon, with new highs of 41.7°C in Seattle on 28 June and 44.4°C in Portland on 27 June. Canada, better equipped for blizzards, also suffered in a deadly, record-breaking heatwave.

A dry winter means exceptional and severe drought now blankets large swathes of the western US states, with hot summer months still to come – leading to worries of another potentially disastrous wildfire season. The drought is intense even for a region that played host to part of a historic six-year drought starting in 2011. “It’s extraordinarily bad already,” says Peter Gleick at the Pacific Institute in Oakland, California.

Spectacularly dry conditions don’t guarantee a wildfire season worse than last year’s devastating blazes, says Daniel Swain at the University of California, Los Angeles. But they do set the stage for one, by creating an abundance of tinder dry fuel. Compared with last year, California has seen a 56 per cent increase in the area burned up to 10 June.

These extremes are playing out in a world that has warmed about 1.1°C since pre-industrial times. So what does the US west coast face if the world warms by the 2.9°C that governments’ current policies have us on track for?

“What we can say for the climate for the region is it’s not going to get better, especially California,” says Friederike Otto at the University of Oxford. “We see an increase in hot extremes basically everywhere in the world, but dry only in specific regions – and this

Temperatures in Portland, Oregon, shattered past records



KATHRYNELSESSER/AP VIA GETTY IMAGES

People seeking refuge from the heat in a cooling centre in Portland, Oregon

is one of them.” Climate change is expected to mean less snowfall and more rain in the western US, reducing the snowpack that provides a crucial supply of water. Mount Rainier in Washington state, a key source of snowpack, has seen melting at triple the normal rate for this time of year.

Modelling by Swain and his colleagues suggests that future rain and snow in the region will also be much more volatile, with dramatic year-to-year swings,



MARANIE STAAB/BLOOMBERG VIA GETTY IMAGES

raising the risk of both flooding and drought. A major US climate report found the south-western US faces potential “chronic future precipitation deficits”.

Katharine Hayhoe at the Nature Conservancy, a US non-profit organisation, says these changes will exacerbate demand for water. Future soil moisture is expected to be lower in winter and spring, a key time for farmers. “If it’s dry as a bone when it’s prepared for crops, you’re going to need a lot more water from underground aquifers, so you’re going to run through it faster,” she says.

None of these climate impacts will be welcome in the western US, especially not another “heat dome” like the one that brought the recent intense heat (see “What is a heat dome?”, right). But, says Hayhoe, “future change is not set in stone”.

Climate researchers agree that the long-term solution is the rapid and deep cut in global greenhouse gas emissions demanded by the 2015 Paris Agreement. The world is

failing on that, a shortcoming that this November’s COP26 climate summit is meant to address.

In the meantime, there remains the big question of how western North America can best adapt to drought, fire and heat, now and in the future. Short-term responses include fireproofing buildings against embers, clearing grass around homes and not stacking firewood under eaves.

Fight fire with fire

“But those are not large-scale, hugely helpful solutions to any of the broader problems and don’t address any of the underlying issues,” says Swain. Medium-term responses give him the most cause for optimism. “What can we do by September? Not a hell of a lot. What can we do in five to 15 years? Probably quite a lot.”

Two key options are thinning vegetation to reduce the fuel available and intentionally starting controlled burns, also known as prescribed fire. Stephen

Pyne at Arizona State University says thinning, which is already under way in California, can play a big role but is hamstrung by time and cost – not just financial but social and political. Consultations with local people can take years. “Things are moving so fast, we don’t have time to spend a decade talking,” he says.

Controlled burns already take place across the western US and

49.6°C

The record high temperature seen in Lytton, British Columbia

Canada. But they aren’t without risk – some have escaped control in the past – and can be unpopular with local people who are understandably afraid of fire and the health impacts of smoke. “There needs to be [prescribed] fire on the ground in large quantities but there are practical and political impediments,” says Swain. “The first step is probably a public education campaign to show not all fires are created equal. Some produce more benefits than harms.”

Partly because of such barriers, Pyne says the firefighters he speaks to in the US west’s rural areas are increasingly trying to transform wildfires into what are effectively controlled burns. Some firefighters aren’t putting out fires on ridges. Instead they back off to easily defensible positions, so critical infrastructure is still protected, and systematically allow the fires to burn out. “That is a hybrid model. It’s not that you’re equally suppressing the fire at all points, you’re adjusting it,” says Pyne.

Stopping fires igniting in the first place will be vital. Upgrading and maintaining energy networks should be “high priority” and can be done quickly, says Swain. Fires

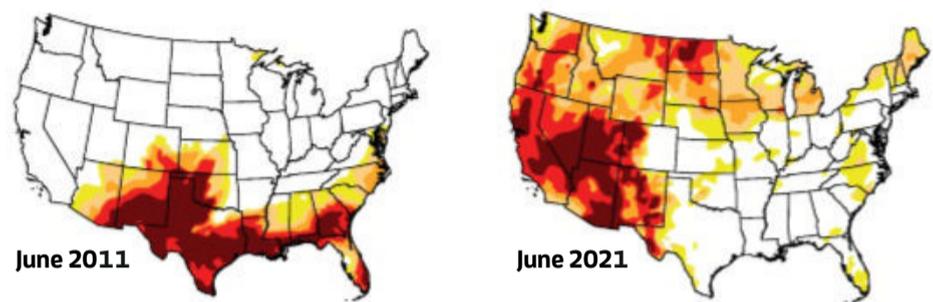
started by power lines often occur in the most dangerous conditions, with strong winds that turbocharge blazes. A notable example is the 2018 Camp Fire in California, which caused 84 deaths and was found to be due to power lines run by the Pacific Gas and Electric Company. The company filed for bankruptcy after pleading guilty to manslaughter.

With 85 per cent of US fires started by people, greater public awareness and penalties may seem like a solution, too. But despite media reports focusing on fires started by gender-reveal parties and children with matches, arson is rare and isn’t often linked to large fires. “The real issue in a landscape that is intrinsically this flammable is there’s only so much you can do to reduce accidental human ignitions,” says Swain.

The western US also desperately needs to accelerate its adaptation to drought that sets the stage for such fires. Some of that is obvious, says Hayhoe, such as reducing demand for water through more efficient toilets, showerheads and other appliances. Some farmers

Extreme drought sets in

In 2011, the western US was free of drought but that year saw the start of a six-year historic drought in the region. The 2021 drought could be worse – it is the most widespread for the past 20 years



June 2011

June 2021

Drought conditions



SOURCE: CURTIS RIGANTI, NATIONAL DROUGHT MITIGATION CENTER, DROUGHTMONITOR.UNL.EDU

are switching from pivot irrigation – mounted sprinklers where much water is lost – to drip irrigation.

Tackling demand is also crucial, says Gleick, because traditional measures to increase water supplies in the region are no longer enough. “We are now at what I call peak water. We can’t have any more water from the Colorado river,” he says. The Colorado river provides water for 40 million people in the US, and one of its key reservoirs hit a historic low this year.

Gleick wants to see more of the behaviour changes called for in emergencies become the norm, such as short showers, letting lawns brown or removing lawns, and washing cars less. In the long run, coastal cities could build desalination plants to use more seawater, but he says alternatives like water reuse plants are a cheaper, better option for now.

In the short term, reducing agriculture’s water demand offers the biggest absolute savings. Gleick says farmers are working on water efficiency, but California, a major food producer, may have to reluctantly accept growing less. He thinks the state’s farmland will need to reduce by around 10 per cent. “I would argue in California some land is going to have to come out of production. We’ve brought more land into production than we have water for,” he says.

Ultimately, the climate-change-fuelled extremes facing the western US will hinge on how ambitiously the world tackles the emissions driving those impacts. But in parallel, it is clear there are ways to adapt to them, and they are becoming increasingly urgent. “I think we can adapt, yes. But the question is will we?” says Gleick. ■

What is a heat dome?

The heatwave in Canada may have killed hundreds of people as temperatures broke national records, reaching a high of 49.6°C in Lytton, British Columbia, on 29 June. The next day, a wildfire burned most of the village. The extreme heat at such a northerly latitude has been linked to a ridge of high pressure, also known as a heat dome.

“What that dome does is suppresses convective activity,” says Katharine Hayhoe at the Nature Conservancy, a US non-profit organisation.

“Convection is what causes those thunderstorms during warm weather, which bring a lot of rain. The dome also does something else: when a storm comes along and there’s this high-pressure system sitting here, it deflects the storm around.” Together, these cause less rain. “And the less rain you get, the hotter it gets – and the hotter it gets, the stronger the dome,” says Hayhoe. That feedback loop was a feature of California’s historic drought, with the phenomenon dubbed the “Ridiculously Resilient Ridge”.

Did Neanderthals get the sniffles?

DNA suggests cold viruses have infected us for millennia – and possibly predate our species

Michael Marshall

COMMON colds and cold sores have afflicted us for at least 31,000 years, suggests DNA from viruses in ancient teeth.

What's more, the sniffles may have plagued us for far longer. The DNA of one cold virus indicates it first evolved around 700,000 years ago, suggesting it predates our species, and also troubled our Neanderthal cousins.

The preserved cold virus is "the oldest virus in humans yet", says Sofie Holtsmark Nielsen, who carried out the work at the University of Copenhagen in Denmark. She and her colleagues studied two fragmented milk teeth that were excavated at Yana in north-east Siberia. The teeth are 31,600 years old, making them the oldest human remains found so far north. Two years ago, a team led by Martin Sikora, also at the University of Copenhagen, got human DNA from the teeth.

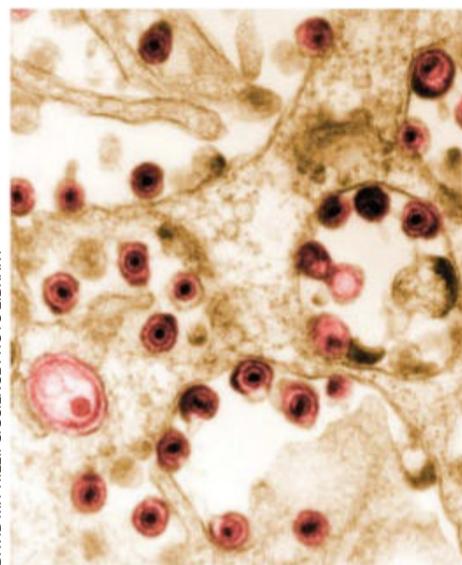
Holtsmark Nielsen has now revisited the DNA from the teeth to look for genes from infectious organisms. She found low-quality DNA from four species of herpesvirus. These included

herpes simplex, the virus that causes cold sores.

Her team also recovered two high-quality genomes of human adenovirus C, which is a common infection today. "Pretty much everyone has been infected with it," says Holtsmark Nielsen. "It's usually a bit like a cold."

Previously, the oldest direct evidence of an identifiable virus infecting a human was from just

A colourised image of human cells infected with the herpes simplex virus



DAVID M. PHILLIPS/SCIENCE PHOTO LIBRARY

7000 years ago: researchers found that hepatitis B has been infecting Europeans for at least that long. It has also been possible to identify bacterial infections from within the past 10,000 years, after the advent of farming, but not from earlier periods.

"It's really a remarkable technical accomplishment to be able to extract this kind of information from material that is that old," says Caitlin Pepperell at the University of Wisconsin-Madison. However, she says it isn't clear that the ancient viruses only caused mild illnesses, as even today adenovirus and herpesvirus can cause serious illness.

The researchers also estimated when adenovirus C first began infecting humans. To do so, they compared the ancient viral DNA with that of modern strains of the virus, and estimated how long ago their shared ancestor lived. It turned out that the shared ancestor of all the adenovirus C samples lived between 487,000 and 963,000 years ago, with a best estimate of 702,000 years ago (bioRxiv, doi.org/gmjh).

That is long before the origin of our species, *Homo sapiens*, the oldest known remains of which are between 250,000 and 350,000 years old. Before our species arose, other hominins like *Homo erectus* lived in Africa and Eurasia. Between 400,000 and 800,000 years ago, an unidentified ancestral group gave rise to three largely distinct populations: our species, the Neanderthals who lived in Europe and western Asia and the Denisovans who lived in eastern Asia.

"This particular adenovirus C... has probably been around as long as humans in the broad sense were around, including Neanderthals, including *sapiens*, including probably *erectus* before us," says Sikora. "The conclusion suggests that these viruses almost certainly have been around even before the emergence of modern humans in some way, and have been infecting us since then."

But Pepperell is sceptical. "The signal gets scrambled when organisms reshuffle their DNA, when they recombine," she says – and adenovirus C does that a lot. ■

Solar sail spacecraft could intercept interstellar objects

TO DATE, astronomers have spotted one asteroid and one comet visiting our planetary neighbourhood from other star systems. In both cases, though, we have only been able to get long-range views of these rare interstellar wanderers as they whip past during fleeting encounters.

Now a group of scientists in the US is looking at using a solar sailing spacecraft to chase down and examine similar objects when they

appear in the future. Such a probe would be pushed through space by the pressure of the sun's light acting on large, metal-coated sails unfurled from the body of the craft.

The team's concept envisages a 50-kilogram spacecraft with six sails spanning some 4000 square metres in total. Once launched, the probe would dive in close to the sun, using our star's searing glow to whisk itself out into the solar system at tremendous speeds.

"With the current sail materials, we can approach the sun to about 22 to 23 solar radii [15 to 16 million kilometres]," says team

member Slava Turyshev at NASA's Jet Propulsion Laboratory in California. Getting that close to our star could enable the craft to reach velocities as high as 170,000 to 260,000 kilometres per hour (arxiv.org/abs/2106.14319).

Achieving those speeds would be vital for intercepting interstellar objects, which have typically hurtled through our cosmic backyard at around 6 or 7 astronomical units

"Once launched, the probe would use our star's searing glow to whisk itself out into the solar system"

per year – 1 astronomical unit being the average distance between the sun and Earth (about 150 million kilometres).

"The architecture proposed is certainly ambitious and technologically challenging, but I think it is feasible," says Matteo Ceriotti at the University of Glasgow, UK.

The spacecraft could "absolutely" visit the approaching Oort cloud object Comet Bernardinelli-Bernstein spotted last month, too, says Turyshev. "We are ready to go. Basically everything's here." ■ Will Gater

Stem cells

Mini-heart grown in the lab pumps fluid like the real thing

Claire Ainsworth

STEM cells have been used to grow an embryonic-like “heart” that can pump fluid around a system of tiny channels on a laboratory slide.

The mini-heart could allow us to explore how physical forces, such as blood flow, shape the early stages of human heart development and give new insights into congenital heart defects.

Current efforts to grow human heart tissue involve coaxing human stem cells to form spheres of heart tissue, known as organoids. While these offer invaluable insights, they don’t accurately mimic the shape of the heart, which, in the earliest stages of its development, looks like a simple, straight tube.

“If we really want to model organ function, we need to figure out how to make these things in the form of tubes,” says David Sachs at the Icahn School of Medicine at Mount Sinai, New York.

He and his colleagues seeded human stem cells, known as induced pluripotent stem cells, onto a plastic plate containing tiny wells connected by hair-thin channels. By applying different combinations of chemical signals, they were able to get the cells to form tubes made of human heart muscle.

The heart tubes pumped fluid around the channels, Sachs told the International Society for Stem Cell Research’s 2021 meeting, held virtually last month.

“This is really the very early chapters in the book. But it does set the stage for doing lots of other stuff in the future,” says Christine Mummery at Leiden University Medical Center in the Netherlands.

The researchers aim to grow a mature mini-heart to investigate heart disease and test drugs. They also plan to send it to the International Space Station to help us understand why some astronauts working in microgravity develop cardiovascular problems. ■

Technology

New type of digital image could slash global data use

Matthew Sparkes

IMPROVEMENTS to the ubiquitous JPEG image format used across the internet will bring global bandwidth savings of 30 per cent, say the creators of the new technology, who have given it away for others to use royalty free.

JPEG is a method to compress digital photographs so that they can be stored using less data. Its arrival in the 1990s kick-started the proliferation of images across the internet, although the technology behind it dates back to work done in the 1980s. The updated version called JPEG XL reduces file sizes from the current format by 50 per cent and improves image quality.

António Pinheiro at the University of Beira Interior in Portugal, one of the team involved who also works on the Joint Photographic Experts Group that manages the JPEG standards, says the original file type is ageing technology and that the new standard represents the state of the art in data compression.

With JPEG XL you will be able to convert old JPEGs without losing any quality, but reduce the file size by at least 15 per cent, while photos taken in the new format will need less than half the current data in some cases.

Although hard disc capacity, memory chips and internet speeds have all improved dramatically since the introduction of the original JPEG standard, compression is still required or the time needed to transfer images online quickly bloats to an unusable extent, says Pinheiro.

JPEG XL will still be able to scale the compression up or down to taste, including an option for lossless images,



which ensures full data is available – something that is often requested by scientists and medical professionals.

“Sometimes in some kinds of medical imaging or astronomy we cannot lose the texture, because professionals can use those textures to extract information, although we can’t see it,” says Pinheiro. “They can detect these patterns because

30%

The amount of bandwidth JPEG XL could save worldwide

they are trained to detect them. If you compress an image, bad diagnosis can happen.”

JPEG XL will also support new features to future-proof it for decades, such as allowing images of more than a billion pixels, animation and encoding that doesn’t require specialised hardware. The team behind the standard hopes that it will replace JPEG, PNG and GIF to become a universal image format for the web.

In the case of JPEG XL, much of the technology can be traced back to work by US firms Google and Cloudinary, and they have given away the rights to it so

Images make up a large proportion of the web

that it can be used for free.

Jon Sneyers at Cloudinary, also part of the XL project, says that a 50 per cent reduction in file size from current JPEG standards is possible and that current web pages devote up to 60 per cent of data to images, meaning that up to 25 to 30 per cent of the world’s bandwidth requirements could be cut.

“For something like Facebook or Google Photos, which basically archives everybody’s photos, it’s a huge deal,” he says. “There’s trillions of images and photos getting created every year now.”

Sneyers says that adoption is almost a political issue, as some companies may have their own file formats, which are subject to royalties, that they would like to see adopted as standards, and that very few software packages currently support the use of JPEG XL.

“Once we have support in at least a big chunk of the [internet] browsers, companies like Facebook will probably start deploying quite quickly and others will follow,” he says. ■

“We didn’t hold back”

The women who developed the Oxford/AstraZeneca vaccine tell **Clare Wilson** what went on behind the scenes to create a covid-19 vaccine that has saved thousands of lives

THE Oxford/AstraZeneca vaccine has been vital for fighting covid-19 in the UK and many low-income countries. The unprecedented speed of its manufacture was only possible because the technology underpinning it had been in development for years before the pandemic struck, by scientists at the University of Oxford.

The research was co-led by Sarah Gilbert, working alongside a team including Teresa Lambe, who co-designed the vaccine’s genetic code, and Catherine Green, who led the manufacturing of the first batches of vaccine used in trials. The trio spoke to *New Scientist* about the rollercoaster of events that have occurred over the past 18 months.

Clare Wilson: Before the pandemic began, which diseases were this type of vaccine being developed against?

Teresa Lambe: In 2013, there was an Ebola outbreak. After that, the World Health Organization and a number of bodies put together a hit-list of viruses that they wanted vaccines against. We tried to make vaccines against all of those: Ebola, Zika, Crimean-Congo haemorrhagic fever, Nipah virus, Lassa virus and Middle East Respiratory Syndrome (MERS).

On the list of pathogens of concern, there was also “Disease X” – the unknown. We always knew we had to have something that we could go quickly with. And that was our ChAdOx1 adenovirus platform [that was eventually used for the Oxford/AstraZeneca covid-19 vaccine].

When did you realise you might need to make a vaccine against covid-19?

TL: I’ve got a brother in China, so I started to follow tweets around a virus that was transmitting in



JOHN CAIRNS

Teresa Lambe is an associate professor at the University of Oxford. Lambe co-designed the Oxford/AstraZeneca vaccine’s genetic code.

China. I thought it was probably going to be influenza; that’s where I would have put my money on. Then its identity became known in early January [2020]. Because we had the mechanisms in place, we decided to press the accelerator and go.

How fast did you act?

TL: The DNA sequence arrived in my inbox quite late Friday night on 10 January [2020]. You have to order the DNA for your antigen. Myself and a colleague spent most of the weekend using the

“I remember coming home on the day the first person got vaccinated and feeling slightly overwhelmed”

information that we’d received to design the last piece of the puzzle to make the vaccine. On Monday, we were ready to order it. There was dialogue about whether we should pay for expedited delivery. It was a minuscule amount in the grand scheme of things. In the end, we went for the faster delivery.

Sarah Gilbert: We were interested in how quickly we might be able to make a vaccine against a brand-



Sarah Gilbert is a professor of vaccinology at the University of Oxford. Gilbert co-led the Oxford/AstraZeneca vaccine’s development.

new pathogen, understanding that it might turn out to be an intellectual exercise. I spent a huge amount of time during those increasingly strange weeks attempting to secure funding. We decided we just had to get on with it, spending money we did not yet have. It would be an understatement to say things escalated fast.

Vaccine sceptics say you went too fast.

SG: We were taking financial risks, we were never taking safety risks. In normal times, we would wait for data to come before we start the next step. The difference was, last year, we started each part of the work at the earliest possible opportunity, knowing that if the work that had gone before didn’t turn out as we had hoped, we might have to just scrap something and go back and start again.

How did working so hard affect you?

TL: We didn’t hold back. People didn’t take breaks, we were working long hours – 12, 14-hour days – people worked at weekends. I have two children and there were periods over the last year where



Catherine Green is an associate professor at the University of Oxford. Green led clinical trial manufacturing of the Oxford/AstraZeneca vaccine.

they would call me Dad because they were so used to saying Dad instead of Mum. But I wanted to make a vaccine and I wanted to make it fast. I didn’t know if we needed it or not, but if we did, I wanted us to be in the best position we could be in.

Did you feel nervous when the vaccine was given to the first volunteers?

TL: It felt surreal. It was in April during the first lockdown and I was still coming into work every day, unlike a lot of other individuals. My walk to work was very, very quiet because there was no traffic on the road. I remember coming home on the day the first person got vaccinated and being slightly overwhelmed.

Catherine Green: For us, the big day was the day before when we certified the batch. The trial had been planned to the minute like a military operation. We were waiting for the final results to come back [to make sure] that it’s good enough to go into people. We were waiting and waiting and waiting. The test results came back that it had got the all clear. So we had a “Phew!”.



How did you feel when the positive results were announced that led to approval?

TL: When I was told the results by the lead statistician – she’s very diligent and she was [slowly] bringing me through the results – I made her stop and tell me whether we had efficacy or not. Then she went back to bring me through all the different nuances, and it didn’t go in. I was very, very happy.

SG: I was confident we would get a good immune response to the vaccine because we’d already done clinical trials with a vaccine against MERS made in the same way given at the same dose. But what nobody knew was how strong that immune response had to be to protect people against coronavirus. Now, with the real-world effectiveness data coming out, there’s a lot more information about the really high levels of protection from the vaccines against hospitalisation. That’s what really matters.

CG: I think the real-world efficacy, for me, has been the one that hits home. I think the estimation last week for England was 27,000 deaths prevented by the vaccination programme since the beginning of the year, and that’s 27,000 people’s grandmas and grandads still with them. That’s huge. For me, that’s been the data that was emotional.

How did you feel when the rare blood-clotting side effect emerged?

TL: With any medicine or any vaccine, you will get rare side effects. Because they’re so rare, they’re not necessarily going to [be revealed] even in trials the size of the one that we’ve done, which was over 20,000 individuals. We

need to delineate what is causing the rare side effects, and that hasn’t been fully delineated.

SG: Because it’s so rare, it makes it difficult to understand what’s really going on, whether the events were happening above the background rate. At one time, Europe was reporting that it was a phenomenon happening in women and not in men. That turned out to be because they were vaccinating predominantly women. The Joint Committee for Vaccination and Immunisation has been continually monitoring the situation and making its risk-benefit analyses, which change as the situation changes. We still have many countries with high rates of transmission that really need vaccines. They need to do their own risk-benefit analysis.

Was it hard seeing this risk emerge?

TL: There have been lots of very hard parts throughout this whole journey. We’ve been living in somewhat of a goldfish bowl for the last year and a half. At times, that has been difficult to deal with. And when there were false news reports around the death of our first vaccine trial volunteer [who was in fact alive and well].

CG: I was really disgusted by

that, because that’s somebody’s family. I don’t know what the motivation is behind the person that would make that claim and circulate it.

What can we learn from the past year?

SG: For outbreaks and pandemics, we need to have access to flexible funding so if something like this happens again, we’re able to go through all the process without having to spend a lot of time trying to raise the money to do it. And we haven’t had infrastructure investment.

92%

The Oxford/AstraZeneca vaccine’s efficacy against hospitalisation from the delta variant after two doses

Catherine runs an excellent, very small, frankly rather old-fashioned manufacturing facility. It does a great job, but it can’t produce very much vaccine. If we’d had an expanded and modernised clinical biomanufacturing facility, our lives would have been so much easier in 2020.

What are you doing now?

SG: We’ve been working closely

with AstraZeneca to optimise the pipeline for making new vaccines against variant viruses. We started months ago, getting all that set up again, not knowing if we’re going to need to switch. But again, we have to do the work so that if we do need to switch, we can. If we don’t do the work, we don’t have the opportunity.

The clinical trial of the beta variant vaccine has started, in Oxford and other parts of the world. And we’re trying to go back to work we were doing before the pandemic on vaccines against other diseases.

Green: Those other diseases haven’t gone away.

Have you had the Oxford/AstraZeneca vaccine yourself?

SG: Yes.

CG: I had it at a football stadium. That was a marvel of organisation and volunteers and of people feeling that this might be the beginning of the light at the end of the tunnel. I did say: “I’m so proud because I made that.”

TL: I haven’t told anyone which vaccine I’ve had. I recommend anyone to take whatever vaccine they are offered, in line with whatever their government is suggesting. My parents have had two different vaccines – but the fact that they’ve been able to have any vaccine is huge.

I’ve had your vaccine. Thank you.

SG: You’re welcome. ■

This article is based on an interview with Lambe and a separate interview with Gilbert and Green.

Gilbert and Green’s book Vaxxers: The inside story of the Oxford AstraZeneca vaccine and the race against the virus (Hodder & Stoughton) is out now.



PUNIT PARANJPE/AFP VIA GETTY IMAGES

Production of the Oxford/AstraZeneca covid-19 vaccine in Pune, India

Genetics

How male seahorses get pregnant

A genetic analysis has found seahorses are missing key genes – and reveals a new mystery

Christa Lesté-Lasserre

A MISSING or dysfunctional part of the vertebrate immune system might explain why male seahorses and pipefishes can carry a pregnancy – and could possibly inspire novel treatments for immune-related diseases in humans and other animals.

Olivia Roth at the GEOMAR Helmholtz Centre for Ocean Research in Kiel, Germany, wanted to understand how seahorses and their relatives – members of the Syngnathidae fish family – became the only animals in the world known to have developed biological male pregnancy. So she and her colleagues sequenced the full genomes of 12 species of syngnathids, including some pipefish species in which males don't actually become pregnant but instead carry fertilised eggs outside the body.

They found that certain major histocompatibility complex (MHC) genes involved in the immune system – such as MHC-2 genes, which have long been considered critical for recognising viruses, bacteria and other invaders – were either inactivated

or missing in the species in which males become pregnant, but not in those where eggs are deposited into the water or are carried by the male outside the body.

The findings make some sense because active MHC-2 genes would make a pregnant male's body attack embryos as invaders, says Roth, who presented her research at the SyngBio 2021 meeting in Guangzhou, China, in May.

In seahorses and some of their relatives, males carry the pregnancy

But the results also create a mystery. Seahorses and their relatives thrive in “an ocean of microbes”, according to Roth. Some do so despite having inactive or absent MHC-2 genes.

Roth says this suggests that other animals with a backbone, including humans, could successfully fight off infections when MHC-2 pathway activity is hampered – for instance, by HIV infection.

“We used to think all vertebrates had [a] set immune system pathway, but now it seems that

a lot more flexibility is possible,” she says. “For immunology, this is really revolutionising because, potentially, we could activate different pathways of the immune system.”

In other vertebrates, the pregnant female's body temporarily downregulates MHC-2 gene function during early pregnancy, but only in the cells that touch the embryo, says team member Jamie Parker, also at GEOMAR.

Roth says that if scientists could tap into the “immune system secrets” of seahorses and understand how they survive without MHC-2 genes, this might lead to new therapies for diseases.

Christian Freund at the Free University of Berlin in Germany says the research is “very interesting”, but that it is too early to think about therapies.

“Maybe [these fish] live in an ecological niche that makes MHC-2 dispensable, but that doesn't necessarily mean it's dispensable for mammals living in quite a different environment,” he says. ■



TONY WU/NATUREPL

Archaeology

Early farmers in the Atacama desert were brutally violent

WHEN coastal hunter-gatherers settled inland to begin farming about 3000 years ago in the Atacama desert, their violence grew more gruesome, according to human remains from the time.

Vivien Standen at the University of Tarapacá in Chile and her colleagues studied the remains of 194 adults buried between 2800 and 1400 years ago in a coastal desert valley of northern Chile.

The team found that 40 individuals were subjected to brutal levels of violence, 20 of whom died from their injuries.

Some bodies still had soft tissue, preserved by the arid desert environment, which offered insight into injuries. One woman appeared to have sustained a torturous and bizarre attack, her chin's skin being stretched to cover her mouth, while her top lip covered her nostrils.

Distinctive tattoos and analysis of strontium isotopes in her teeth – which can reveal where people lived because the ratio of isotopes to each other changes

based on what they eat and drink – indicated she may have been an outsider from southern Peru.

All other people from the group subjected to violence, however, were local. Three people were buried naked in a pit without usual funerary offerings. Their skulls were smashed, probably by a stone mace. Strontium analyses indicated they ate seafood, suggesting they were hunter-gatherers from the nearby

“All evidence points to the same conclusion: local people fighting over limited resources”

coast attacked by farmers (*Journal of Anthropological Archaeology*, doi.org/gmbn). Most violence occurred when cultivation started, tailing off as farming communities became more established.

“This region is one of the driest deserts in the world and thus offers very restricted water sources and fertile lands,” says Tom Dillehay at Vanderbilt University in Nashville, Tennessee. “All evidence, whether skeletal, rock art, isotopic or weaponry, points to the same conclusion: local people fighting over limited resources.” ■

James Urquhart

Evolution

Common aquarium fish could help reveal how teeth evolved

Claire Ainsworth

A PET fish adorned with tooth-like scales is helping biologists tackle a long-standing debate about the origin of teeth, and explore how body structures can be lost and regained during evolution.

The suckermouth armoured catfish is commonly found in pet shops and, unusually for a bony fish, has tooth-like structures called odontodes covering its skin. These physically resemble teeth, erupting from thickened patches of skin to form layered structures of pulp, dentine and enamel, and similar genes appear to be active in these and in teeth during development.

But which evolved first, and how did tissues gain or regain such traits?

The evolutionary history is complicated, because while ancient fish had similar structures, they were lost in most bony fish, but retained in those with cartilage-based skeletons, like sharks. They re-emerged again independently in four different bony fish groups, including armoured catfish.

Now Shunsuke Mori and Tetsuya Nakamura at Rutgers, the State University of New Jersey, have analysed gene activity in developing suckermouth armoured catfish skin odontodes. They uncovered a network of genes very similar to those found in developing teeth. "Most of the genes are shared," says Nakamura.

One of these genes, *pitx2*, is needed for the first steps of tooth development, yet is absent from the skin odontodes of sharks. When Mori and Nakamura used gene silencing techniques to reduce the activity of *pitx2* in the catfish, the odontodes didn't develop properly (bioRxiv, doi.org/gk94).

This showed the gene is needed for catfish skin odontode development, suggesting that evolution had redeployed the tooth genes to recreate skin odontodes in the catfish. ■

Technology

AI-guided combat drone swarm used in Gaza attacks

David Hambling



DURING operations in Gaza in mid-May, the Israel Defense Forces (IDF) reportedly used a swarm of small drones to locate, identify and attack Hamas militants. This is thought to be the first time a drone swarm has been used in combat.

Drones are usually controlled individually by remote operators, but a swarm is a single networked entity that flies itself using artificial intelligence. It can cover a wide area and keep operating even if it loses many units, and only requires a single human operator to direct it at targets.

An IDF Paratroopers Brigade support unit used the swarm to target Hamas militants who had been firing rockets into Israel, an IDF spokesperson told *New Scientist*. "The swarm was utilised in the combat area, in which there were many rockets launched into Israeli territory. As far as we know, this is the first use of this type of tool." Hamas didn't respond to a request for comment.

The drones were supplied by Elbit Systems, according to local media reports. The IDF spokesperson didn't confirm this, saying only that standard

drones were used in the swarm. Elbit Systems produces Thor, a 9-kilogram quadrotor drone that is reportedly almost silent, along with other specialist drones that can land and provide persistent observation or deliver explosives.

"The operation of the swarm is by a single operator who controls all the drones, there

"A handful of swarming drones is probably not a big risk, but what about 10,000?"

is a commander next to him for making significant decisions," says the IDF spokesperson.

The drone swarm gathered intelligence, located targets and carried out attacks on Hamas forces, as well as providing targeting information for guided mortar weapons, according to the IDF spokesperson.

An IDF commander quoted in local media claimed that the first attack struck Hamas rocket launcher equipment hidden in an olive grove. The commander said that the swarm unit carried out more than 30 successful operations, some against targets many kilometres

Drones used by the Israel Defense Forces that work in a swarm

from the Gaza-Israel border.

"The reports suggest the IDF is the first military to field an operational drone swarm," says analyst Zak Kallenborn at the National Consortium for the Study of Terrorism and Responses to Terrorism in Maryland. "However, without knowing more specific details about the drone swarm's capabilities, it's tough to gauge how significant or worrisome the achievement is."

Arthur Holland at the United Nations Institute for Disarmament Research in Geneva, Switzerland, agrees that this is potentially significant.

"The systems used in this case probably fall quite far short of the large, dynamic, intelligent swarms that could someday have a highly disruptive effect on warfare," he says. "But if confirmed, they are certainly a notch up in the incremental growth of autonomy and machine-to-machine collaboration in warfare."

The concern is that larger, more capable and more autonomous swarms will inevitably follow. Many other nations, including the US and China, are also working on swarms of small armed drones.

"A handful of swarming drones is probably not a big risk, but what about 10,000? We may be looking at the emergence of a new weapon of mass destruction," says Kallenborn.

The IDF is planning to expand its drone operations. "There is a plan to equip the various land units with additional swarms," says the IDF spokesperson. ■

An end to 'surveillance capitalism'? Internet giants are talking about tightening up online privacy, but these moves aren't just about the customers, writes **Matthew Sparkes**

ONLINE privacy is getting a shake-up. Some of the world's largest technology firms are starting to offer a new type of privacy on their platforms. It will appease some customers' concerns around online advertising, but shouldn't be to the detriment of the companies.

Last month, Apple announced that it will offer a form of anonymous browsing in which third parties will no longer be able to track you from website to website and build an archive of your habits, preferences and circumstances – as long as you are willing to pay a monthly fee.

The firm had already begun warning its customers how each app was tracking them and asking whether they wanted to allow it in April. Many companies reliant on tracking for revenue were less than keen on the policy, and it is understandable when you consider the size of the online advertising industry. Google and Facebook, which dominate this market, brought in about \$182 billion and \$86 billion dollars of revenue respectively last year.

While neither Facebook nor Apple has released data on how Facebook app users chose when they were prompted, it is safe to assume that at least a subset of them decided to cut Facebook out of the loop – and some reports at the time suggested 80 per cent would opt out.

Facebook declined a request to comment on this story, but said in a blog post that the move was “more about profit than privacy” and was aimed at pushing app developers towards Apple's own advertising products.

Google, too, is working on measures that it says are protection for customers. The company has pledged to stop supporting cookies – tiny files left on your computer to track your browsing –

and replace them with its Privacy Sandbox (though the move has been delayed until 2023).

The Privacy Sandbox platform will allow the same tracking to take place, but only Google will see the data. The firm's paying advertisers will then be able to target you based on that data, but not identify you. You will be hidden among a group of other people who, say, live in London, enjoy cycling and have cats. Facebook's advertising works in a similar way, although it has led to embarrassing scandals in the past where third parties were able to access sensitive customer data.

“Instead of sharing (or making it possible for advertisers to reconstruct) your browsing history, what Chrome [Google's web browser] has done instead is try to put you in a cohort of tens or thousands of other people [with the same habits or circumstances],” says Jochen Eisinger at Google.

Many people are increasingly uncomfortable with the extent to which they are tracked, analysed and marketed to. A survey last year revealed that 64 per cent of people clear their cookies and browser

Online privacy is becoming a big issue for internet users



YUICHIRO CHINO/GETTY IMAGES

history and 41 per cent turn off cookies in their browser, but many people don't have the technical knowledge to take those steps.

Any timely and insightful adverts you may have seen online highlight just how extensive and accurate these personal profiles are. For example, one woman who had a miscarriage later discovered that Facebook's algorithms had deduced she was pregnant and were unthinkingly serving her adverts for baby products. So the move by

\$182bn

The amount of ad revenue Google brought in last year

internet giants to improve privacy is certainly understandable. But how substantive are the changes?

Bruce Schneier at Harvard University is sceptical that the moves are genuinely going to make a difference. “I think anything that tries to add privacy is largely a PR move. Every app spies on you,” he says.

William Budington at digital rights group Electronic Frontier Foundation agrees with the old adage that if you aren't paying for the product, you are the product. We are able to have

free email, social media and video platforms because advertising – made efficient by personal data collection – supports them.

Apple is the exception to the rule, says Budington, as most of its income is made by selling expensive devices. Its privacy features seem to be the strongest of all – but there is a catch, in that they are only available to those who can afford them. This risks a future of privacy haves and have-nots. Apple declined a request to comment on this story.

Budington says that people can take steps to protect themselves and that a little bit of effort can go a long way. A simple ad blocker can stop 90 per cent of the tracking that goes on online, he says. But even without cookies and with an ad blocker, there are ways to track you.

Fingerprinting, for example, is a technique that takes advantage of the dozens of little bits of information that your browser gives to websites to make sure they display and work properly: the resolution of your screen, the type of browser and computer, what time zone you are in and so on. Together, they allow companies to track you with surprising accuracy.

There are tentative signs that new restrictions on harvesting data could be introduced. The EU has put forward draft legislation called the Digital Services Act, which wouldn't stop firms gathering data but would force them to explain how they are using it to serve you adverts.

The Biden administration in the US could pass proposed legislation that, again, wouldn't prevent companies collecting data, but would give citizens the right to ask for it to be deleted. In the UK, a new body called the Digital Markets Unit is being set up to investigate issues in the technology industry, but no firm policy has been put forward yet. ■

Plants

A rare specimen

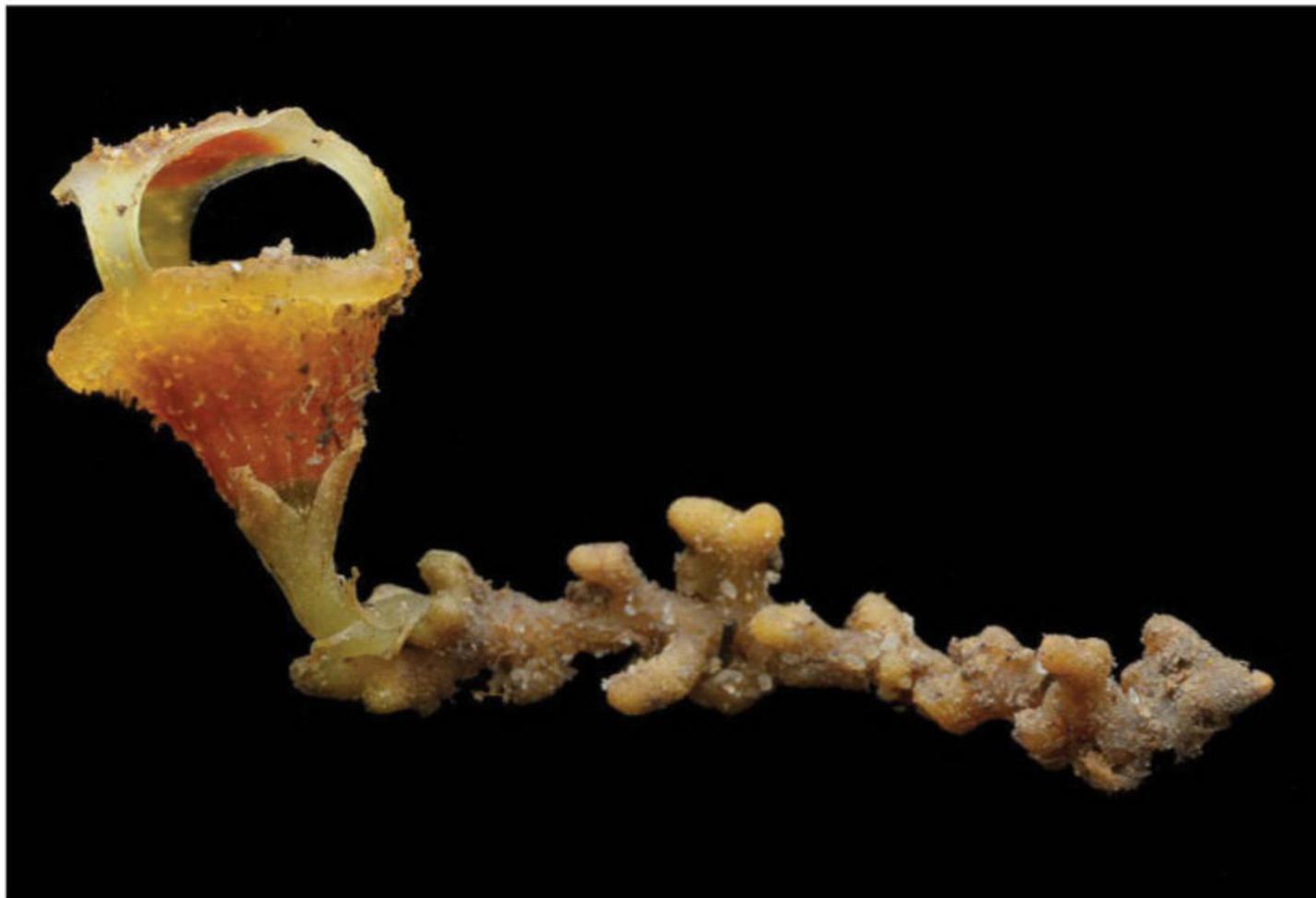
Strange new fairy lantern plant is already critically endangered

Adam Vaughan

THIS bizarre-shaped plant from a Malaysian rainforest appears to be so vanishingly rare it should already be considered critically endangered. It was found near a mountain trail by Nikong Dome, who lives with Indigenous communities in the rainforests of Terengganu state.

The discovery was “completely unexpected and astonishing”, says Chris Thorogood at the University of Oxford. Named *Thismia sitimeriamiae*, the plant belongs to a strange group called fairy lanterns. Around 25 new species of the group have been discovered in the past five years, from Asia to the US (*PhytoKeys*, doi.org/gk9v).

Thismia sitimeriamiae remains elusive in the wild. It only flowers briefly before withering, and the original plant’s home was later found destroyed by wild boars, with only a single specimen discovered each time on two subsequent visits to the area. ■



UNIVERSITY OF OXFORD



Animal behaviour

Beetle walks on underside of water’s surface

IT ISN’T a circus trick. An Australian beetle has been seen walking upside down in a pool of water, on the underside of the surface. Researchers think this is a style of locomotion that has never been recorded before in an animal with legs.

John Gould at the University of Newcastle in Australia came across the beetle (in the family Hydrophilidae) by chance while searching for tadpoles during fieldwork in the Watagan mountains in Australia. He quickly pulled out his phone to film it. “To see something walk along the underside of the water’s surface as if it was just any regular solid was pretty incredible,” he says.

Certain beetles’ ability to walk on the underside of water has been mentioned a handful of times in scientific papers, but has never been described or captured on video before.

Aquatic beetles are known to carry a bubble as a temporary oxygen supply when they venture underwater to lay eggs or search for food. But air bubbles can have another role too. Diving insects called backswimmers, for example, use it to achieve buoyancy in a water column, allowing them to remain in the same position without having to swim continuously.

Jose Valdez, a researcher at the German Centre for Integrative



JOHN GOULD

This beetle (in the family Hydrophilidae) is walking upside down on the underside of water

Biodiversity Research in Leipzig, who studied the upside-down beetle with Gould, thinks that this air bubble on the Australian beetle’s abdomen is used in a similar way and is key to the inverted water-walking. The bubble helps the beetle attach itself to the underside of the water (*Ethology*, doi.org/gk95).

It is rare for animals to move

on water’s undersurface, but it isn’t unheard of. Freshwater snails of the kind found in home aquariums can do so. Research suggests that such snails push themselves forwards on the underside of the water with their foot by creating pressure differences in a film of mucus on top of it. However, the beetle is the only known animal with legs to walk this way.

This style of locomotion could help conceal the beetles, allowing them to hide from predators both above and below the water’s surface. “It could also help them avoid detection when hunting prey underwater,” says Valdez. ■ **Sandrine Ceurstemont**



MAREK RYBARJALAMY

Geology

Welcome to Icelandia, a possible new continent

ICELAND could be the only exposed part of an entire continent, dubbed Icelandia, that is mostly submerged beneath the Atlantic Ocean.

Gillian Foulger at Durham University in the UK and her team have published the idea in the book *Footsteps of Warren B. Hamilton: New ideas in Earth science*.

Iceland (pictured) lies on the Mid-Atlantic ridge, where two tectonic plates are slowly moving apart. Magma wells up along the ridge, before cooling and solidifying into rock, forming more seabed.

Earth's outer layer, the crust, is typically thinner – about 6 to 7 kilometres – under the oceans than it is under continents, but Foulger says Iceland is an anomaly at 40 km thick. In general, geologists argue that this can be explained by the presence of a so-called geological

hotspot – an unusually hot region in the mantle under the crust that leads to greater volcanic activity.

But Foulger and her team have an alternative explanation. They argue instead that Iceland is made of continental crust and so are large areas of the surrounding seabed. This hidden continent of Icelandia, if it exists, has a surface area of 600,000 square kilometres.

Icelandia would be a relic of a time millions of years ago, when the continents that are now on opposite sides of the Atlantic Ocean were joined in a single supercontinent called Pangaea. The continents have since been pulled apart by the motion of the plates. However, Foulger thinks Icelandia is one chunk of Pangaeian continental crust that survived and now sits under Iceland. **Michael Marshall**

Archaeogenetics

Skull reveals oldest case of the plague

THE bacterium behind the Black Death, which wrought devastation in medieval times, has been found in the skull of a man who lived 5000 years ago in what is now Latvia, making it the earliest known plague strain.

Analysis of ancient DNA in the hunter-gatherer's skull suggests that the strain of *Yersinia pestis*, which causes the bubonic plague, was less transmissible and less harmful than later versions, says Ben Krause-Kyora at Kiel University, Germany, and his colleagues. The lack of the bacteria in three other people buried next to the man is one hint of a less deadly disease, says Krause-Kyora.

The apparent lower virulence leads the team to suggest that the plague wasn't to blame for the decline of European people between 5000 and 6000 years ago, as claimed by a 2018 paper

on Swedish farmers' genomes.

Nonetheless, the high abundance of the bacteria found in the skull of the man, who was probably aged between 20 and 30 when he died, implies he succumbed to the plague, says Krause-Kyora. The man may have been bitten by a rodent such as a beaver, which are known to carry *Y. pestis*. Remains of the animals have been found at the same site by the river Salaca in Latvia (*Cell Reports*, doi.org/gk97).

The evidence points to the plague spreading from animal to human at the time, rather than human to human, says Krause-Kyora. The bacteria hadn't yet gained the genetic mutation that enables fleas to carry it, and that allowed it to infect and kill so many people centuries later.

However, Simon Rasmussen at the University of Copenhagen, Denmark, says the evidence is weak for the claim that the plague was milder 5000 years ago.

Adam Vaughan

Space

Tiniest dwarf star may go out in a bang

THE smallest white dwarf star found is about the size of Earth's moon, but more massive than the sun. It may be shrinking, which could lead to a colossal explosion.

Ilaria Caiazzo at the California Institute of Technology and her colleagues discovered the star and found that it rotates very quickly, spinning once every 6.9 minutes. The magnetic field at its surface ranges between 600 and 900

megagauss – more than 1 billion times stronger than Earth's field.

The star, about 130 light years from Earth, has a radius of about 2140 kilometres, 400 km bigger than the moon. But it also has a mass about 1.3 times that of the sun, close to the limit for how massive white dwarfs can become. While most white dwarfs form from single stars at the ends of their lives, this one's high mass indicates that it may be the result of a merger of two white dwarfs.

Because of the extreme pressure at its core, the researchers say that a strange atomic process may take place there that turns protons into neutrons, allowing it to become even more compact.

"It's not only the smallest white dwarf ever found, it's also shrinking," said Caiazzo. "If this continues, it might collapse." That could result in either an extraordinarily dense neutron star or an explosion in the next few hundred million years (*Nature*, doi.org/gk96). **Leah Crane**



CALTECH

Really brief



Super atomic clock to be sent to Venus

An atomic clock 25 times more accurate than existing space clocks will soon be tested on a NASA mission to Venus. A version of the clock was tested in Earth orbit in 2019 to confirm its accuracy – which is essential for spacecraft to self-navigate rather than be guided from Earth (*Nature*, doi.org/gk92).

Dinosaurs declining before disaster hit

A new analysis of fossil data provides support for the idea that non-avian dinosaurs were already losing species diversity 10 million years before they vanished after an asteroid strike. Global cooling might have been a factor, the authors suggest (*Nature Communications*, doi.org/gk93).

Best ever view of odd auroras on Mars

The United Arab Emirates' Hope orbiter has captured the best images ever of scattered auroras on Mars. The planet had, but then lost, an Earth-like global magnetic field. Parts of its crust are still magnetic and produce localised auroras. Studying them may help us understand how Mars lost most of its atmosphere.

Biotechnology

Stomach of cows can digest plastic

ENZYMES made by bacteria in the stomach of cows can break down common plastics. The discovery could lead to new ways of dealing with such materials after use.

Georg Guebitz at the University of Natural Resources and Life Sciences in Austria and his colleagues visited a local slaughterhouse and collected samples of the liquid from one of the four parts of a young cow's stomach, the rumen. They

found that the liquid contained many types of enzymes, including cutinases.

The team demonstrated that these enzymes could break down three types of widely used polyesters – polyethylene terephthalate (PET), polybutylene adipate terephthalate (PBAT) and polyethylene furanoate (PEF), often used to make products such as bottles, textiles and bags. The enzymes degraded these plastics within one to three days when at a temperature of about 40°C to match that of a cow's stomach (*Frontiers in Bioengineering and*

Biotechnology, DOI: 10.3389/fbioe.2021.684459/full).

"We found that the diet of cows contains foods that have a 'shell' that is similar to polyesters," says Guebitz. This explains why the microbes within the rumen produce enzymes that can also deal with synthetic polyesters.

The enzymes could be used to break down polyesters on a larger, commercial scale, says Guebitz. However, some researchers are cautious about this idea, as the approach has yet to be proven better than existing enzyme technologies. **Krista Charles**

Palaeontology



Fossil dung reveals remains of ancient species of beetle

THERE is a new way to learn about ancient insects with the discovery that we can find fossilised beetles inside prehistoric animal droppings.

Martin Qvarnström at Uppsala University in Sweden and his colleagues made the discovery by scanning 230-million-year-old fossilised droppings, or coprolites, with synchrotron microtomography, which is similar to a CT scan. This revealed lots of beetle fragments and a few nearly whole beetles preserved in the droppings.

The beetles – the first to be described from ancient dung – belong to a new species, which the researchers have named *Triamyxa*

coprolithica. It was probably semiaquatic and had a convex body shape, says Qvarnström.

Previously, amber was the best source of well-preserved insects. But the earliest amber deposits formed about 140 million years ago early in the Cretaceous period, meaning we can't rely on amber to learn about beetle evolution before that.

These coprolites get around this, opening a window on an earlier period, the Triassic. The droppings with *T. coprolithica* probably came from *Silesaurus opolensis*, a reptilian dinosaur relative that ate beetles (*Current Biology*, doi.org/gk62) **KC**

Health

New malaria vaccine uses live parasites

A NEW kind of malaria vaccine involves injecting people with the malaria parasite, then a few days later giving them a medicine that kills the pathogens. Early trials have shown promising results.

Malaria is spread by mosquitoes that carry the parasite involved. An existing vaccine, Mosquirix, works by using a molecule found on the surface of the parasite.

Patrick Duffy at the US National Institutes of Health and his team tried an alternative: injecting people with the parasite, then quickly giving them a malaria medicine to prevent illness.

They tried two antimalarial drugs and different doses of the parasite in a "human challenge" study; volunteers were vaccinated then three months later exposed to the malaria parasite.

When the antimalarial pyrimethamine and a high vaccine dose of parasite was used, seven out of eight people avoided getting sick, if the same strain of parasite was used in the vaccine as for the later exposure. If a different strain was used, seven out of nine people were protected. Another antimalarial drug, chloroquine, protected six out of six people against a different strain (*Nature*, doi.org/gk7r). **Clare Wilson**

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The columnist

We need a new tech revolution, says **Annalee Newitz** **p25**

Aperture

The best Astronomy Photographer of the Year shots **p26**

Culture

The Surrogate explores a difficult dilemma **p28**

Culture columnist

Jacob Aron takes a gaming romp across the multiverse **p30**

Letters

The long arm of long covid-like symptoms **p31**

Language revamp needed

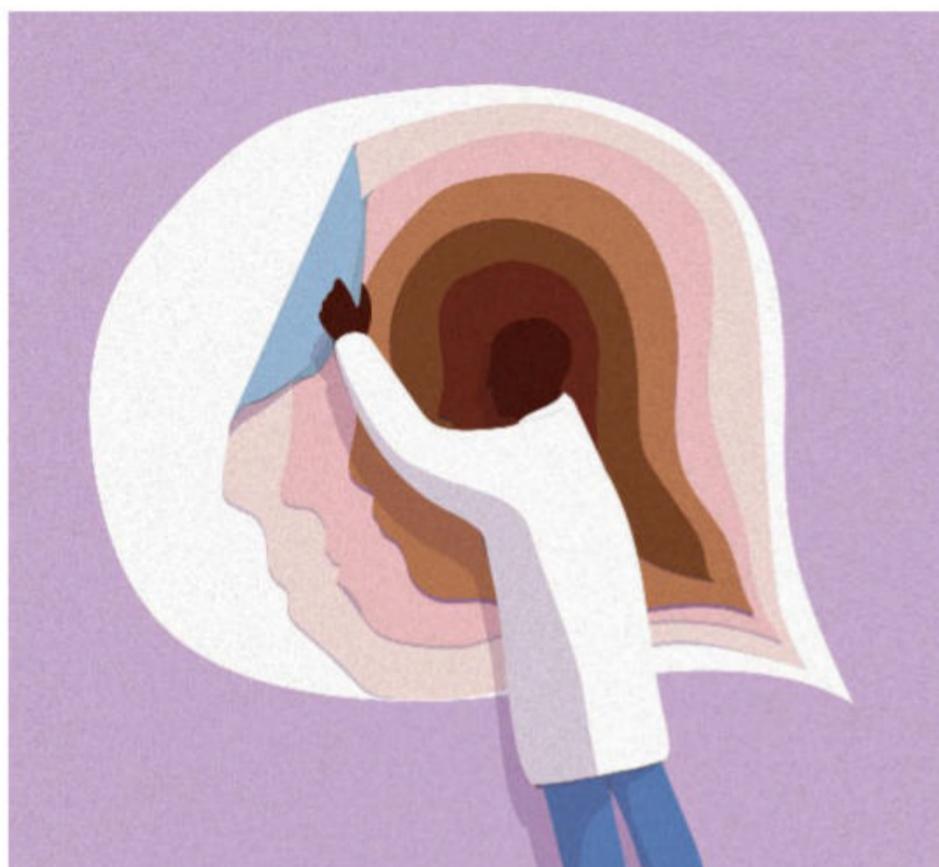
The terminology used in genetics needs a complete overhaul to break free from its problematic past, says **Adam Rutherford**

UNSHARED science is of little value. The whole scientific endeavour relies on ideas, methods and data being available to all. The words we use are vital to making sure that we are all on the same page and our ideas are conveyed accurately. But in my field of genetics, the language we use isn't up to scratch. Terms in common usage present problems ranging from being scientifically confused or ambiguous, to being rooted in a racist history that echoes in our present.

Every scientific discipline has its own jargon used to summarise or label the complexity of the world. And as our genome is the richest data set we have ever tackled, it is no surprise that human genetics is particularly burdened with terms that strive to encapsulate our ancestry and the secrets of our behaviour, evolution and disease.

Genetics is also a field with a pernicious history. Its origins are inextricably entwined with the 18th-century invention of race, then using pigmentation and skull measurements to hierarchically taxonomise people. With that came scientific racism marshalled into the justification of slavery and subjugation, and the eugenics projects of the early 20th century followed not far behind.

Contemporary genetics has unequivocally demolished the attempts to use ancestry, anatomy and genetics to assert a biological basis for race. Although people around the world differ, the genetics underlying those



differences doesn't correspond to the racial classification that we use today. "Black" – meaning people of recent African descent – covers more than a billion people with more genetic diversity than the rest of the world put together. From a genetic point of view, it isn't an informative term. Yet we use it. This is why we call race a "social construct" – race exists because we perceive it, but has no meaningful biological basis.

Nevertheless, the scientific language of the past resounds today. That is why I and colleagues in various fields of genetics are calling for a change in these language conventions, which, we argue, don't serve scientific

insight and shackle us to the prejudices of history.

Some examples are widespread. Caucasian, for example, is a word used today in official forms, public discourse and in many academic papers. Does it mean white European? Does it include people from south Asia or North Africa? Different definitions have included these populations and others. Furthermore, it was originally coined to indicate the "beauty" and "superiority" of white Europeans. It has no place in science today.

Other examples are arguably less prejudicial, but equally unsound. Bantu is often used to broadly describe people from

southern Africa with a shared linguistic heritage. Yet the diversity of dialects in more than 400 million people renders their grouping imprecise and not inherently meaningful. Even terms like "ethnicity" and "ancestry" have subtly different meanings when used in different fields and by different people.

In the genetics community, there is growing recognition that we have to change our language. The American Society of Human Genetics stated in 2018 that "the invocation of genetics to promote racist ideologies is one of many factors causing racism to persist".

Humans are all of one species, but people from around the world are different, and genetics reflects those regional adaptations and different evolutionary journeys. Grouping people is a necessary part of understanding similarities and differences in our DNA.

Our intention isn't to police language, but to prompt it to evolve. Some genetics terms should be consigned to the dustbin; others will require thought and discussion. Our hope is to spark a conversation for changing to a lexicon that better serves our understanding of human diversity, and simultaneously frees us from a troubling history. ■



Adam Rutherford is at University College London and is the author of *How to argue with a racist*

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This changes everything

The technologies of tomorrow We need a new information revolution, one that prepares us for a warming world with extreme weather, writes **Annalee Newitz**



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

Annalee's week

What I'm reading

R. U. Sirius's oral history of the original cyberpunk magazine, MONDO 2000.

What I'm watching

The brilliant show We Are Lady Parts, about a Muslim feminist punk band trying to make it in London.

What I'm working on

I'm researching the ways fandom is steering the future of pop culture.

This column appears monthly. Up next week: James Wong

AS I write this, it's 13°C and foggy in San Francisco. But 1000 kilometres north, in Portland, Oregon, it hit 47°C just days ago. Across the border in Canada, it reached 49°C. Coroners are blaming the heat for hundreds of deaths in the US and Canada. Climate experts are warning that it's only a matter of time before my region of the west is broiling under a "heat dome" (see page 10) – catalysing wildfires bigger than those that burned 1.7 million hectares in California last year.

Heat domes are statistically likely to become more intense and common every year due to climate change, just as hurricanes and flooding are. As the weather gets consistently weirder, it's becoming easier to accept that we live in a world that is rapidly changing – not because of the internet or some fantastic new scientific discovery. It's changing because of nature – or at least its reaction to us.

This realisation is especially weird for those of us who grew up learning that humanity tamed nature a long time ago, and that the future of our civilisations will be determined by technology. Now it seems that nature is getting the last laugh. Maybe our great industrial machines beat it back for a while, but unfortunately the fossil fuel we used to power those machines has given nature the upper hand again.

I keep thinking about one of the unexpected side effects of the heat dome in Portland, which is that it caused the city's streetcars to melt. To be more precise, as Robinson Meyer put it in *The Atlantic*: "A power cable on a major bridge warped, twisted around some metal hardware, and scorched. Elsewhere, the wires that run above the track expanded and sagged so much that they risked touching the train cars." By

afternoon, the city had shut down much of its transit system. To understand how truly staggering this scenario is, consider that Portland is famous for being damp and chilly. It's a northern, coastal city, full of people who don't own sunblock or air conditioners.

Now that's going to change. People in the Pacific Northwest, also home to cities like Seattle and Vancouver, are snapping up air conditioners. That means we can look forward to more strains on these cities' energy grids. At the same time, as the Portland trains show, electrical infrastructure isn't built to handle extreme

"One of the unexpected side effects of the heat dome is that it caused Portland's streetcars to melt"

temperatures. I can all-too-easily imagine a near future where wires are melting throughout a city, imperilling people's health, mobility and their access to information online.

Moments like these jump-start technological revolutions. Already, there are engineers at work trying to build air conditioners that are more efficient and don't depend on coolants made from greenhouse gases like hydrofluorocarbons. It's odd to imagine a world where climate controls on a building could be more life-changing than the internet. But that's where we are headed. We have to start thinking about innovation in the context of our real-life environment rather than the cyberworld we have built inside our computers.

It's not as if we are going to chuck away our mobile devices and the apps we use to show each

other the new dance moves we have taught our cats. Still, the next wave of the information revolution will need to focus on ways to get life-saving instructions to people in peril. Yes, that will inevitably involve some government regulation to stop misinformation from circulating. It's dangerous to have wild speculation about chemtrails zooming around when people need to know whether they should evacuate or how to get to cooling centres with fresh water.

Beyond that, we might need special devices for communicating with first responders when the network goes down. Of course, many vulnerable people will only have those technologies if a government or other public agency steps in to help.

That's why the next technological revolution will have to be political. To protect ourselves from nature – and to rebuild our infrastructure to be sustainable – we must invent new ways to create communities. I'm not talking about electing someone more progressive, or staging a coup. I'm talking about a political shift that transforms the world as much as trains did. Or as much as the internet is doing right now. Perhaps when this revolution is over, we will no longer have nations, and we will have invented new forms of democracy.

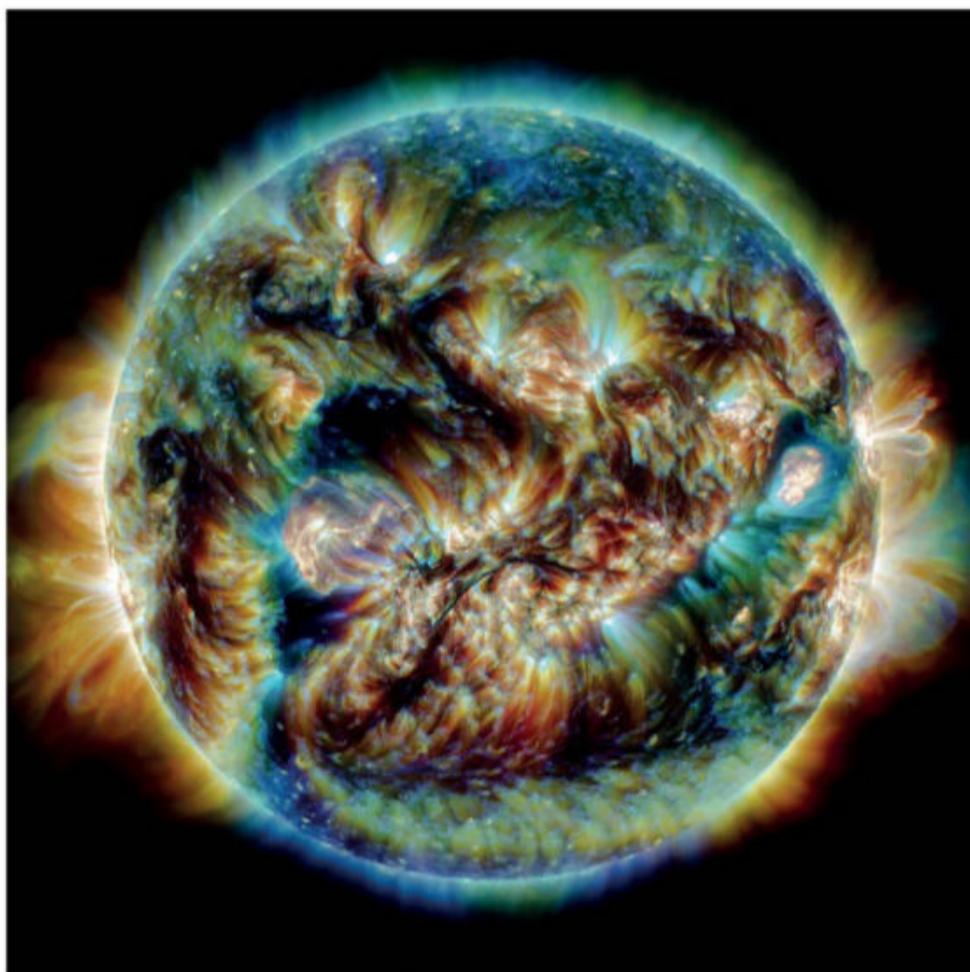
We can't save ourselves with machines alone, though green air conditioners are a good start. We are going to need social infrastructure to support us, to provide poor and marginalised people with the tools to survive what's coming. I no longer think of the future as a gleaming game world full of robots. Instead, I dream of a new social system – one where our greatest scientific innovations don't make us rich, but will help us survive catastrophe. ■

L-R: ICELAND VORTEX © LARRY RAE; MILKY WAY RISING OVER DURDLÉ DOOR © ANTHONY SULLIVAN



L-R: THE CAVE © MARKUS VAN HAUTEN; DOLPHIN HEAD NEBULA © YOVIN YAHATHUGODA; THE TUMULT OF THE SUN © HASSAN HATAMI





Stellar shots



THESE spellbinding images are among the shortlisted entries for the Astronomy Photographer of the Year 2021, organised by the Royal Observatory in London.

At top left, the aurora borealis is showcased in *Iceland Vortex* by Larryn Rae, who can be seen at the centre of the image. Rae's panoramic shot highlights the scale of this iconic light display, which is caused by charged particles colliding with atmospheric gases.

Anthony Sullivan's *Milky Way Rising Over Durdle Door* (top right) shows the Jurassic Coast World Heritage Site in Dorset, UK – famous for its bounty of ancient rocks and fossils – as illuminated by our galaxy. The two bright spots towards the left of the image are Jupiter and Saturn.

The aurora borealis features again in *The Cave* (bottom left), a composite image by Markus van Hauten, taken at Iceland's Breiðamerkurjökull glacier.

Dolphin Head Nebula (bottom centre) by Yovin Yahathugoda shows a giant interstellar cloud of gas and dust at the heart of the constellation Canis Major.

To create *The Tumult of the Sun* (bottom right), Hassan Hatami merged thousands of shots of the sun taken by the Solar Dynamics Observatory, a NASA spacecraft that is studying our solar system's star.

The competition winners will be announced on 16 September. ■

Gege Li

A difficult dilemma

What if a prenatal test reveals your surrogate fetus has a medical condition? The tensions are brilliantly played out in a new film, finds **Clare Wilson**



Film

The Surrogate

Jeremy Herch

UK cinemas

THE Surrogate is billed as being about a moral dilemma, so I assumed that the film would address some of the complex ethical questions surrounding surrogate pregnancies, when someone deliberately conceives in order to give the baby away.

For example, if the surrogate is paid a fee, some feel that the arrangement can seem exploitative, and even when people do it for altruistic reasons, problems can arise if participants change their minds halfway.

The film touches on these questions, but the issue under the microscope here is a broader one. What happens if a prenatal test reveals that a fetus has a medical condition, and the parents can't agree on what happens next?

The Surrogate spans a few weeks in the lives of Jess, a web designer, her best friend Josh and his husband Aaron, as Jess carries a baby for the two men.

At first, all goes well, and Jess is almost annoyingly upbeat as she explains the unusual situation to her concerned family and sometimes to random strangers. In one scene, she tells a waitress: "They're the new parents. I'm just the vessel."

Then a prenatal test reveals that the fetus has Down's syndrome. As the three main characters agonise over whether to continue the pregnancy, cracks emerge in their once united front. To prepare, Jess is keen to get to know families with children with Down's syndrome; the two prospective fathers not so much.



MONUMENT RELEASING

The children with Down's syndrome we meet are adorable, but their parents warn about the hurdles ahead.

Jess gets to know one happy family, but the mother says: "I underestimated how much time I would spend on the phone fighting bureaucrats."

"As the three main characters agonise over whether to continue the pregnancy, cracks emerge"

The father is just tired. They send their child to an expensive private school and it seems clear that bringing up a child with Down's syndrome is easier if you are cushioned by wealth.

Although the subject matter is fascinating, the main reason for watching this film is that it is superbly written and acted, especially by Jasmine Batchelor, who plays Jess. Every line of

dialogue, every facial expression, is pitch perfect – from the trio's joy at the result of the pregnancy test, through their stunned silence on the diagnosis, to the tears as their relationship is strained.

Your opinions on Jess, Josh and Aaron may well be influenced by your views on abortion. At one point in the film, we are invited to judge the two men negatively for their unwillingness to bring up a child with Down's syndrome. But as Josh complains, the majority of straight couples choose to end such a pregnancy, so why should gay men be held to different standards?

The issues aren't black or white, and nor are the characters. Many people with Down's syndrome live happy, fulfilling lives, but Josh, it turns out, has his reasons for being less optimistic about the future. As a consequence, he points out that Down's syndrome spans a range of abilities, and the people who get media attention for their

Aaron, Jess and Josh must navigate the ethics of an unusual surrogacy

accomplishments are likely to be at one end of the spectrum.

As the rows between Jess and her friends escalate, they cut to the heart of the growing debate over the ethics of prenatal testing. Politicians in Northern Ireland and some US states are trying to ban abortions that are sought on the grounds that the fetus has Down's syndrome, and disability rights groups have tried to prevent the introduction of early prenatal testing for the condition.

But the arguments of the trio, while they are fascinating, never feel like sermonising or forced exposition – they come across as the genuine reactions of real people caught in a difficult situation.

The film may be hard to watch if you have a personal stake in the question, or, conversely, it could feel like essential viewing. ■

The dog that 'talked'

Is a dog called Stella really the world's first talking dog?

Chris Stokel-Walker explores the claims in a book by her owner



Book

How Stella Learned to Talk: The groundbreaking story of the world's first talking dog

Christina Hunger
Pan Macmillan

WHEN Stella, a chocolate brown dog, began moving around the house, Christina Hunger realised her dog was unusual. The 8-week-old puppy acted like the children that Hunger, a speech-language pathologist, worked with. "She was communicating how toddlers communicate right before they start saying words," she writes in *How Stella Learned to Talk*, her book about her experiences with the dog.

Hunger asked a simple question: if dogs can understand words, what if they had another way to say words? Her book charts attempts to get Stella to communicate using an augmentative and alternative communication (AAC) device, similar to the ones she uses with children who don't speak. Hunger now claims Stella is "the world's first talking dog", and encourages others to coax their dogs to "talk" by pushing paw-sized buttons associated with different words.

One of the key apparent breakthroughs in communication came when Hunger was watering plants and Stella was watching her. The dog left the room and went to her AAC. There, she pressed the word Hunger had programmed for water. "I started realising she might be able to use words for different functions, not just requesting something," says Hunger.

Stella seemingly began combining words for the situations she was trying to communicate to

Hunger. That, says Hunger, is evidence that Stella was engaging in communication, not being conditioned to hit a button when an environmental change occurred. Though others dispute this.

Stella is still developing her language skills, says Hunger. She is able to combine up to five words to create phrases and short, simple sentences. Stella uses her vocabulary every day, mixing up the words to communicate different goals to different people.

The success with Stella shows that we need to keep researching this area, says Hunger, because dogs are hearing human words every day and making associations. "They just haven't had a way to say them themselves. As more and more people keep teaching their dogs, we're going to discover this range is normal, just like it is with human language," she writes.

Not everyone agrees. "It's really cool what Christina did with Stella, and I think it's awesome that people work on improving their relationship with non-human animals," Dirk van der Linden

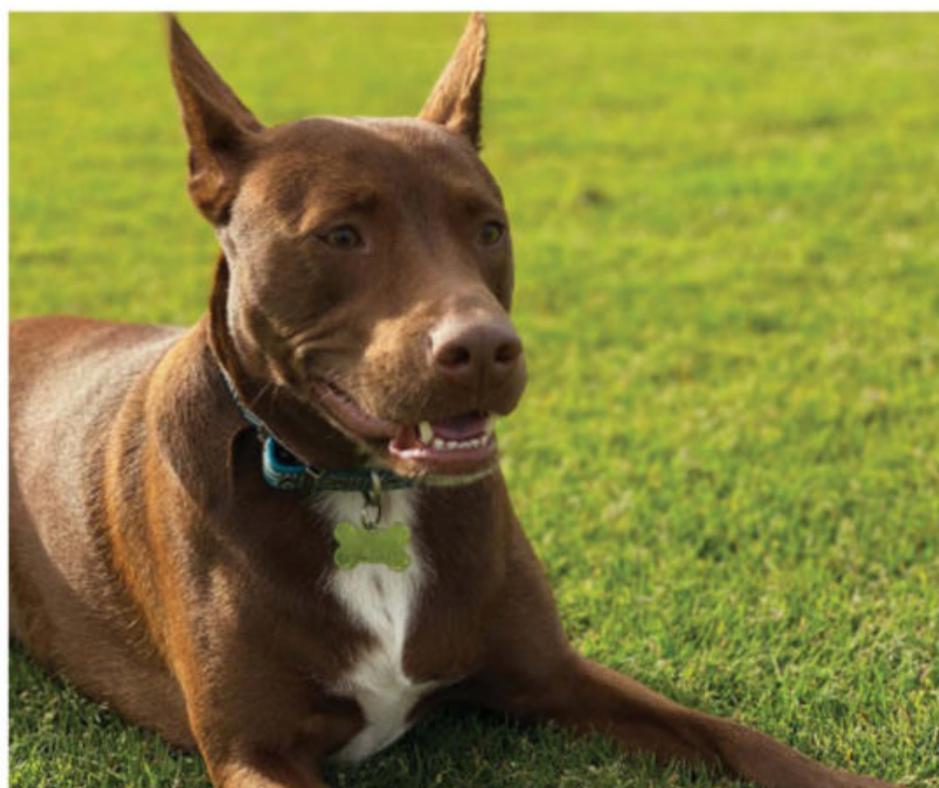
at Northumbria University, UK, told *New Scientist*. "Stella doesn't 'talk', but she's been trained to associate pushing a button with a particular outcome. That is still useful, and that's a fair way for us to enable interspecies interactions. But let's not confuse ourselves and say that animals are suddenly talking or understanding us, and let's especially not confuse ourselves it is the animal's duty to understand us."

Van der Linden worries that normalising the idea that dogs can communicate in a human-like way with us will encourage owners to demand that the pets rise to meet human level of communication, rather than focusing on understanding their animals.

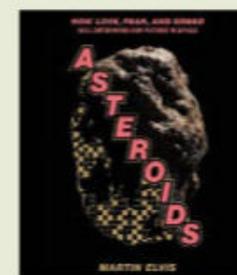
Hunger stands by her findings. "In the past year and a half, we've seen thousands of people who aren't speech therapists teach their dogs to use words as well," she says.

But getting your schnauzer to engage with the book rather than tear up its pages may be a way off. ■

Chris Stokel-Walker is a technology writer based in Newcastle upon Tyne



CHRISTINA HUNGER



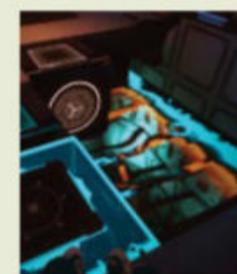
Read

Asteroids and their valuable raw materials are our next frontier, says astrophysicist Martin Elvis. In his new book on asteroid exploration, he explains the motives and reasoning behind this expensive and unforgiving endeavour.



Visit

What Listening Knows at Messums Wiltshire, UK, is an installation by Australian artists Sonia Leber and David Chesworth. It is built around the soundscapes of the Wiltshire countryside. Don't forget to ask about the virtual tour.



Play

Gravitational, a virtual reality game from Studica Solution for the HTC Vive headset, turns access issues faced by a wheelchair user into an ingenious sci-fi thriller. It is an unusual experience for everyone. Toy with gravity at your peril!

Stella likes a walk and purportedly also a natter

The games column

A romp across the multiverse Amazing visuals, cinematic techniques like never before and inventive weapons – *Ratchet & Clank: Rift Apart* is perfectly timed to take full advantage of the PlayStation 5 console, says **Jacob Aron**



Jacob Aron is *New Scientist's* deputy news editor. Follow him on Twitter @jjaron



INSOMNIAC GAMES

Ratchet, star of the *Ratchet & Clank* series, is a Lombax, a fox-like alien

drastically reduce loading times. Not only can you boot into a game much faster, but developers can swap game resources in and out of memory extremely quickly without a loading screen. *Rift Apart* uses this to seamlessly transition between dimensions, which is very impressive.

It is true that the game doesn't make as much of this as it could – only one level sees you really flipping between dimensions with regularity – but popping through different locations at speed is something we just haven't seen in video games before. It even makes cinematic techniques such as hard cuts or split screens possible, both of which are rarely used in games.

Beyond the visuals, the draw of the *Ratchet & Clank* series is the huge range of inventive weapons you play with. My favourites include the Topiary Sprinkler, which releases a small turret that sprays enemies with water and turns them into topiary hedges, and the Lightning Rod, which shoots electricity that can arc from enemy to enemy and stun them.

All in all, I had a great time tearing through the game over a week or so, though seeing as PS5 games now sell for £70, you might question whether you get your money's worth (like most of the games I feature in this column, the publisher provided a review copy). It does at least have a challenge mode that unlocks once you beat the game and allows you to replay it with more advanced weapons.

I'm not going to pretend that *Ratchet & Clank: Rift Apart* is particularly deep or has much to say about the state of the world, but sometimes you just want a fun romp, and this it delivers. ■



Game

Ratchet & Clank: Rift Apart

Insomniac Games
PlayStation 5

Jacob also recommends...

Game

Resistance 3

Insomniac Games
PlayStation 3

Insomniac loves to put creative weapons into its games, and the Resistance series is no exception. With Earth invaded by aliens in the 1950s, the third in the trilogy is the best of the lot.

Film

Guardians of the Galaxy

James Gunn

If you haven't seen this Marvel classic, sign up to Disney+ and enjoy a movie that is essentially Star Wars, but funny, with better music.

I WROTE in my last column that, despite supply chain issues, I have finally got my hands on a PlayStation 5 console. It turns out to have been perfect timing to try one of its best games so far: *Ratchet & Clank: Rift Apart*.

It always takes a year or so for game developers to start taking advantage of the added power of a new console, and the pandemic has only exacerbated this as studios struggle to work from home. This means that most titles released to date for the PS5 and the other new console, the Xbox Series X, have been designed to also work on their predecessors, limiting what they can do.

Not so with the latest in the long-running *Ratchet & Clank* series. These are wacky sci-fi adventures starring Ratchet, a type of fox-like alien known as a Lombax, and Clank, his robot pal, and are known for their humour and outlandish weapons. The games are a bit like a cross between a Saturday morning television cartoon and the film *Guardians of the Galaxy*, but are still smart enough to be engaging.

Rift Apart opens with a parade in the pair's honour, and the PS5 makes it an absolute visual feast – the animation and fur of Ratchet's face in close-ups matches anything that movie studio Pixar can do. Of course, things don't go as planned and the parade is invaded by the series baddie Dr Nefarious, who uses a weapon called the

“My favourite weapons include the Lightning Rod, which shoots electricity that can arc from enemy to enemy”

Dimensionator to break down the barriers between universes and send the pair on a quest to stop him. Our heroes work alongside their multiverse alter egos, Rivet and Kit, who you also play as throughout the game.

The dimension-hopping that results is where the PS5 really shines. I normally avoid talking tech specs in this column, but indulge me briefly. Both new consoles contain high-speed, solid-state drives (SSDs), which

Editor's pick

The long arm of long covid-like symptoms

26 June, p 10

From Robert Law, Hong Kong, China

I read with interest your article on long covid – how some people may take a long time to recover after a coronavirus infection. I wonder whether similar things may happen with covid-19 vaccination.

When I had my second shot of the Pfizer/BioNTech vaccine two months ago, I was really under the weather for 36 hours, with tiredness, lethargy and slight fever. The tiredness continued for another week or so, and was especially noticeable during exercise.

However, my 40-year-old daughter continued to have a headache, tiredness and lethargy for more than a month after her second dose. She says she still isn't completely herself after nearly six weeks, and gets tired easily during exercise. I wonder if others have had the same experience.

From Ingrid Wall, Cambridge, UK
Your article covered much-needed information about the causes of long covid and its similarities with chronic fatigue syndrome.

However, it is a pity that the discussion wasn't broadened to other comparable conditions, such as functional neurological disorder and conversion disorder. The similarities of these to long covid have been reviewed in recent medical publications. I firmly believe that investigations into long covid may shed light on these too.

Is there a third way to deal with coronavirus?

19 June, p 10

From Robert Peck, York, UK

The comparison of mitigation and elimination strategies for covid-19 misses an interesting alternative approach – tolerance.

This focuses on accepting covid-19's spread and deploying practical, focused hygiene

measures rather than societally disruptive interventions. It has been used in Sweden and in Florida, where it was introduced in time for the winter wave.

It also matches the advice of Donald Henderson – the mastermind of smallpox's eradication – and his colleagues in a 2006 paper on handling respiratory pandemics.

ET is watching us: worry about what it will think

3 July, p 20

From Howard Freeland, Sidney, British Columbia, Canada

You report that it is possible that aliens orbiting 1402 stars near Earth could be looking at us right now. That is very worrying.

Before being watched by others, we need to comb our hair and put on our best clothes. Suppose that aliens could pick up our television broadcasts? Xeno-sociologists in the Proxima Centauri system are currently watching the early years of the Trump administration with bemusement, as they are just over 4 light years away.

But they probably aren't as perplexed as any observers that are around 52 light years away, who will be trying to understand us while watching early broadcasts of *Monty Python's Flying Circus*.

Time to turn back the clock on expert decision-making

19 June, p 40

From Chris Lewis-Cooper, Usk, Monmouthshire, UK

Daniel Kahneman and Olivier Sibony give a lucid account of variability, or noise, in expert judgements, including a definition of what constitutes such a decision. In essence, any choice that can't be reduced to an algorithm can be classed as an expert judgement.

Until about 10 years ago, so-called expert systems were often used as computer support tools for expert decisions. Lately, these seem to have been pushed aside for more trendy technologies, such as artificial intelligence, which is mainly focused on generating complex and often hidden algorithms to simulate expert judgements.

The best of the pre-AI systems went a long way towards indicating both an unbiased consensus decision and a total tolerance range due to various sources of noise. Is it time to revisit the potential of these kinds of expert systems in supporting expert judgements?

One day we may see two giant black holes collide

12 June, p 18

From Alex Bowman, Glasgow, UK

Regarding the story "Cosmic collisions may push huge black holes off kilter", what would happen if and when two galaxies merged and their supermassive black holes collided? Maybe it would generate an explosion that would be the largest since the big bang. Both galaxies would surely be ripped apart.

The gravitational waves produced would be immense and easily measured. The universe is vast, so this has probably occurred more than once.

Is it time to rename our not-so-great species?

Letters, 26 June

From Dave Smith,

Alnwick, Northumberland, UK

James Fenton correctly states that the word "natural" is pointless unless it is defined in opposition to "artificial". I have often wondered whether our species

is misnamed. Perhaps it should be *Homo callidus*, meaning clever, crafty or sly, as in "man who is too clever for his own good". If so, the natural behaviour of *H. callidus* is self-aggrandisement: to get bigger, richer or more powerful.

In turn, this reflects the letter in the same edition from David Seager, speculating on the successor to our species.

Unlikely though it seems, may I hope for a new subspecies: *Homo sapiens veritas*, or "truly wise man"? This creature will naturally exhibit the self-abnegation needed to solve climate change and species loss. At the moment, sadly, such behaviour is entirely artificial.

To cut carbon fast, many things may have to go

Letters, 12 June

From Bryn Glover, Kirkby

Malzeard, North Yorkshire, UK

I would fully endorse Paul Gulliver's sentiments about the climate-harming pollution of space tourism, but I wonder how the principle of not "generating greenhouse gases for amusement" might be extended and, if this were done, how we should rank the pastimes involved.

For example, would Formula 1 and other big business motor sports continue to be acceptable after package holiday flights and Sunday afternoon drives in the country were outlawed, or would it be the other way round?

I don't believe such notions are fanciful: to meet the minimum climate targets, on which we all agree, we must stop burning fossil fuels. Ideally, we should stop completely now. But practicalities demand a phased reduction – so who or what goes first? ■

For the record

■ A 2018 study led by Angelo Gemignani and Andrea Piarulli on slow breathing's effect on brainwaves (19 May, p 34) found no link between the nasal stimulation used and sleep or drowsiness.



Want to get in touch?

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

Healthcare's future

A *New Scientist* online event revealed the scientific advances that will keep our minds and bodies in the best of health. **Loyal Liverpool** tuned in

FROM microrobot surgeons and virtual reality diagnostics to psychedelics, what is the future of healthcare?

New Scientist's all-day virtual event on 26 June, sponsored by Alzheimer's Research UK, was filled with inspiring talks from leading experts in health and medicine about the coming revolution in healthcare, with thought-provoking questions from the audience.

Viewers had access to a wide range of talks and discussions across three virtual stages, tackling big questions in health and healthcare, including: how we could take vaccine technology to the next level in our battle against covid-19 and other diseases like cancer; the role of genomics and artificial intelligence in healthcare; and how magic mushrooms might form part of a future treatment for depression.

It is impossible to talk about health at the moment without considering the enormous impact that the covid-19 pandemic will continue to have globally. On the main stage, Nisreen Alwan at the University of Southampton, UK, explained why countries mustn't ignore the massive burden of chronic illness, or long covid, that follows acute waves of coronavirus infection.

"If somebody survives the infection or the acute illness in the short term, that mustn't be confused with full recovery," said Alwan. We need to learn from other chronic conditions, such as myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS), she said.

There is early evidence that existing covid-19 vaccines may reduce or eliminate symptoms of long covid in some people. Anna Blakney at the University of British Columbia in Vancouver spoke on the

mind and body stage about the next generation of mRNA vaccines, including a vaccine containing mRNA that can amplify itself inside cells.

It would take just two Olympic swimming pools worth of the Pfizer/BioNTech covid-19 vaccine to fully vaccinate everyone on the planet, said Blakney. "It really puts into perspective how one company would be able to make vaccines for the entire world."

But it might be possible to improve mRNA vaccine technology, allowing us to make these vaccines even more potent, so that each drop can go further in terms of getting people jabbed, said Blakney. "What [a] self-amplifying RNA vaccine enables us to do is use a much lower dose of RNA, so typically a 100 times lower dose."

"Virtual reality and wearable technology could enable early diagnosis of dementia"

Meanwhile, on the technology stage, Dennis Chan at University College London described innovations that could revolutionise the diagnosis of dementia, which is getting more prevalent as the populations of many nations age.

The number of people living with dementia around the world is projected to more than triple from 50 million in 2018 to 152 million in 2050. Early diagnosis is crucial to enable the use of treatments that can help delay the onset of symptoms. But many of the existing memory and "pen-and-paper" tests used to diagnose

dementia are hopelessly outdated and most people are only diagnosed once they have already started to develop symptoms, said Chan. "The field is in dire need of a refresh," he said.

That's why his research team is investigating the potential of virtual reality, machine learning and wearable technology to enable much earlier diagnosis of the disease – years before symptoms first appear.

One test that Chan's team has developed involves people completing a VR navigation task. In an initial study, he and his colleagues found that this test was able to distinguish people with preclinical Alzheimer's disease from those experiencing mild cognitive impairment for reasons that were unrelated to dementia.



DAN KITWOOD/GETTY IMAGES/CANCERRESEARCH UK

Missed out?

To watch the Future of Healthcare talks on demand, visit [newscientist.com/science-events/future-of-healthcare](https://www.newscientist.com/science-events/future-of-healthcare)



Caroline Williams answers viewers' questions about how movement affects the mind (below)



ageing in humans, in an effort to prevent or delay the unhealthy period at the end of life when people's risk of developing conditions such as cancer goes up.

Also on this stage, Bruna Giribaldi at Imperial College London shared the results of a recent clinical trial, which she managed, investigating whether psilocybin – the main active ingredient in “magic mushrooms” – could help treat depression. Findings from the trial are leading researchers to rethink the way that mental health conditions such as depression might be treated in the future, with a growing emphasis likely to be on identifying and tackling their underlying causes.

When you give someone psilocybin, certain areas in the brain that don't usually connect with each other start doing so, said Giribaldi. “There's massive amounts of things happening in your brain and also massive potential for change,” she said.

The trial compared the effects of a high dose of psilocybin with the current gold-standard drug treatment for depression, a selective serotonin reuptake inhibitor (SSRI), in 59 people with moderate to severe depression. Participants also had sessions with a therapist alongside drug treatment.

Giribaldi and her colleagues found that psilocybin performed better than the SSRI on several different measures of depression. “It definitely shows that there is a lot of potential here and we need to do a lot more research,” she said.

Christos Bergeles at King's College London wrapped up the day of talks on the technology stage, providing a glimpse of the future of surgical robotics, including tiny robots that could be used to assist with delicate microsurgeries, such as in the eye.

Alongside all the talks, researchers from King's College London's School of Biomedical Engineering and Imaging Sciences wowed the audience with activities, live demos and workshops throughout the day. Viewers were able to see the role 3D printing plays in healthcare, use origami to explore folds in the brain and chat to researchers about career paths in the healthcare sector.

The day provided a unique insight into the science and technology that will underpin healthcare in years to come. All the talks are available to watch on demand. ■

Science and technology underpin healthcare in both labs and hospitals

“Where we're going now with this, is actually going even earlier into the disease,” said Chan.

As well as developing better diagnosis and treatments for conditions commonly associated with ageing, researchers are investigating ways to target the ageing process directly, for instance through diet or by using existing drugs to promote health in later life.

Linda Partridge at University College London spoke on the mind and body stage about ongoing research aiming to tackle



KENZO TRIBOUILLARD/FPV VIA GETTY IMAGES

Sponsored by



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

Consciousness expanded

How a physical brain creates the feeling of being is one of life's greatest mysteries – but one we are starting to crack. Join us on a journey into the recesses of human consciousness, guided by the answers to 10 questions that reveal how our everyday experience of reality is more mind-blowing than we imagine

1

What is consciousness?

IN ESSENCE, consciousness is any kind of subjective experience. Being in pain; smelling onions frying; feeling humiliated; recognising a friend in the crowd; reflecting that you are wiser than you were last year – all of these are examples of conscious experiences. In a field fraught with disagreements, this is something that most, but not all, researchers agree on. Go any deeper, though, and the rifts open up.

The 17th-century French philosopher René Descartes famously divided the universe into “matter stuff”, such as rocks and physical bodies, and “mind stuff”. In the 20th century, philosopher David Chalmers at New York University built on Descartes’s separation, known as “dualism”, and the work of later thinkers, to distinguish between “easy problems of consciousness” and “the hard problem”.

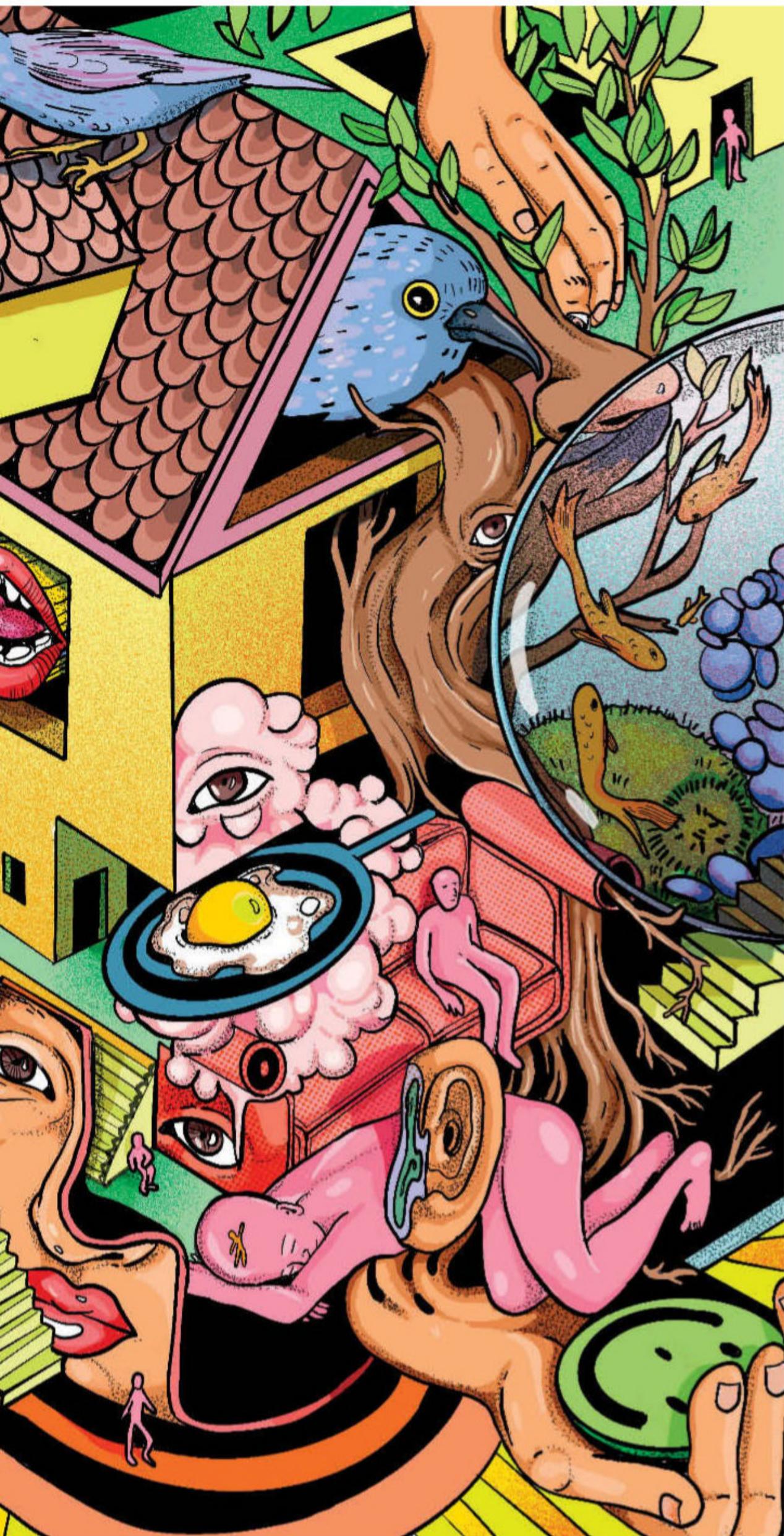
The easy stuff consists of explaining the brain processes associated with consciousness, such as the integration of sensory information, learning, thinking and being awake or asleep. Though we are making steady progress, these problems have yet to be cracked: they are easy

only in the sense that the known strategies of cognitive and neuroscientific research should eventually provide full explanations.

The hard problem, which Chalmers introduced at a scientific meeting in 1994, is to explain why and how we have subjective experiences at all. “Consciousness poses the most baffling problem in the science of the mind,” Chalmers said. When we think and perceive, there is a “whirl of information-processing” in the brain, as he put it, but also very distinctive subjective states of mind. The puzzle is how a 1.3 kilogram organ with the consistency of tofu can generate the feeling of being.

Some believe the hard problem can never be solved – it is beyond the capabilities of human cognition. Others think that, with a better understanding of the brain, it will simply go away. Anil Seth at the University of Sussex, UK, sees a third way. He thinks that tackling the easier stuff will allow researchers to address the hard problem indirectly. To this end, he has developed a framework that highlights different aspects of consciousness to be





EVA REDAMONTI

investigated. Other theorists divide it up differently, but for Seth the three main components are conscious content, conscious self and conscious level.

Conscious content is whatever you are conscious of, including awareness of sensory perceptions. Conscious self is a unique component of conscious content that refers to self-awareness – the subjective feeling of being you – and includes being aware of your own awareness and reflecting on your conscious thoughts, known as meta-consciousness. And conscious level refers to differences in so-called “global states”, such as being asleep, under anaesthesia or being awake (see “How many states of consciousness do humans have?”, page 36).

These aspects of consciousness aren’t independent, says Seth. “If you explain all the different kinds of conscious content – everything you might be conscious of – then you’ve probably explained everything,” he says. But he thinks breaking consciousness down like this is the best approach to tackling what it is. **Emma Young**

2

How many states of consciousness do humans have?

Consciousness was traditionally thought to be like a light switch: it is on when you are awake and off when you are sleeping, anaesthetised or in a coma. However, when we dream while asleep we often have subjective experiences that are similar to our waking ones. Taking this into account led to the conclusion that, instead of two states of consciousness, there are three.

This idea didn't hold for long, though. One driver of the shift in thinking was research looking at people who are in a coma, where the brain is considered to be entirely unresponsive, and others who are in a persistent vegetative state, which is marked by a sleep-wake cycle, but with no response to stimuli. People in the latter state would appear to be more conscious than those in a coma, and both seem less conscious than someone under mild sedation. Neuroscientists and philosophers alike began arguing that there are many states of consciousness: it is more like a dimmer-switch or a ladder with zero consciousness at the bottom and maximum consciousness at the top.

This picture was further complicated by a startling finding: a few people diagnosed as being in a persistent vegetative state have brain activity indicative of some awareness. In 2010, for example, a team that included Adrian Owen, then at the University of Cambridge, reported several cases of people who could respond to questions using their brain activity, picked up by an fMRI brain scanner. These included a 29-year-old man who was able to give yes or no answers to queries by imagining doing a different activity for each word.

Next came claims of levels of consciousness beyond alert

wakefulness. In 2017, a team led by Anil Seth at the University of Sussex, UK, reported that people who had taken LSD or psilocybin (the hallucinogenic compound in magic mushrooms) experienced a "higher" level of consciousness: at least, their brains showed more diverse electrical activity with the drugs than without them. The ladder of consciousness was expanded to accommodate this and other states, including hypnosis, sleepwalking, epilepsy-induced unawareness, being half asleep (sleep is no longer regarded as an all-or-nothing phenomenon) and daydreaming.

Multi-faceted state

Now, the ladder model itself is being challenged. Owen is in the vanguard. He and two colleagues have described it as "untenable". They argue that, just as someone who is blind is no less conscious than a sighted person, so someone who has taken a mild sedative, say, is no less conscious than someone in a regular state of wakefulness.

Think about a toddler's experience of the world, says Owen. An adult might look at the Eiffel Tower and be aware of its name and location and what was happening in their life when they last saw it, whereas a toddler might be conscious of just a big tower. In some ways, but not all, their conscious experience of the world isn't the same as an adult's. If that adult developed Alzheimer's disease, they may then come to have a similar awareness of the Eiffel Tower as a toddler, but their conscious experiences wouldn't be the same. "Consciousness is multi-faceted," says Owen, "and trying to measure it along any single dimension, including 'depth', will inevitably be futile."

Instead, he and his colleagues propose a more complex, multidimensional framework. Rather than being points on a line, states of consciousness would be represented by a spider's-web-type shape, with spikes indicating the extent to which someone possesses each dimension. Unfortunately, we don't yet know enough about consciousness to say what many of these dimensions are, let alone measure them. That is a concern to researchers, including Seth. Nevertheless, the idea has been influential. "It's on the money," says Seth. Emma Young

There is an ongoing debate about degrees of consciousness



TOMMY TRENCHARD/ALAMY

3

Can physics explain consciousness?

“Consciousness may emerge from quantum collapse in the brain”



If physics explains all the phenomena in the universe, and if consciousness is part of the universe, then it seems that physics can explain consciousness.

Of course, this assumes that consciousness isn't separate from the material reality that physics explains – which runs counter to René Descartes's dualist view of mind and matter. Some have no problem with that. They include Daniel Dennett at Tufts University in Massachusetts and Michael Graziano at Princeton University, who argue that our intuitive sense that consciousness needs an explanation that goes beyond objective descriptions of the physical world is misplaced. Consciousness is a mirage produced by sophisticated neural mechanisms in the brain, they contend, so we need no new physics to explain it. Rather, we need a better understanding of how the brain creates models: of the world, of a self in the world and of a self subjectively experiencing the world.

Other non-dualists don't outright deny that consciousness may have unusual properties that need explaining. If they are correct, then quantum mechanics may offer an explanation.

Quantum systems can exist in a superposition of all possible states simultaneously, and classical reality emerges when this superposition collapses into a single state. One idea is that this happens when the mass of a quantum system crosses a threshold. According to theoretical physicist Roger Penrose at the University of Oxford and anaesthesiologist Stuart Hameroff at the University of Arizona, consciousness emerges as the result of such collapses occurring in the brain. In their model, called orchestrated objective reduction (Orch OR), microscopic structural elements within neurons, called microtubules, enter into states of quantum superposition. These span networks of neurons and when the mass of the microtubules in a superposition exceeds some threshold, it collapses, producing conscious moments.

There are many dots to be connected for this idea to be taken seriously. One is to show that microtubules can attain states of quantum superposition in the relatively balmy



If physical processes in a brain create consciousness, what are they?

VICTOR DESCHWANBERG/SCIENCE PHOTO LIBRARY

temperatures of the human brain. According to Hameroff, preliminary and unpublished work by Jack Tuszynski at the University of Alberta, Canada, and Gregory Scholes at Princeton University has achieved that. “They have found evidence for quantum states in microtubules persisting for up to 5 nanoseconds,” he says.

The next step is to expose microtubules to anaesthetics, which selectively disrupt consciousness while leaving non-conscious brain functions intact. “The prediction is that anaesthetics would dampen microtubule quantum states proportional to known anaesthetic potencies in putting humans and animals to sleep,” says Hameroff. This provides a way to test Orch OR, he says, and Bruce MacIver at Stanford University in California is looking into conducting such an experiment.

But what if consciousness is separate from material stuff and so outside the purview of physics? If so, Orch OR probably has it backwards, says Johannes Kleiner at the Munich Centre for Mathematical Philosophy in Germany.

In a yet to be published paper, he and Kobi Kremnitzer at the University of Oxford show mathematically that if non-material consciousness were to affect material reality, in our physical reality, superpositions would appear to spontaneously collapse. “So the arrow is from consciousness to collapse,” says Kleiner. “In Orch OR, it's from collapse to consciousness.” **Anil Ananthaswamy**

4

What is consciousness like in other animals?

Children know the fun of throwing a ball into the sea, only to watch the waves fling it back. Jennifer Mather and Roland Anderson at the Seattle Aquarium were surprised to find octopuses playing similar games. Their toy was a floating pill bottle, which they were free to ignore or explore as they wished. Six of the aquarium's octopuses soon lost interest, but two showed childlike curiosity, pushing it with their arms or shooting jets of water to move it against the tank's current. It is hard to interpret this as anything other than play, which many researchers argue requires some form of conscious awareness.

Many animals exhibit behaviours similarly suggestive of an inner life. Conscious creatures may include our primate cousins, cetaceans and corvids – and potentially many invertebrates, including bees, spiders and cephalopods such as octopuses, cuttlefish and squid. The challenge, of course, is to understand how the inner lives of these creatures differ from our own.

In the past, scientists spoke about “levels of consciousness”, as if there were a hierarchy with humans on top. But in a paper published in 2020, Jonathan Birch, a philosopher at the London School of Economics and his colleagues argue that we would do better to consider five separate elements of conscious experience. The first is perceptual richness, or how well an animal can discriminate different details in each of its senses. The second is evaluative richness – broadly speaking, the capacity to differentiate between positive rewards and noxious stimuli, which could be analogous to human emotions such as pleasure or pain. The third, unity, concerns the extent



Each arm of an octopus could be independently conscious

AZOR WILDLIFE PHOTO/LAMY

to which an animal integrates the information from its sensory organs into a single experience. Then there is temporality: does the creature's past experience influence its present behaviour, and can it plan for the future? The fifth dimension is selfhood. This may be tested by assessing whether an animal recognises itself in the mirror, or has so-called theory of mind – the ability to understand that another animal has its own mind.

Many ways of being

According to Birch and his colleagues, it doesn't make sense to ask whether one animal is more or less conscious than another, since each species may score highly on some of these facets of consciousness, but low on others.

Research by Birch's co-author Nicola Clayton at the University of Cambridge offers a good example.

Scrub jays, a type of corvid, bury food to eat later, which demonstrates high temporality because it involves planning for future scarcity and remembering the location of caches. Their use of deception when hiding food in the presence of a rival bird, meanwhile, shows theory of mind, which suggests a relatively sophisticated sense of selfhood, too.

Cephalopods, by contrast, haven't yet shown evidence of self recognition. But the octopuses' enjoyment of play may be a sign that cephalopods can experience something akin to pleasure – evidence of some evaluative richness. They also have extraordinary perceptual richness, with complex vision that can detect polarised light and the ability to taste-by-touch with their suckers.

Perhaps the most startling difference between species concerns the unity of their conscious

experience. We have two eyes but we seamlessly integrate the two visual fields into a single conscious experience, thanks to the thick nerve tract connecting our left and right brain hemispheres. Birds lack that connective structure, leading Birch and his colleagues to speculate that within each individual there may be “a pair of conscious subjects, intimately cooperating with each other”.

Or consider the octopus. Two-thirds of its neurons are located in its arms, and there is some evidence that each limb operates semi-autonomously. “You could conceive of there being eight conscious experiences associated with the different arms, that are partially unified with the experience associated with the brain,” says Birch.

That is a consciousness so alien, it is almost impossible for us to imagine. David Robson

5

When did consciousness evolve?

Given that there is a variety of conscious experience across the animal kingdom, it is natural to ask when and how consciousness first emerged. Can we thank a single common ancestor? Or did it evolve independently in different lines?

Andreas Nieder at the University of Tübingen in Germany favours the latter explanation. He recently conducted an ingenious experiment to discover the brain processing underpinning visual consciousness in corvids such as crows. The birds were trained to respond to different coloured squares, some of them almost imperceptibly faint. Neurons in a region called the pallial endbrain lit up whenever the crows reported seeing the squares, but not when they failed to spot them, suggesting that this area is essential for their conscious visual perception. In humans and primates, a different part of the brain, the prefrontal cortex, performs the same job. For this reason, Nieder thinks that consciousness probably emerged separately on multiple occasions, in much the same way that wings appeared separately in insects, birds and bats.

Eva Jablonka at Tel Aviv University in Israel and Simona Ginsburg at the Open University of Israel take a different view. In their book *The Evolution of the Sensitive Soul*, they argue that birds, mammals and other vertebrates inherited consciousness from a common ancestor. Their argument hinges on a type of thinking known as unlimited associative learning, which involves learning about novel stimuli and linking them together even if time has passed between experiencing two stimuli. It also entails forming chains of such links so that the same stimulus can be interpreted in different ways depending on the context.

Importantly, these associations can be updated: something that triggered danger may come to be a sign of reward if circumstances have changed. Jablonka and Ginsburg believe that this kind of complex learning is impossible without consciousness to direct attention, evaluate different cues in the environment and integrate experiences over time. So, what can it tell us about the origins of consciousness?

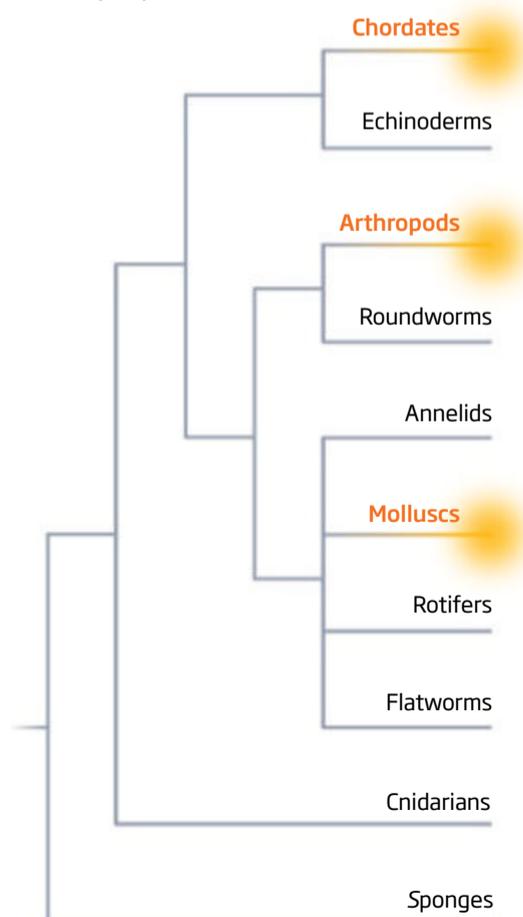
Unlimited associative learning has been documented in many diverse species. “Even

little fish are able to do this,” says Jablonka. That leads her and Ginsburg to propose that consciousness must have emerged in early vertebrates around 530 million years ago.

They suspect certain groups of invertebrates, including arthropods like honeybees and spiders, can also think in this way. If so, their earliest ancestors evolved consciousness independently of vertebrates, around 500 million years ago. The shell-less cephalopods are relative latecomers to the table. The fact other molluscs don’t appear capable of unlimited associative learning suggests to Jablonka and Ginsburg that consciousness in octopuses, cuttlefish and squid originated around 300 million years ago. “I think it is one of the most promising approaches we have at the moment for how to study the evolution of consciousness,” says Jonathan Birch at the London School of Economics. **David Robson**

The enlightened ones

Signs of consciousness have been found in animals from at least three different **phyla**, suggesting it evolved more than once and is far more common than most people think



Models of consciousness

There are many ideas about how consciousness arises. Here are five of the most influential. Although each has its own proponents, they aren’t all mutually exclusive.

GLOBAL NEURONAL WORKSPACE

Information entering the brain from the outside world or the body competes for attention in the cortex and a structure in the centre of the brain called the thalamus. If the signal it generates is stronger than signals from other information, it is broadcast across the brain into the global workspace. Only then do you consciously register it.

ATTENTION SCHEMA

The brain evolved to contain a model of how it represents itself. This attention schema is like a self-reflecting mirror. It is what creates the subjective feeling of consciousness. There is no “ghost in the machine”; consciousness is just a mirage created by sophisticated neural processing.

PREDICTIVE PROCESSING

The brain is a prediction machine, meaning that what we perceive is the brain’s best guesses about the causes of its sensory input. As a result, much of conscious experience and selfhood is based on what we expect, not what is there.

INTEGRATED INFORMATION

Consciousness isn’t confined to brains. It arises in any system as a result of the way information moves between its subsystems. The degree of integration of this information is measured with a metric called phi. Any system with a phi of more than zero is conscious.

ORCHESTRATED OBJECTIVE REDUCTION

Quantum mechanics can explain consciousness. Microscopic structural elements within the brain, called microtubules, can exist as a superposition of all possible states. This quantum system collapses into a single state when the mass of the microtubules in it exceeds a certain threshold. The collapse is what creates consciousness. **Kate Douglas**

6

How would we know if a machine were conscious?

There is disagreement over whether machines can ever be conscious, let alone how we would know if one were. Your view may depend on how you see consciousness.

If the subjective feeling of consciousness is an illusion created by brain processes, then machines that replicate such processes would be conscious in the way that we are. How would we know this? Daniel Dennett at Tufts University in Massachusetts thinks a Turing test, in which a machine has to convince a human interrogator that it is conscious, should, if conducted "with suitable vigour and aggression and cleverness", be enough.

Michael Graziano at Princeton University thinks we could take a more direct approach. His attention schema hypothesis sees consciousness as the brain's simplified model of its own workings – a representation of how it represents things. He believes it is possible to build a machine that possesses a similar self-reflective model. "If we can build it in a way that we [can] see into its guts, then we will know this is a machine that has a rich self-description," he says. "It is a machine that thinks and believes it has consciousness. And those are confirmable because you can understand, in principle, how the machine is processing information."

For Graziano, consciousness could appear in any machine, whether it is purely in software or constructed of matter, biological or otherwise. Anil Seth at the University of Sussex, UK, isn't so sure. "I think it is still an unknown whether consciousness is substrate-independent," he says. For him, determining whether a machine is conscious requires making informed judgements based on whether, for

example, it has analogues of brain structures that we know are important for consciousness in humans, and what it is made of (brain organoids, for example, are made of biological material).

Identifying consciousness in a machine may be more straightforward if you subscribe to the integrated information theory of consciousness. In principle, this simply entails ensuring that ϕ , a quantity indicating the degree of information integration within the system, is greater than zero. In practice, calculating ϕ is computationally intractable for anything but the simplest of systems. So, even if a machine were designed to integrate information, it would be far beyond our abilities to tell whether it is conscious.

Disintegrated circuits

Phil Maguire at the National University of Ireland, Maynooth, goes further. He notes that, by definition, integrated systems can't be understood by looking at their parts. "Machines are made up of components that can be analysed independently," he says. "They are disintegrated. Disintegrated systems can be understood without resorting to the interpretation of consciousness." In other words, machines can't be conscious.

Selmer Bringsjord at Rensselaer Polytechnic Institute in Troy, New York, agrees – but for different reasons. He thinks our subjective feeling of being conscious is the outcome of non-material stuff of some sort, and that this is crucial for some of our intelligent behaviour. For him, machines can never possess this essence, so will never be conscious or intelligent in the way that we are. Anil Ananthaswamy

7

What is consciousness for?

Consciousness has deep origins and appears to have evolved several times (see "When did consciousness evolve?", page 39). This alone suggests that it must provide important benefits when it comes to survival. But what might these be?

Biologists hadn't grappled with this question until quite recently. Many of those who are now considering it, think one probable answer is flexibility of behaviour. "We are better able to react to the contents [of the conscious mind], as opposed to the unconscious content that will usually trigger automatic reflex-like responses," says Andreas Nieder at the University of Tübingen, Germany. Being conscious also offers a way to evaluate the world – through feelings that make an individual aware of whether something is good or bad. And consciousness entails selective attention, which allows the brain to focus its processing activity on what is most important.

As a result of all this, instead of reacting in set ways to given stimuli, conscious animals can make complex decisions. "That would be a survival benefit that helps an individual, and then the entire species, to survive better in the changing world," says Nieder.

Greater behavioural flexibility also fits with the idea that consciousness is associated with a particular type of thinking called unlimited associative learning – the ability to combine multiple cues into a single perception. This allows animals to respond flexibly to the challenges they face, rather than relying on hardwired behaviours. It means, for instance, that they can better discriminate between a healthy and a poisonous source of food based on small perceptual differences. "Associative learning is one of the greatest adaptations on the planet," says Eva Jablonka at Tel Aviv University in Israel.

According to Jablonka and Simona Ginsburg at the Open University of Israel, consciousness first emerged around 530 million years ago and the resulting behavioural complexity it brought had huge knock-on effects. It created greater competition among species, driving the rapid diversification of animal species known as the Cambrian explosion. Predators, for example, would have been better at

8

Is consciousness detectable in the brain?



EVA REDA MONTI

“The emergence of consciousness led to much of the beauty in nature”

detecting their prey, which, in turn, would have needed to find new ways to avoid detection – pushing the predators to become even more sophisticated in their strategies. “There is a kind of ongoing co-evolutionary arms race,” says Jablonka.

But the emergence of consciousness didn’t just allow animals to adopt more complex behaviours. Jablonka suggests that it is responsible for much of the beauty that we see in nature too. It led different species to evolve camouflage, for example. And it pushed plants to evolve colourful flowers that would stick out from the competition to attract pollinating insects. “It changed the world completely,” she says. “The world would have been a very different place, and a very much more boring place, without consciousness.” **David Robson**

One of the most famous outstanding wagers in science is that by 2023, a specific signature of consciousness in the brain will have been identified. Betting against this wager – made in 1998 and with a case of fine wine at stake – is David Chalmers at New York University, the originator of the “hard problem” of consciousness (see “What is consciousness?”, page 34). Betting on it is Christof Koch, who heads the Allen Institute for Brain Science in Seattle, Washington. With two years to go, where do things stand?

We aren’t there yet. Progress has been made in understanding which brain regions and networks are involved, but there is still fierce debate.

Some researchers ascribe a vital role to the prefrontal cortex (PFC), which is responsible for sophisticated cognitive processes including attention, decision-making and planning. They argue that for sensory information to become a conscious perception – for you to actually see a red apple, say – it has to be processed not just by the sensory cortex, but also here.

Neuroimaging studies of people and macaques support this idea. But sceptics say that the PFC activity they show could relate to thinking about a stimulus and planning a response, rather than being conscious of it. Koch also points to patients who have had large regions of their PFC surgically removed due to tumours or epileptic seizures. “They go on living, by and large, a normal life, never complaining that they have been turned into zombies,” he says.

To probe further, research published this March reviewed evidence from studies that involved inserting electrodes into various parts of human brains and asking volunteers about the effects. Omri Rappaport at New York University and his colleagues concluded that stimulation of only two regions of the PFC, the orbitofrontal cortex and the anterior cingulate cortex, sometimes ➤

alters reports of conscious experience. Based on what is known about the function of these subregions and what the participants reported, it seems likely that they support the emotional aspects of conscious experience, as well as self-consciousness and meta-consciousness (the awareness of being aware). But they may not be involved in more fundamental sensory perceptual awareness. It appears that an area towards the rear of the brain's cortex – the “posterior hot zone”, as Koch calls it – is crucial for this.

Joined-up thinking

One posterior region apparently important for consciousness is the parietal cortex, which processes sensory information from the body. Earlier this year, Mohsen Afrasiabi and Michelle Redinbaugh at the University of Wisconsin-Madison and others reported research on macaques that were sleeping, anaesthetised or awake. They concluded that connectivity between the parietal cortex and two other brain regions, the striatum and the thalamus, is a “hallmark” of conscious states. “Our findings highlight the importance of integration between parietal and subcortical structures and challenge a key role of the frontal cortex in consciousness,” says Afrasiabi.

Studies of people who have regained wakeful consciousness after being in a vegetative state also support the idea that integration of activity in different regions is key for various aspects of consciousness. This notion is central to the global neuronal workspace model too (see “Models of consciousness”, page 39). “While there is much disagreement about which brain areas are most crucial for subjective experience, most theories do agree that consciousness is dependent on interactions and communication within and between different brain areas,” says Redinbaugh. The exact nature of the interactions isn't yet clear as current technology can't measure everything that needs to be measured at once.

With the clock ticking on his wager, Koch anticipates defeat. “The extent to which more frontal regions of the cortex, let alone other brain regions, contribute to consciousness will remain open for many years to come,” he says. “After all, the brain is the most complex piece of active matter in the known universe.” Emma Young

9

Is the universe conscious?



Panpsychists tend to view the universe as conscious

For some, the question of whether the universe is conscious makes little sense. “It presupposes a view of consciousness as some special something which is detached from psychology,” says Daniel Dennett at Tufts University in Massachusetts. “Is the universe embarrassed? Is the universe happy? If it can't be any of those things, then the claim that it's conscious is, I think, vacuous.”

Others don't dismiss the question outright, however. In particular, the integrated information theory (IIT) of consciousness raises the spectre that any physical system can be conscious. A metric called phi measures how much integrated information a system possesses, and any with a phi that is even a smidgen more than zero is conscious. That would include, for example, a thermostat, which might simply be conscious of being on or off. Hard-line proponents of IIT are led towards panpsychism, the idea that everything in the universe is conscious – including, possibly, the universe itself.

In February, mathematician Johannes Kleiner at Ludwig Maximilian University of Munich, Germany, and Sean Tull at Cambridge Quantum Computing Limited, UK, came a step closer to a formal analysis of the idea. They published what they call the mathematical structure of IIT. They identified the mathematical space that describes the states of physical systems on the one hand, and the mathematical space that describes experiences that physical systems may be having on the other. They then developed an algorithm to map the elements of one space to the other.

If IIT says a physical system is conscious because its phi is greater than zero, then this new maths lets you map its physical state to an experience.

So, in this way of thinking, is the universe conscious? “The interesting bit is that you can ask that question of the theory,” says Kleiner. “You can plug in the state of the universe, if you happen to be able to describe it, and then the mathematical mapping would give you an answer.” Unfortunately, he adds, right now such calculations are possible for only the trivially simplest of systems.

Philosopher Kelvin McQueen at Chapman University, California, is more circumspect about IIT and its implications for panpsychism. Panpsychism as an idea originated because some philosophers went searching for the intrinsic nature of the material world and came up empty, he says. Take an elementary particle's inertial mass, which is defined as its disposition to resist acceleration given an applied force. “But what is mass in and of itself that gives rise to that disposition? What's its intrinsic nature?” he says. “The panpsychists like to say, ‘well, the only thing that's intrinsic that we know of is consciousness, so mass is ultimately really a kind of consciousness.’ They imbue consciousness in elementary particles.” However, according to IIT, an individual elementary particle isn't a system that is integrating information. So IIT isn't synonymous with panpsychism. “It doesn't say everything is conscious,” says McQueen. And the universe could be one of those things that isn't, even though it has conscious systems within it. **Anil Ananthaswamy**

10

Does consciousness make reality?

To answer this question, we must first consider how the reality of everyday experience emerges from the more esoteric quantum reality.

A quantum system exists in a superposition of all possible states, which collapses into a single state (classical reality) only when someone or something observes or measures it – at least, according to standard quantum theory. However, this theory fails to define exactly what constitutes a measurement or an observer, and how exactly that collapse happens. Since the 1950s, many theorists have tried to solve this “measurement problem” by getting rid of the need for collapse-causing measurements and observers. The Many Worlds interpretation of quantum mechanics, for example, says that

there is no collapse and that each classical state in the superposition is physically realised in a different world. So-called collapse theories, meanwhile, propose that superpositions collapse randomly into one of the many possible classical states once the mass of the matter in the quantum system crosses some threshold, and so resists superposition. There is no empirical evidence to prove or disprove these ideas.

Another possibility is that consciousness causes collapse. The Nobel prizewinning theorist Eugene Wigner speculated just this in the 1960s. He eventually disavowed his own meanderings, however, and the idea went out of favour, partly because there was no way to formulate such a theory with

mathematical precision. Recently, however, David Chalmers at New York University and Kelvin McQueen at Chapman University in California came up with an admittedly speculative but mathematically grounded account of how consciousness can cause collapse.

Quantum collapse

They start with integrated information theory (IIT), taking it as an exemplar of a mathematical account of consciousness. IIT says that any system that integrates information is conscious. Chalmers and McQueen consider IIT as applied to quantum systems, reasoning that any such system that integrates information can enter a superposition of conscious states.

They then posit that conscious states are resistant to superposition, in much the same way that, in other models, mass that crosses some threshold resists superposition and causes collapse. So if a quantum system enters a superposition of states in which at least one of the states is conscious (according to IIT), then that consciousness will collapse the system.

In this way of thinking, “consciousness creates classical reality”, says McQueen. “But it doesn’t create quantum reality. It’s converting quantum reality into classical reality.”

Previous attempts to solve the measurement problem by appealing to consciousness have run into a major problem: if classical reality requires the presence of conscious humans, how did the universe evolve classically to the point where human consciousness appeared? The new idea avoids this because IIT doesn’t limit consciousness to biological beings. The universe could have begun as a quantum system and continued evolving quantum mechanically until matter first became able to integrate information. This consciousness then started to collapse quantum reality, creating the sort of classical reality we experience today.

Anil Ananthaswamy ■

Emma Young’s new book is *Super Senses: The science of your 32 senses and how to use them* (John Murray)

Anil Ananthaswamy’s latest book is *Through Two Doors At Once* (Dutton)

David Robson is the author of *The Intelligence Trap: Revolutionise your thinking and make wiser decisions* (Hodder & Stoughton)



If you don't look, does classical reality actually exist?

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A better path

Pavements, oddly enough, weren't really made for walking on. It's high time for a rethink, says **Anthony King**

WHEN Viveca Wallqvist first phoned a local asphalt company, she didn't mince her words. "I have something to tell you," she said. "Your material is really hard – too hard. People are getting hurt." Her comments didn't go down well. "They were like, 'Who is this crazy scientist?'" she recalls. Asphalt is supposed to be hard, they said. But a few days later, the company rang back. It was the beginning of a journey that could reinvent the ground we walk on.

Wallqvist's passion is rare. It is more than two millennia since the Romans laid their first *pavimentum*, from where we get the word "pavement". Since then, very few people have questioned the fact that the pavements we walk on are, in effect, extensions of the road surface, made of stuff with properties that almost exclusively reflected the needs of horse-drawn and then motorised vehicles rather than pedestrians. Wallqvist, a materials chemist at the Research Institutes of Sweden in Stockholm, is determined to change that.

Meanwhile, in London, plans are afoot to build a giant research facility to test new, spongier walking surfaces. It is the brainchild of Nick Tyler at University College London, who is also convinced that pavement pounding is harming us. The average person takes around

200 million steps in a lifetime, he notes, and we aren't evolved to deal with such hard surfaces.

So, after waiting more than 2300 years for a pavement evangelist, two have come along at once. You might not read anything into that. On the other hand, perhaps, it's a sign that sidewalks are about to get a makeover.

The Romans were meticulous engineers, famous for their road building. Excavating down almost a metre, they placed flat stones at the bottom, then small stone fragments in mortar. Next came a compacted layer of broken pottery and brick, crushed stone and gravel, mixed with lime mortar. Atop they placed irregular stones about 15 centimetres thick – the *pavimentum*. This remained the pinnacle of pavement technology until the 18th century, when the first modern roads were built. And it wasn't until the 19th century that engineers really began to innovate.

In the 1820s, British engineer Thomas Telford recommended that London's main streets be surfaced with granite slabs. However, hooves and wheels on granite created an ear-splitting din and, by the early 1840s, businesses in busy Oxford Street were petitioning for wooden pavements so they could hear their customers. They weren't alone. In the US, cedar blocks were laid on roads in Minneapolis and

cypress in Omaha. "Lower Manhattan had a network of wood streets in the early part of the 20th century," says Robin Williams, an architectural and urban historian at Savannah College of Art and Design in Georgia. "It's shocking, but it made sense. It was quiet for the banks and trading floors."

Yet wood surfacing had drawbacks. Horses could fall when it became wet or icy, and it decayed in less than five years. The main alternative was macadam, named after Scottish inventor John Loudon McAdam. First laid in the 1820s around St James's Square in London, it consisted of layers of rocks and gravel for drainage, with crushed stones on top. "The stones had to fit comfortably into your mouth, a very human measure," says Williams. Poorly made macadam streets still turned into a quagmire of glutinous mud and equine deposits, however. The solution came with the addition of asphalt (a semi-solid form of petroleum also known as bitumen), to create a smooth, super-absorbent surface called tarmacadam. Even so, around half the streets in progressive, 19th-century cities remained unpaved. "Pavement was expensive," says Williams. Savannah even tried feet-slicing oyster shells, which were a fraction the cost of the alternatives. It also had roads of vitrified ►



TOP: GORDON SCAMMELL/ALAMY; BOTTOM (L/R): FRANCK LEGROS/GETTY IMAGES; DAVID KEITH/JONESIALAMY; THE PHOTO WORKS/ALAMY

Paving materials come in many forms (clockwise from top: granite, cement, marble, cobbles), but being hard makes them less than ideal for pedestrians

“The average person takes 200 million steps in a lifetime. We aren’t evolved to walk on concrete”

brick, granite blocks, cobblestones, macadam and asphalt, a typical late 19th-century medley.

In the 20th century, asphalt gradually became the material of choice. It first gained ground in the US in the 1890s after bicycles were mass-produced and the League of American Wheelmen, a cycling lobby, launched a campaign for smooth-surfaced roads. In 1901, the tarmacadam recipe was perfected with the addition of angular, interlocking stone chips, or aggregate. From the 1920s, with the rise of automobiles, asphalt came to dominate because it allowed for smooth acceleration, whereas car wheels spun on macadam surfaces and chewed them up.

On the margins

Amid all this innovation, pedestrians were barely considered. For most of history, they had to share the highway with other road users. Pavements began appearing in the mid-19th century on the busiest London streets. Initially, all that delineated walkway from street were upright posts, but, by 1881, something like the pavements of today appeared, with granite and limestone slabs used to elevate walkers above the road surface. Nevertheless, engineers mostly neglected the needs of pedestrians. Things haven't improved much since then, according to Tyler. "Footways are not thought about," he says. "They are the gap between the traffic bit and the buildings, both of which get a lot of thought."

Although modern urban roads usually have

Our word for pavement comes from Roman roads like the Appian Way



pavements, Tyler believes they are made of inappropriate materials. He particularly rails against the common use of concrete, a superhard composite of cement, water and sand, gravel or stone. "The human species was not evolved to walk on concrete," he says. "We evolved to walk on savannah." As a result, he argues, unforgiving pavements are responsible for increases in knee and hip replacements, as well as cumulative damage to cartilage, tendons and bones. Intuitively, that makes sense, but evidence is sparse (see "Born to run – on grass", right). "It is really hard to study," says anthropologist Daniel Lieberman at Harvard University. Tyler is giving it a go though.

His group is now working on a pilot study to compare the effects of walking on different surfaces, including concrete and the material used for the London Olympics running track, which has a subsurface made from two layers of vulcanised rubber to increase its give. More than 100 volunteers will be put through their paces, striding 700 times up and down different strips while kitted out with pressure sensors and accelerometers. The results will be fed into a model designed to simulate a lifetime of walking, developed by scientists at Aalborg University in Denmark. "We will put data into that model to see what happens to knee cartilage after 200 million steps," says Tyler.

That's just the start. The team is awaiting the construction of a £50 million research facility in London that will cover 4000 square metres, with 600 square metres of floor space that can be reconfigured with different materials. Tyler dubs it a scientific film set. When it opens later this year, he will be able to build streets 100 metres long and investigate how crowds up to 500-strong interact with the urban environment. "There's lots of work around designing materials for roads, but the only engineering around footways is how heavy a vehicle it can support. There is nothing about what friction or sponginess footways should be," says Tyler. He plans to put softer, spongy material down at the entrance to the facility so that politicians and other visitors can experience the difference. "I don't think there is a policy person in the world who has thought about this," he says.

Wallqvist has come to similar conclusions independently. "It all went wrong from the beginning," she says. Asphalt and concrete are made for cars. "They are so hard. Why should

Born to run – on grass

Our ancestors evolved to walk on the savannah. "We were walking regularly by 5 million years ago," says Madhusudhan Venkadesan at Yale University. "Closer to 2 million years ago, the second big change happened." We became long-distance runners – and that brought a range of physical changes.

Our feet probably became stiffer and more shock absorbent, while our toes shortened to be less prone to stress fractures. Our foot arch functions like a spring for running. And the heel bone sticks out to allow for a larger muscular lever via the Achilles tendon that connects our calf muscle to the bone. "You see changes all the way through our body, even to our neck muscles and head position," says Venkadesan, who studies the biomechanics of animal movement.

Given this heritage, some researchers believe that a lifetime of running – or even just walking – on hard surfaces causes cumulative damage to our bodies. Lifetime damage is difficult to prove, but Isabel Sacco at the University of Sao Paulo, Brazil, and her colleagues have shown how hard, modern surfaces might be causing injuries.

They measured foot pressure in volunteers jogging on asphalt, concrete, rubber and natural grass. Compared with the hard surfaces, grass generated peak pressure between 9 and 17 per cent lower on the rear of the foot, and between 5 and 12 per cent lower at the front. That may not sound like much, but it could have a big benefit. "Annual running-related injury incidence for long-distance runners can be as high as 79 per cent," says Sacco. "One of the well-known risk factors for running-related injury is the running surface."

we walk on them?” As well as the cumulative damage they cause, she is concerned about falls. Research published in 2020 found that in Sweden, falls account for 45 per cent of all injuries. In older adults, more than 60 per cent of falls occur on pedestrian paths. What’s more, around 30 per cent of the damage to someone hit by a car is due to the impact of being flung onto the asphalt. And surface impact is the main cause of non-collision cycling injuries.

Wallqvist decided to do something about this. For the past few years, she has been working with asphalt companies to develop softer asphalt by replacing the hard aggregate with rubber from shredded tyres. “It has nice soft properties,” she says. It is also plentiful, with enough waste tyre rubber produced each year to cover the entire surface of France. In 2017, Wallqvist and her colleagues published results from the first trials of various formulations of their softer asphalt. As well as being more impact-friendly, the addition of rubber also reduced ice formation, an important issue in Sweden. One blend even included phosphorescent silica so that it glowed in the evening.

Softer sidewalks

Since then, this bouncier asphalt has been laid on a small forest track outside Uppsala, Sweden, where walkers and cyclists can try it. An asphalt company also plans to use it to surface a stretch of busy road in Lund, also in Sweden. “In our opinion, this softer material should be standard for every pedestrian and cycle track,” says Wallqvist. She suggests areas outside hospitals could initially be paved with rubberised asphalt as a priority. These new surfaces would be particularly life-changing for older people who are deterred from walking for fear of an accident, she adds.

Rethinking pavements would also help tackle the issue of “pavement poverty” in places where vehicles take priority over pedestrians. Increased access to safe sidewalks could have big health benefits, not just in low-income countries, but also across the US. More than 30 per cent of adults in 122 countries – and nearly half of those in the US – are physically inactive, and studies show that hard, paved surfaces deter people from walking. “We evolved to be physically active and we increase our vulnerability to a wide range of disease

Experimental asphalt being laid in Lund, Sweden. The addition of recycled car tyres makes it safer to walk on and fall on



CARL ZIDE/IMASSBALANS

when we are not,” says Lieberman. These conditions include type 2 diabetes, osteoporosis and heart disease. Physical activity also improves mental health, mood and memory.

The potential benefits of a pavement revolution are clear. Nevertheless, Tyler accepts that cost is a barrier. His Olympic running track surface comes in at around £34 per square metre. Concrete costs just £5 per square metre and, although it might be ugly, it is extremely durable. Of course, there are the health costs of poor paving. “Cheap concrete paving turns out to be pretty expensive when you count the injuries it causes,” says Tyler. But there is another hidden cost: concrete production is a huge source of carbon dioxide. If the cement industry, which produces the chief ingredient of concrete, were a country, it would be the third largest emitter in the world, behind only China and the US. In 2015, it generated around 2.8 gigatonnes of CO₂. That’s 8 per cent of the global total.

By contrast, Wallqvist’s approach comes with environmental benefits. Not only does it use recycled tyre rubber, but including this in the mix can also lower the temperature required for asphalt laying, reducing energy consumption and generating fewer fumes. The current formulation contains around 60 per cent rubber, but Wallqvist hasn’t finished innovating yet. “We are trying to include even

more rubber content. The more the better in terms of impact absorption properties and prevention of injuries,” she says.

Tyler’s work is still very much in the experimental phase, and he anticipates that the key problem will be durability. “How do we get robustness without making the material hard? That’s the challenge,” he says. He wonders about using natural materials such as grass or vegetation. The reason we left those behind is because they don’t cope well with rain and usage. “The holy grail would be to use what we actually evolved to walk on,” says Tyler. “That could be a massive success, but we would need an effective substructural system that could support good drainage.”

Surely, creating better pavements isn’t beyond us, though. After all, it is more than half a century since the first moonwalk. That was the culmination of a massive technological effort – so perhaps what we need are more engineers who are passionate about pavements. “The footway pavement is really the Cinderella of urban infrastructure,” says Tyler. But, as we all know, Cinderella lived happily ever after. ■



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



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Puzzles

Try our crossword, quick quiz and logic puzzle **p53**

Almost the last word

Why do we find out-of-tune music unpleasant? **p54**

Tom Gauld for *New Scientist*

A cartoonist's take on the world **p55**

Feedback

The benefits of bluffing and alien hotspots **p56**

Twisteddoodles for *New Scientist*

Picturing the lighter side of life **p56**

Stargazing at home

The heart of the Milky Way

The dark skies around the new moons of 10 July and 8 August are perfect for peering at the Milky Way's centre, 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

The naked eye
Dark skies
A clear night

EVERY star you can see in the sky with the naked eye belongs to our galaxy, the Milky Way. Most of these, including our sun, are part of a spiral arm that stretches out from the heart of the galaxy.

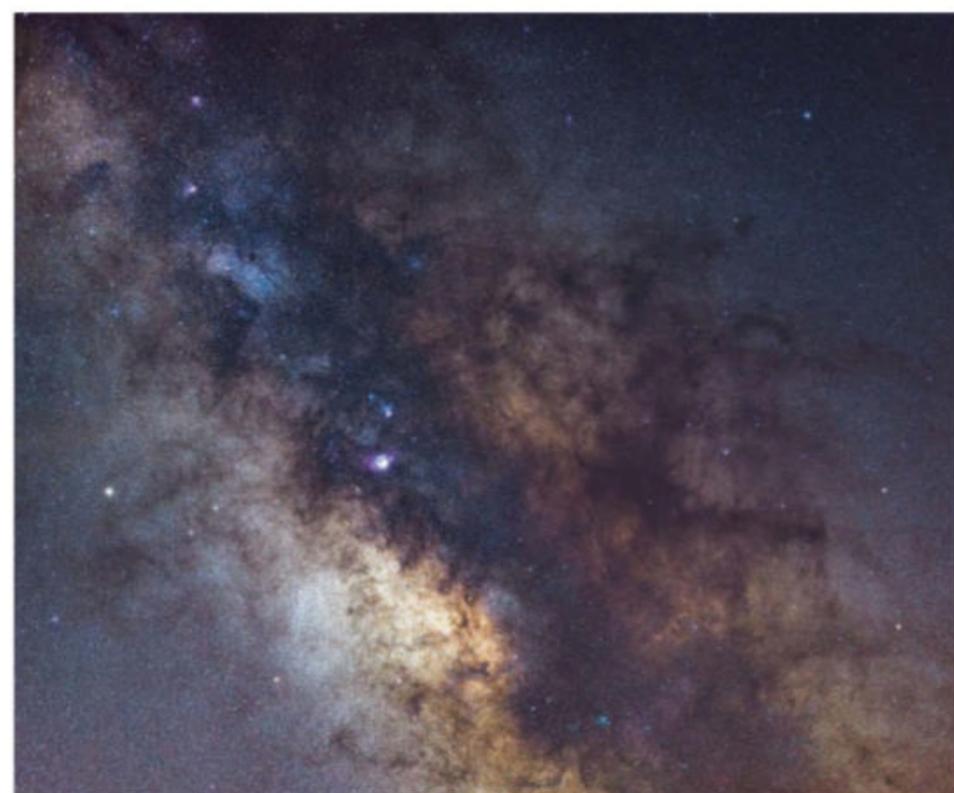
But the Milky Way's dense centre is packed with stars and other spiral arms that sit in a flat disc in space. From our position, the view towards the middle of this disc looks like a band arching across the sky.

Astronomers aren't sure precisely how many stars are contained in our galaxy, but estimates put it at between 100 billion and 400 billion. The central core is one of the densest parts of the galaxy, which means that a lot of these billions of stars lie there.

They are held in place by the huge force of gravity created by a supermassive black hole at the heart of the Milky Way called Sagittarius A*, which is about 4 million times the mass of the sun. Most spiral and elliptical galaxies have a black hole like this at the centre.

Sagittarius A* sits some 26,000 light years from the sun. We can't see the black hole directly, but it is possible to see the bright cluster of stars that lie around it, making up what is called the galaxy's central bulge.

Some part of the disc of the Milky Way is visible all year round, and the area you can see will vary depending on when and where you are looking. The best time to see it is from March to September. The rest of the year, Earth is on the



ANTONIO SOLANO/ALAMY

wrong side of the sun for you to get a perfect view of the centre of the galaxy.

To see the Milky Way's centre, you need dark skies and a clear night. Pick a time when there is little or no moonlight to reduce the glare from our natural satellite and try to go as far away from city lights as you can.

The new moons on 10 July or 8 August would be perfect. Give your eyes time to adjust to the darkness, which should take around 40 minutes.

Make sure that the night is as dark as it can be. This is particularly important in the northern hemisphere if you are trying to see it in the summer months and might mean staying up until the early hours. In the southern hemisphere in July, your

best view is at around midnight.

If the conditions are right, you should have no trouble finding the band of the Milky Way. It will appear as a large, hazy streak across the sky.

The black hole at the core of the galaxy is in the Sagittarius constellation, on the border with the constellation Scorpius. In dark skies, you can clearly see the central bulge and a brighter collection of stars in the region.

In the northern hemisphere, this will be visible when looking south. The best views of the central bulge will be from the southern hemisphere, where it will be high in the sky. ■

Stargazing at home appears every four weeks

Next week

Science of gardening

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

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T340

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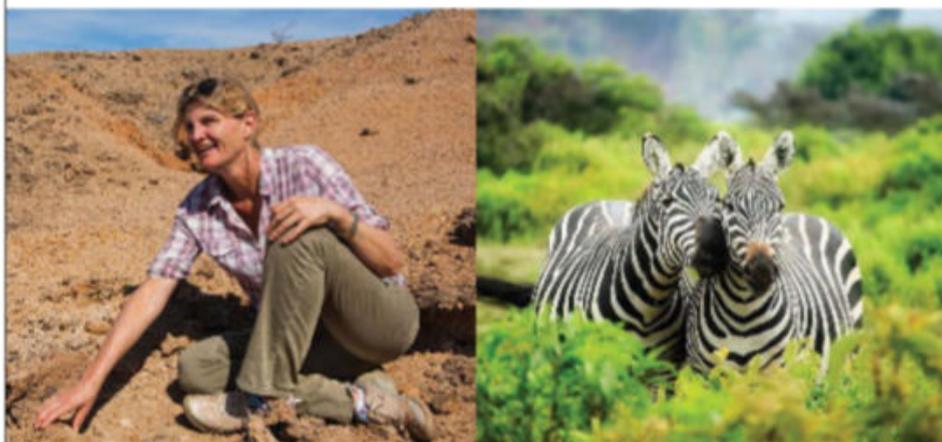
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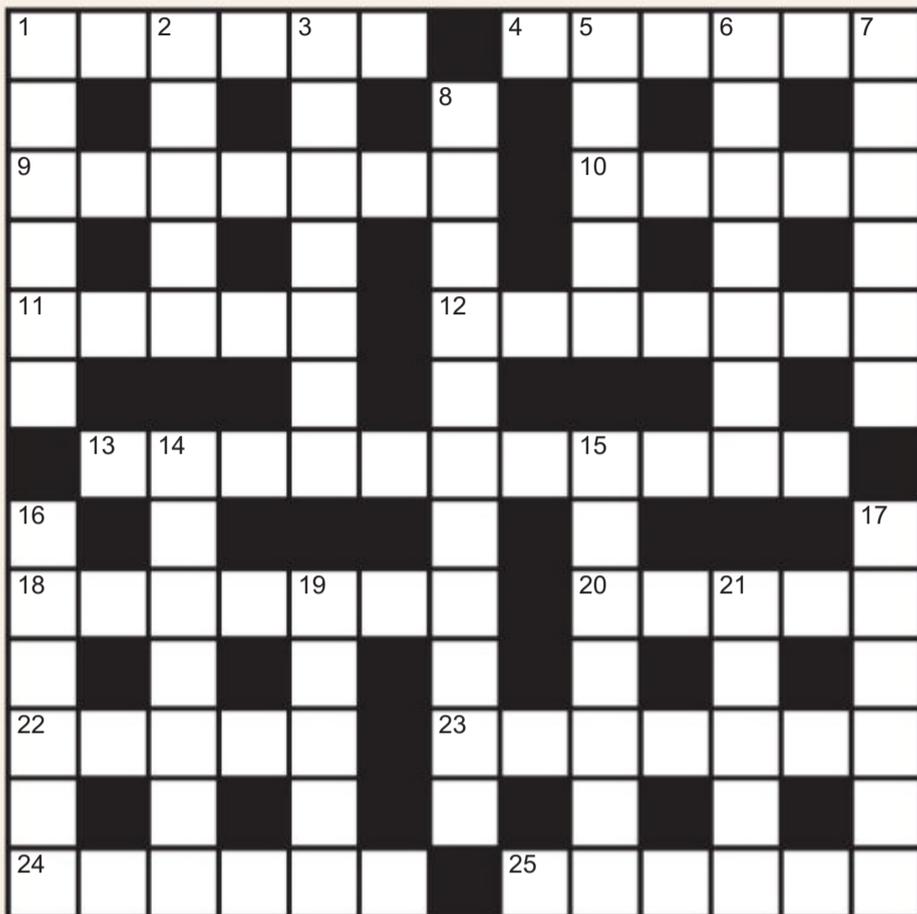
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Cryptic crossword #61 Set by Wingding



Scribble zone

Answers and the next quick crossword next week

ACROSS

- 1** Stork has vaccine, one meeting resistance at university (6)
- 4/1D** Vaccine scientist Jack inspired by wild deer and wren (6,6)
- 9** Medical equipment it's unnecessary to cut end off (7)
- 10** Epoch remembered partly for natural pigment (5)
- 11** South Africa briefly read out student's work (5)
- 12** Energy recycled: time's up! (7)
- 13** Making unpredictable orders, snaring Modi (11)
- 18** Cover incorporated onto iron oxide (7)
- 20** Peculiarly, how setter might make MMR from memory? (5)
- 22** Bathed in light, AstraZeneca took it easy (5)
- 23** Vegetable gets everyone covered by vaccine (7)
- 24** A long way to understand coronavirus's inception (6)
- 25** See 6 Down

DOWN

- 1** See 4 Across
- 2** Drinks, a common vaccine side effect, reportedly? (5)
- 3** Put down in grass and passed on (7)
- 5** Hang fruit for the audience (5)
- 6/25** Composed harmonies that provide 16 (1,4,2,3,3)
- 7** Smart doctor regularly eases malady, finally (6)
- 8** A shame to ignore social media origins for eye condition (11)
- 14** Carbon captured by Portuguese dictator, leaving head in castle (7)
- 15** Atoms reassembled on church organ (7)
- 16** Late prince said to get booster (6)
- 17** Network of science subjects support beginning and end of story (6)
- 19** Intergovernmental organisation expected to be disproportionate (5)
- 21** Listener's handed a concerning variant (5)

Quick quiz #109

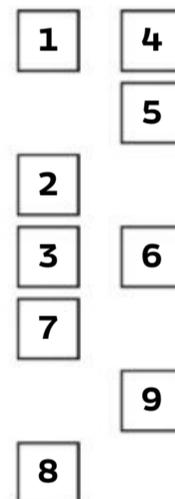
- 1** Who was the first woman to be elected to the French Academy of Sciences as a full member?
- 2** An infection caused by parasitic worms is also known as what?
- 3** What name is given to the effect of the sun's heat on an asteroid's motion?
- 4** In what year was the Tesla coil patented?
- 5** Which filaments secreted by bivalve molluscs let them attach to solid surfaces?

Answers on page 55

Puzzle

set by Rob Eastaway

#121 Creative addition



There is an old adage that one person's "creativity" is another person's "cheating". This week's puzzle will test which side of the fence you sit on.

The numbers 1 to 9 have been written on cards and left on a table: the left-hand column adds up to 21 and the right one to 24. Move just one card so that the two columns add up to the same total. There's a classic "Aha!" solution to this puzzle, but my daughter came up with a solution I wasn't expecting. Since then, I have been offered at least 10 more distinct solutions.

How many solutions can you find that you regard as "creative" rather than "cheating"?

Answer next week



Our crosswords are now solvable online

newscientist.com/crosswords

Musical discord

Why do we experience music that is out of tune as unpleasant?

Hazel Russman

London, UK

It depends on what you mean by “out of tune”. If you are referring to melodies, the answer is that people have built-in expectations of how a tune will develop, based on whatever musical scale their culture uses. If we expect a combination of scale sequences (G, A, B, C, for example) and notes that harmonise with one another (such as E, G and C), then a note that isn’t part of the scale sounds irritating.

If the question refers to discordant harmonies, the answer is more complex. Whenever two notes sound together, we hear an additional “beat” note whose frequency is the difference between the two. If the two notes are sufficiently far apart, the beat note has a high enough frequency to become subconsciously audible. For example, if you play

“The Highland pipes can sound strange and out-of-tune because they are tuned to a scale that isn’t used for anything else”

C and G together, the beat note is another C, an octave below. We experience this coincidence as harmony. A beat note that doesn’t harmonise makes the chord sound ugly.

Julian Money-Kyrle

Whetham, Wiltshire, UK

Two notes sound particularly harmonious together when their frequencies have a simple mathematical relationship, such as the frequency of one note being $\frac{2}{3}$ or $\frac{3}{2}$ of the other.

For example, the interval between the note A (frequency 440 Hz) and an E (660 Hz) has a ratio of 2:3 and is a perfect fifth. One of the notes between them, C,



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This week’s new questions

Superstitious creatures What is the evolutionary reason that we and other animals such as orangutans and pigeons display superstitious behaviour? *Austin Davis, Swadlincote, Derbyshire, UK*

Speed limit How does a photon “know” to travel at the speed of light? *Gideon Wegh, London, UK*

(550 Hz) forms a major third with the A below (ratio 4:5). Deviations from this sound out of tune.

However, music is more complicated than this, and two things that particularly affect our perceptions are whether it matches our expectations, and whether the various musicians are in tune with each other.

It is impossible to devise a perfect tuning system and this problem has plagued musicians since the time of Pythagoras. Many tuning systems – known as temperaments – have been devised. To modern Western ears used to instruments tuned using a system known as equal temperament, music played using other tuning systems can sound quite strange and out-of-tune. You can hear this on recordings

of Johann Sebastian Bach played on historic Dutch and German organs, for instance. The Highland pipes are another example, because they are tuned to a scale that isn’t used for anything else.

The other way that music can sound out of tune is when the instruments in an ensemble aren’t properly tuned to each other. An instrument can also be out of tune with itself. The piano, for instance, has three strings tuned to each note, which give a richness of tone when correctly tuned, but sounds terrible when they go out of tune.

Kevin Conroy

via Facebook

It might be something to do with pain or discomfort – not ours at hearing it, but the pain that causes screams, yelps, off-key cries.

Could there be evolutionary reasons for superstitious behaviour?

When birds sing, they do so with harmonies. When alarmed, however, they squawk and scream. Perhaps the melodious noises represent safety to our “animal” brains and off-key noises represent danger, making us uncomfortable when we hear something out of tune.

Kerry Graf

via Facebook

We like sounds that are natural harmonics of each other. Discordant sounds, like fingernails on a blackboard, have many competing frequencies, and are heard as uncomfortable.

Nolan Francisco Trinidad

via Facebook

When you play music, you first pick your key note, which is a sound of a certain harmonic frequency or pitch. For music to sound in tune, we select the notes that are “multiples” of the key note. If we perform a musical piece in the C major scale, our brain will recognise a pleasant pattern if only the notes from the C major scale are played.

If I play a note that doesn’t belong to the scale – F#, for example – it will stand out as an unpleasant sound. Why? Because our brain recognises patterns, and relates symmetry and balance to beauty and asymmetry and disorder to strangeness.

Dental dilemma

Is toothpaste essential? Aside from fluoride, is there any evidence of its value?

Stephen Johnson

Eugene, Oregon, US

In addition to fluoride, which isn’t always an ingredient, there are additional benefits to toothpaste.

Toothpaste is slightly abrasive, which aids stain removal. It also contains surfactants, which help to lift biofilms. On top of this,



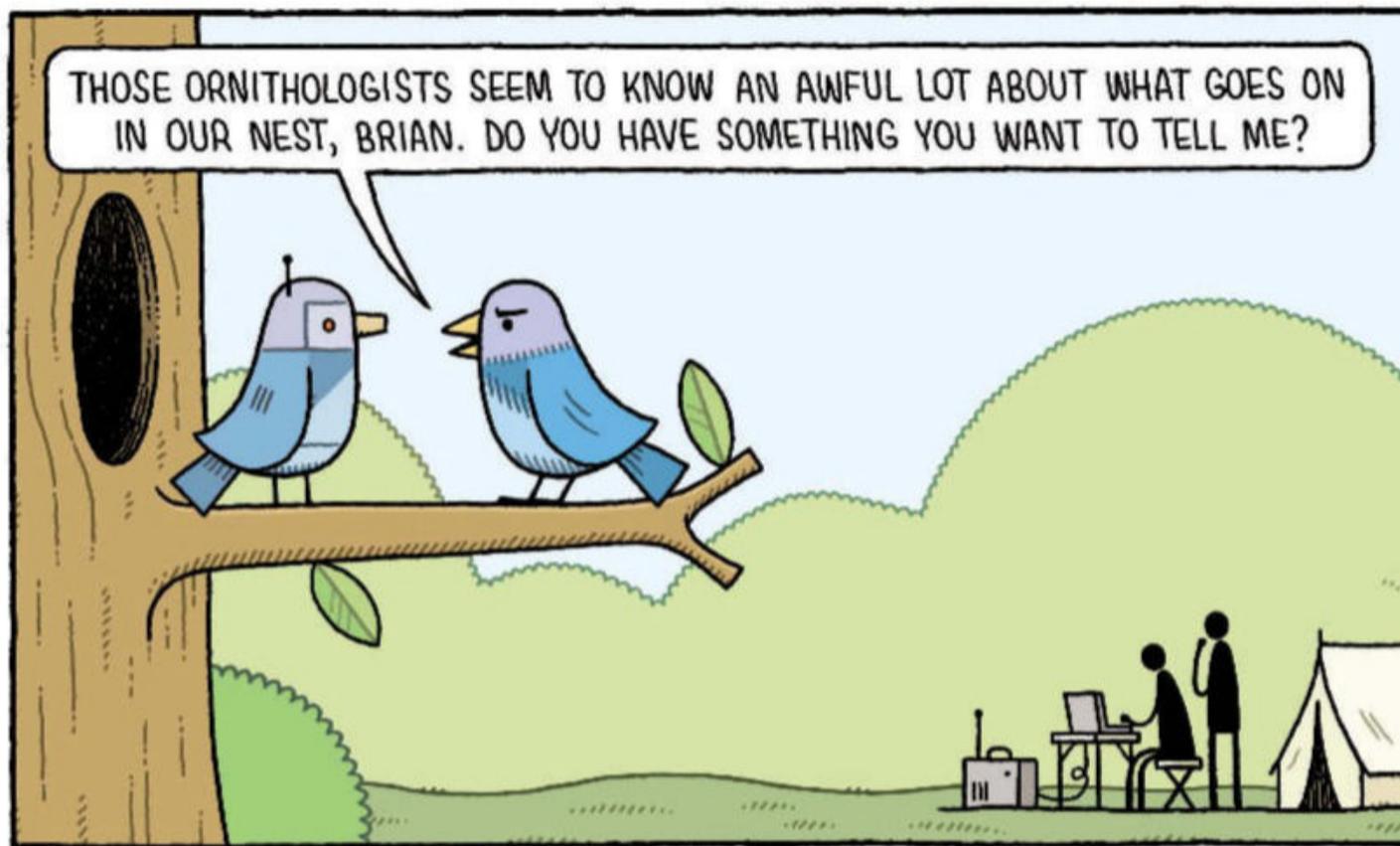
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Tom Gauld
for *New Scientist*



there may be whitening agents, texture modifiers and of course flavourings that attempt to act as breath fresheners.

If fluoride is your goal, there are fluoride varnishes that can be applied in a dental office and prescription toothpaste with much higher fluoride levels.

Tom Smits (dentist)

Zandvoort, The Netherlands

No, it is the brush that is of value. Apart from the fluoride, toothpaste is for the flavour.

Bacteria have to be in a layer at least 2 millimetres deep for the bottom ones to become anaerobic. Only then do they become harmful. The ingredients in toothpaste have no effect on the bottom ones, and to reach these you need a brush. But then you have already solved the problem, by stopping the bacteria building up to a harmful level.

Geert Catteeuw

Roosdaal, Belgium

I have a full dental prosthesis and haven't used any toothpaste for

“A small wheel is less likely to be able to roll smoothly over an obstacle in the path, which isn't great for the rider”

10 years. I scrub the prosthesis with a hard brush and water, and use a softer brush for the gums.

This takes more time than it would if I used toothpaste, and more water, but at least I am not releasing toothpaste into the drain (and the oceans), which I think is a good thing.

Big wheels

Bicycle frames come in different sizes to match the height of the cyclist, but the wheels stay the same size. Would there be any benefit in a taller rider having bigger wheels? (continued)

Michael Paine

Sydney, Australia

The previous discussion about bicycle wheel size is related to

several road safety projects that I have undertaken on recreational scooters, children's bicycles and mobility scooters, which have small wheels compared with road bikes.

A small wheel is less likely to be able to roll smoothly over a relatively small obstacle in the path. This is a simple geometric relationship – the contact force (which is effectively at right angles to the tyre surface) will have a larger horizontal component with a smaller wheel. This means that the vehicle will experience a larger deceleration than a vehicle with larger wheels and may even stop suddenly, which isn't great for the rider.

The safety tests that I used for my projects included an obstacle test that demonstrated this relationship. The mobility scooter requirements, which are now part of a Standards Australia technical specification, include a raised obstacle test as well as a simulation of the gap at a railway level crossing, which has similar geometric challenges. ■

Answers

Quick quiz #109

Answers

- 1 Yvonne Choquet-Bruhat, in 1979
- 2 Helminthiasis
- 3 The Yarkovsky effect
- 4 1891
- 5 Byssus. These filaments can be spun into sea silk, a rare fabric

Quick crossword #86

Answers

- ACROSS** 1 In sum, 4 Limestone, 9 Colitis, 10 Cornell, 11 Dirac, 13 Rowan, 15 DLR, 16 NHS, 17 Ratio, 19 Cubic, 21 Ethyl, 23 Sigma, 24 PMT, 25 Arc, 26 Curie, 28 Pilot, 29 Iceberg, 31 Heparin, 33 Gasometer, 34 Tesla

- DOWN** 1 Incidence, 2 Solaris, 3 MIT, 4 Laser, 5 Mac, 6 Siren, 7 Overdub, 8 Euler, 12 Coral, 14 Wrong, 18 Taser, 19 Cramp, 20 Catatonia, 22 Hackers, 24 Polaris, 25 Aging, 26 Cream, 27 Ether, 30 Gut, 32 Pit

#120 More Catch up Solution

Yes, Ann can guarantee victory. A tower of 23 or more will win the game for Ann, so she needs to add at least 15 to her current tower of height 8.

If Bob takes stack 9 (call the move "B9"), Ann plays 7 (A7), and can follow that with A8 or A4 & A6 depending on Bob's next move. Likewise, she can force a win with the following moves: B8-A9 ; B7-A6; B6-A8. The only other option for Bob is B4 then B6/7/8/9, which Ann can follow with A9 or (if 9 is already taken), A8. It is deceptively difficult to develop a general strategy for this game.

Would we lie to you?

We are truth-seekers in the knowledge multiverse, seeking an uncertain path towards enlightenment through a cascade of collapsed quantum realities.

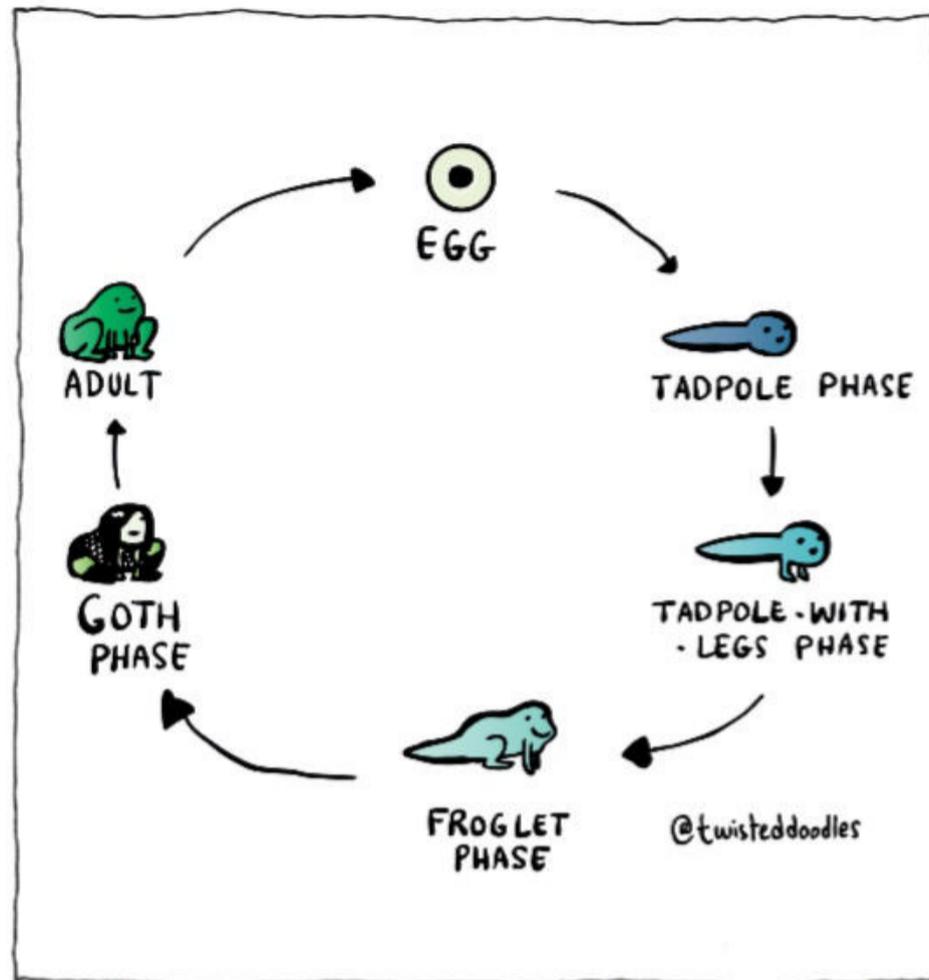
Feedback types this sentence with only half an eye on a new paper in the journal *Evolutionary Psychology* from Martin Harry Turpin at the University of Waterloo, Canada, and his colleagues, titled "Bullshit Ability as an Honest Signal of Intelligence".

We were of course aware that bullshitting – defined helpfully by the researchers as "an intent to be convincing or impressive without concern for truth" – was a highly active area of psychological research long, long before a colleague waved this paper in front of our nose with a meaningful stare. Although naturally we favour the characterisation of bullshit in Daniel Mears's 2002 classic paper "The ubiquity, functions, and contexts of bullshitting" as "misleading, yet possible, though frequently improbable, accounts or impressions of self or reality".

In this latest study, the researchers first analysed participants' willingness to bullshit by asking them to rate their knowledge of 10 concepts, four of which didn't exist. Ability to bullshit was then tested by subdividing participants into Bullshit Producers, who were tasked with coming up with explanations for the concepts, and Bullshit Raters, who were asked to rate how satisfying they found them. Finally, the susceptibility of all participants to bullshit was measured by getting them to rate the profundity of 10 meaningless, but grammatically plausible, statements, 10 motivational quotations – a sort of halfway house to bullshit, we imagine – and 10 mundane statements.

The headline result – that ability to bullshit was correlated with high intelligence as measured via independent tests – masks a wealth of insights worth taking into the next management seminar or similar celebration of bullshit.

Twisteddoodles for New Scientist



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Consideration of items sent in the post will be delayed

Ability to bullshit proved to be unrelated either to susceptibility to bullshit or willingness to bullshit, suggesting that perhaps sometimes you just need to get over yourself. A high ability to bullshit led to the bullshitted assessing bullshitters as more intelligent, suggesting it is highly worthwhile doing so.

Interestingly, willingness to bullshit was also correlated to susceptibility to bullshit, proving, in the researchers' words, that "it may indeed be possible to 'bullshit a bullshitter'". Given we find all the insights from this study highly intelligent and convincing, we are now slightly worried.

Left hanging

The dangling modifier is the cruellest of syntactical misconstructions, and few of us don't descend into gibberish when

we have a microphone suddenly shoved into our faces. So we have every sympathy with the passer-by who, when asked on ABC news last week whether he had seen the southern right whale recently spotted cavorting in Wallis Lake in New South Wales, Australia, exclaimed happily: "Yes, I saw it driving across the bridge!" Give them time, give them time.

A rather less explicable example, combining a new and alarming addition to the cosmic zoo with one of our favourite entirely unintelligible measurement comparators, comes courtesy of a pull-quote in a *Guardian Weekly* article on gravitational waves, declaring "50m – The number of elephants weighing the same as a thimbleful of merging neutron stars once they stop collapsing, sending GWs through space".

Our thanks to Barry Smith-

Roberts and Tim Stevenson for those. We can only marvel at the wonders of evolution reading these things.

They shall not grow old

Meanwhile, *The Times* declares in a leader article spotted by Hilary Johnson that "another extinct human, *Homo longi*, has been found in China, which scientists believe could be our closest living relative".

This is perplexing on many levels, although not as personally distressing as the BBC News website headline "5,000-year-old man was 'oldest plague victim'". As Alex Hodge points out, that must have been a bumper after he made it that far.

Heavens above

Neatly combining two of last week's items, on importunate PR emails and new attempts to explain unidentified aerial phenomena, or UAPs, a PR agent for psychicworld.com writes asking us whether we had received their previous communication.

Narrowly avoiding the obvious joke, we concentrate on the substance, which is a league table of European countries ranked according to their number of "alien visits". That Ireland by far and away tops the list, with 105 sightings of UAPs, mainly in the form of "light formations" lasting an average of 13 minutes, we can only ascribe to the confusing atmospheric conditions that often prevail late at night on the Atlantic seaboard.

Alien intelligence, for we are apparently assuming that is what it is, seems least interested in San Marino. The landlocked Apennine country recorded a grand total of zero sightings lasting 0 minutes across the unidentified time periods, or UTPs, that the numbers cover.

Oddly, there is no figure given for the other tiny Italian enclave, Vatican City. This we can only put down to a desire not to skew the statistics. ■

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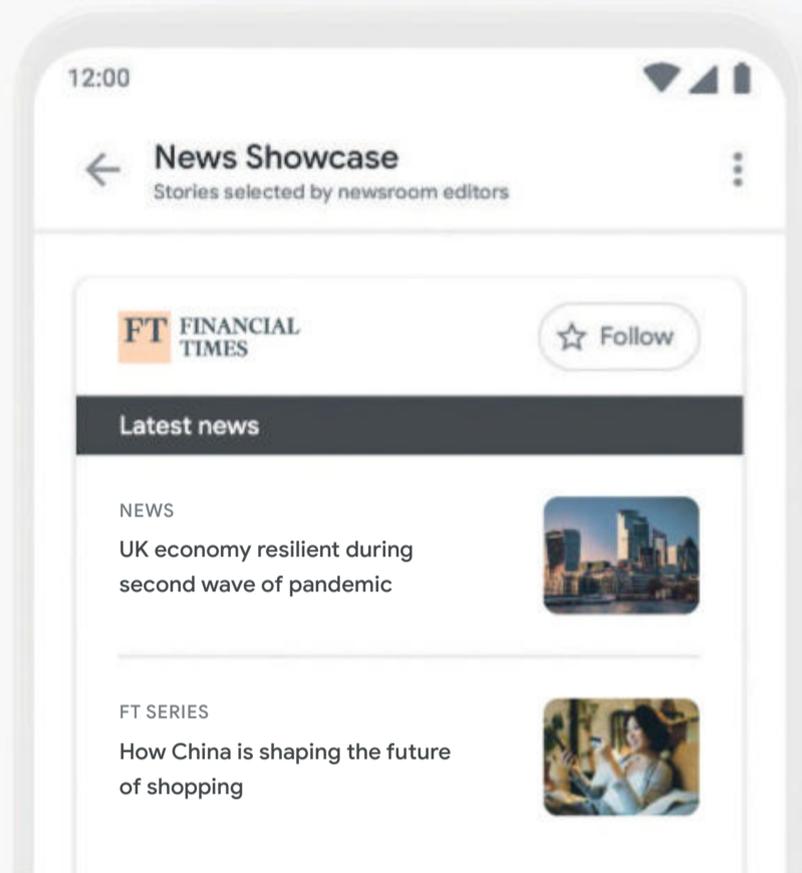
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