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WEEKLY October 17–23, 2020

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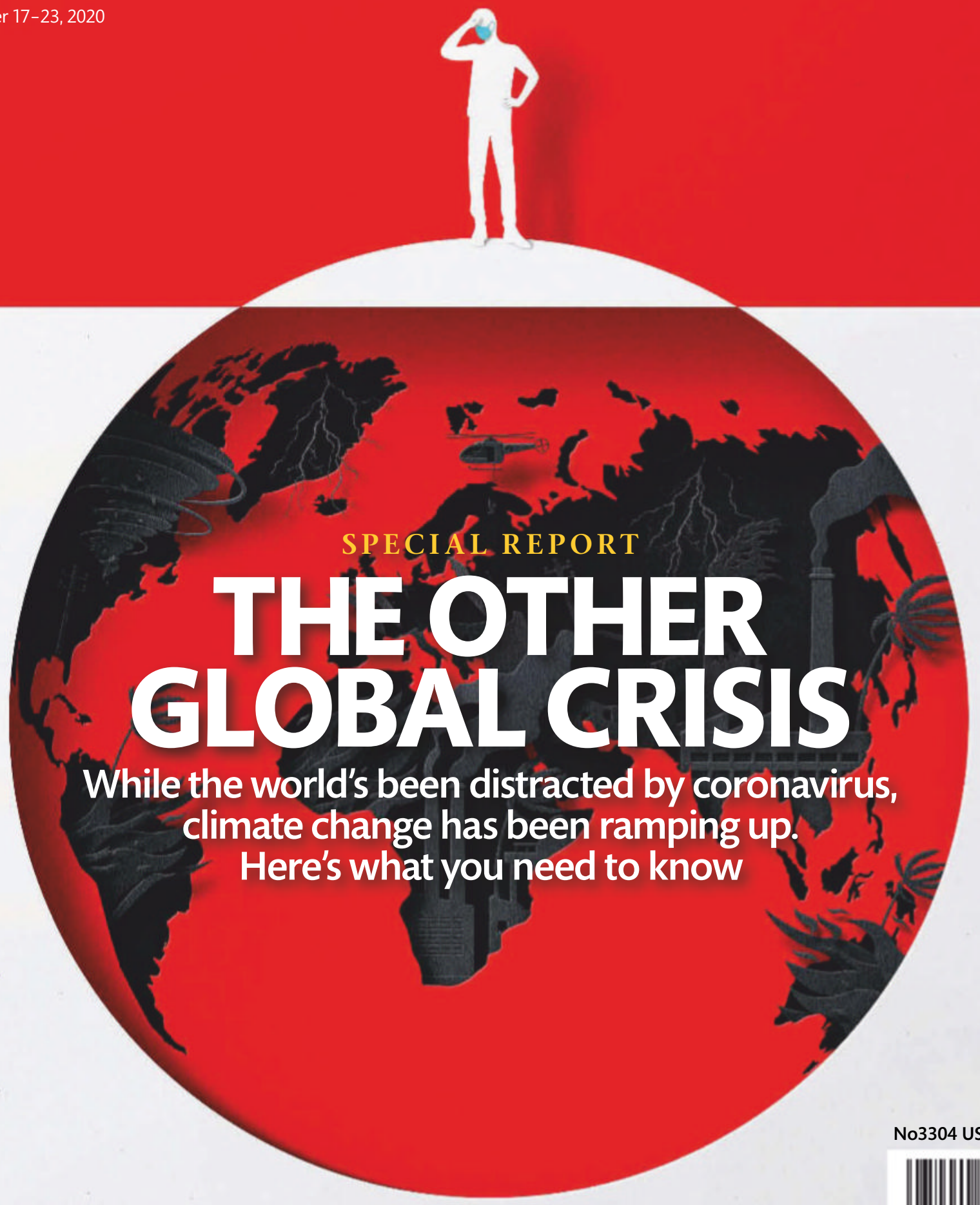

SPECIAL REPORT

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This week's issue

On the cover

34 The other global crisis
While the world's been distracted by coronavirus, climate change has been ramping up. Here's what you need to know

Vol 248 No 3304
Cover image: Eiko Ojala

40 How to make an extra dimension
Quantum trickery creates new directions in space

45 Er, like, what?
The secret signals we send with our ums and ahs

10 Sonic zoom
We now know the ultimate speed of sound

8 Naked mole rats attack
11 Stone Age people of Ireland
12 Your coronavirus questions answered 20 Aquatic asteroid

40 Features

"With the shackles of traditional dimensions cast off, things could quickly get wild"

News

8 Earth 2.0
Planetary digital twins could help us tackle climate change

9 Where's the beef?
Dairy cows are being implanted with beef cattle embryos to boost profits

16 Cold season
How the covid-19 pandemic affects other diseases

Views

23 Comment
We must pay attention to the subtle effects of climate change, says Hannah Cloke

24 The columnist
Graham Lawton on finance and climate change

26 Letters
Life beyond our planet

28 Aperture
Prize-winning photo of orphaned macaque for sale

30 Culture
New documentary on the impact of online media

NASA/GODDARD/UNIVERSITY OF ARIZONA

20 Water, water everywhere NASA reveals asteroid Bennu's secrets

Features

34 The forgotten crisis
How has the climate been faring as the world has grappled with the coronavirus pandemic?

40 Synthetic dimensions
We have begun to cook up extra dimensions in the lab and investigate what lurks within

45 Er, like, what?
Our ums and uhs are a hidden language we all understand

The back pages

51 Stargazing at home
Spotting the Red Planet as it orbits near Earth

52 Puzzles
A cryptic crossword, a bridge too far and the quiz

54 *Almost* the last word
Why are cabbages made up of a tight bundle of leaves?

55 Tom Gauld for *New Scientist*
A cartoonist's take on paradoxes

56 Feedback
Coronavirus erotica and black hole bargains

Elsewhere on New Scientist

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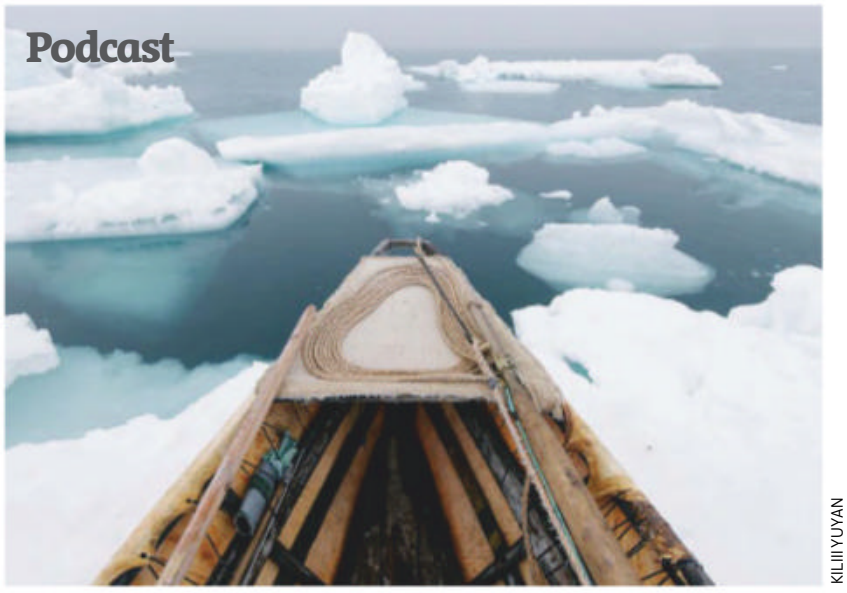

KILIII YUYAN

Thin ice How Arctic peoples dealt with climate change in the past

Video

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Get a digest of the week's most essential health stories, including the latest covid-19 news, in your inbox every Saturday, carefully curated by *New Scientist* health reporter Clare Wilson.

Clare Wilson

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The other emergency

Covid-19 has delayed climate action, but we have the technology to make big changes

AT THE height of the first wave of coronavirus lockdowns, we commented here on the falls in pollution and carbon emissions because of car-free roads and plane-free skies. We also warned that "we must be realistic that this will have little if any long-term effect on global warming" (*New Scientist*, 30 May, p 5).

Five months on, and the scores are on the doors. Global emissions are indeed more or less back to where they were before the pandemic. Meanwhile, more valuable time has been lost in creating a workable plan to restrict global warming to the "safe" level of 1.5°C set out in the 2015 Paris agreement (see page 34).

Yet the coronavirus pandemic has shown us that another world is possible. Governments can act decisively: in the words of natural hazards researcher Hannah Cloke, we now have "more than enough precedent to spend money to save people's lives" (see page 23). And individual behaviour and culture can change in weeks rather than years.

True, the emissions bounceback has shown us limits to behavioural change. But no serious plans advocate harmful coronavirus-style restrictions as a template for how to drastically cut emissions. Systems need overhauling, with sweeping, deep-reaching changes to how we power our homes, industry and transport, and how we use land.

"What happens next will depend on the colour of post-pandemic financial stimulus, and the technologies that leaders back"

The good news is that the technology and know-how to do that now exists, in ways it perhaps didn't even a decade ago. What happens next will hinge on the colour of the financial stimulus that follows the pandemic, and the technologies that leaders back. They need to be green.

As this week's columnist, Graham Lawton, points out, individuals aren't powerless to effect systemic change, either. Bare economic reality is already greening the financial system. Anyone lucky enough to have a pension or other savings pot can exert pressure to accelerate that process (see page 24).

Coronavirus won't be the last crisis the world faces as climate change grinds on. The mathematics of cutting carbon emissions demands that, like covid-19 vaccine trials, we must tackle these crises in parallel, not in series. It is time to start firing on all cylinders. ▮

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Post New Scientist, PO Box 3806, Chesterfield MO 63006-9953

 New Scientist ISSN 0262 4079 is published weekly except for the last week in December by New Scientist Ltd, England. New Scientist (Online) ISSN 2059 5387.
New Scientist Limited, 387 Park Avenue South, New York, NY 10016

Periodicals postage paid at New York, NY and other mailing offices
Postmaster: Send address changes to New Scientist, PO Box 3806, Chesterfield, MO 63006-9953, USA. Registered at the Post Office as a newspaper and printed in USA by Fry Communications Inc, Mechanicsburg, PA 17055

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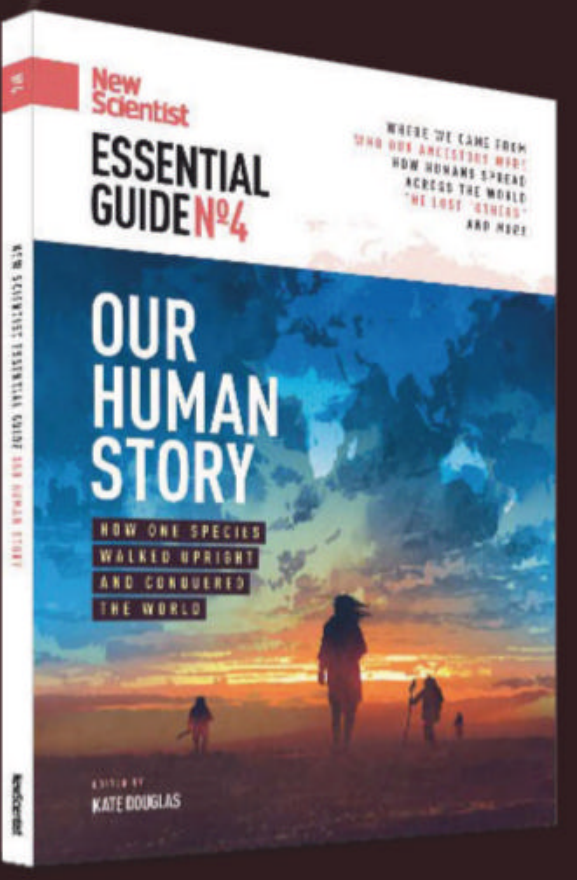

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Patrons in a pub in Liverpool watch the news that bars there must close

England

Three-tier covid-19 alert

The UK government ignored scientific advice and is bringing in three levels of restrictions for England, reports **Layal Liverpool**

A NEW three-tier system for setting coronavirus rules in England was announced by UK prime minister Boris Johnson on 12 October. The approach falls short of advice from science advisers who called for tougher measures several weeks ago.

Under the new framework, which began on 14 October, different sets of restrictions of increasing severity will be applied to separate regions based on infection rates, as well as the rate at which infections are rising.

Speaking in parliament, Johnson said that the system was intended to simplify and standardise current measures, which already vary according to region and have been criticised for being overly complicated.

The new system begins with a lowest alert level called medium, or tier 1, rising to high (tier 2) and then very high (tier 3).

The Liverpool city region, which recorded around 600 cases of covid-19 per 100,000 people in the week ending 6 October, has been classed as tier 3. Those living in the area aren't allowed to meet people from different households indoors and in some outdoor settings, except members of a support bubble, while gyms, pubs and some other businesses are required to shut until the measures are reviewed.

Most regions that already had some form of additional restrictions are under tier 2, meaning that people aren't allowed to mix with those from other households indoors. This medium alert level covers most of England. Measures include the rule of six, which limits gatherings to six people, and a 10 pm closing time for restaurants and bars.

"This is not how we want to live our lives," said Johnson during the announcement. "But is the narrow path we have to tread between social and economic costs of a full lockdown and the massive human – and, indeed, economic – cost of an uncontained epidemic."

Some scientists have welcomed the simplification of the rules. "The introduction of a three-tier system does provide greater clarity," said Linda Bauld at the University of Edinburgh, UK, in a statement. Bauld said the new guidelines are in line with recent evidence linking infections to contact between households and visits to hospitality venues.

However, documents released on the same day as the announcement reveal that scientific advisers called for more stringent measures weeks ago, raising concerns that the new system may be too little, too late.

A paper from the government's Scientific Advisory Group for Emergencies dated 21 September includes a recommendation of a two-week "circuit-breaker" lockdown to curb the spread of infections in the UK. Not acting now to reduce cases "will result in a very large epidemic with catastrophic consequences in terms of direct COVID related deaths and the ability of the health service to meet needs", the group wrote.

Other recommendations that also weren't implemented at the time include banning contact between different households other than members of a support bubble, closing bars, restaurants, cafes, indoor gyms and personal services such as hairdressers and moving almost all university and college teaching online.

James Naismith at the University of Oxford has warned in a statement that delaying action now could lead to more stringent measures later on: "There is a risk that we will end up having to lock down again (perhaps with a different name but in effect the same thing). If we do so the duration of lock down will likely be longer as a result of delay."

Climate change

Virtual Earths to be created

Digital twins of Earth that model human and physical systems in detail could help plans to mitigate climate change, says **Adam Vaughan**

WORK is set to begin within months on building "digital twins" of Earth to better predict the future of climate change, extreme weather and the environment. The Destination Earth project aims to create a tool for everyone from politicians to energy companies to simulate in unprecedented detail how human and physical systems will change in a warming world.

Three digital twins are initially planned. These simulations, built on satellite and field data, will cover extreme weather and disaster risk management, climate change adaptation and the oceans. More twins will come later.

The European Union is funding the project and sees it as vital to informing government decisions on the EU's Green Deal, which aims to reduce carbon emissions to net zero by 2050. For example, some twins could let policy-makers model the impact of swapping out gas power stations for renewables, or one crop for another.

"It's key for us and future generations. We have so much data and computing and we need to use it better to support environmental objectives," says Massimo Craglia at the European Commission's Joint Research Centre

Peter Bauer at the European Centre for Medium-Range Weather Forecasts (ECMWF), one of three groups being consulted on the project, says it will accelerate efforts to model Earth at a national or regional level that policy-makers can use. Destination Earth should bring a dramatically improved level of mapping resolution – greater detail at a local level – than most observations and modelling today. It will also use machine learning to make sense of the patterns in the petabytes of data produced daily by the European Space Agency (ESA), the ECMWF and the European Organisation for the Exploitation of Meteorological Satellites.

Digital twins of Earth could help inform policy-makers

"It's certainly a level up, in terms of getting a better insight into the processes of our planet, with different observations and modelling and AI," says Josef Aschbacher at ESA. It will also help examine scenarios such as how extreme weather will affect a specific city for the next decade or how southern Europe will have to adapt as more arid conditions lead to more fires and drought, he says.

The digital twins won't replace climate models, says Bauer. However, they could help climate scientists by allowing them to plug their models into the system to run at a better resolution, with more processes such as cloud formation and with more "ensembles" of models, in which parameters are slightly tweaked and models run many times to assess likely outcomes.

The budget for the project hasn't been published yet, but Bauer says it will be significant. An earlier vision of a similar scheme known as Extreme Earth had been allocated a budget of €10 billion over 10 years before it was axed, but Destination Earth will probably cost less. If a budget is agreed by the European Commission before the year's end, as is hoped, work will begin on Destination Earth early next year. The twins should then be available for use by 2023. ▮

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Animals

Naked mole rats invade their neighbours

THOUGH normally the most sociable of mammals, naked mole rats have been seen invading neighbouring populations and even kidnapping newborn pups, which become workers in the conquering colony.

The mole rats (*Heterocephalus glaber*) are one of a handful of mammal species that are eusocial: they live in large underground colonies in which most members are sterile workers and only one individual, the queen, reproduces, similar to honeybees.

Stan Braude at Washington University in St Louis, Missouri, and his colleagues observed the animals attacking their neighbours in the 1990s, but couldn't confirm their suspicions.

The researchers were tracking colonies of naked mole rats in Meru National Park, Kenya, and noticed 26 examples of colonies expanding their territory into burrows previously occupied by others. The team repeatedly captured entire colonies, marked each animal, then returned them to their burrows. This allowed them to track individuals over successive years.

In May 1994, they began capturing two neighbouring colonies and noticed that the queen of one had wounds on her face, suggesting that the other colony had attacked. They put the animals back in their burrows, but the following year they found two pups from the attacked colony living as workers in the other one.

"Naked mole rats live in underground colonies in which most members are sterile workers"

For years, Braude suspected he had simply made a mistake. "We just didn't have the tools to make sure that I hadn't totally screwed up," he says. Now, genetic analyses of tissue samples from the original animals have confirmed that the pups really had ended up in a different colony (*Journal of Zoology*, doi.org/fctc). It seems the pups became completely integrated into their new home. ▮

Michael Marshall

Archaeology

Eurasia's oldest known balls may have been for sport

Colin Barras

THE first ball games in Eurasia may have been played 3000 years ago, according to a new analysis of three leather balls unearthed in an ancient cemetery in northern China.

The Yanghai cemetery contains more than 500 graves and was in use between about 3200 and

PATRICK WERTMANN

Balls like this one were stuffed with either leather strips or with wool and hair

1850 years ago. Archaeologists working there a few years ago uncovered three leather balls from three graves. The balls, each about 9 centimetres in diameter, had been stuffed with either leather strips or with wool and hair. Two of them had a red cross painted on one side.

They were first thought to be 2400 to 2800 years old, making them the earliest known balls in Eurasia. Patrick Wertmann at the University of Zurich in Switzerland and his team have now carbon-dated the wool stuffing of one ball and concluded it is between 2930 and 3210 years old. They also carbon-dated artefacts from the graves that yielded the other two balls. They fell within the same range (*Journal of Archaeological Science: Reports*, doi.org/fcr2).

Ten curved, wooden sticks were also found in the cemetery, similar to those used to play polo, a game for horseback riders. Whips and riding trousers in the graves suggest the men buried with the balls rode horses. But the "polo" sticks came from much younger graves. We can't be sure what the balls were for, but Wertmann suspects they were used in some kind of sport – played perhaps for exercise, for fun or as part of military training. ▮

Farming

Dairy cows are bearing beef cattle to boost profits

Michael Le Page

FARMERS in the US have begun implanting dairy cows with the fertilised embryos of beef cattle, so they produce calves bred for beef rather than for milk production. The idea is to make dairy farming more profitable.

Cattle have been bred for either milk or beef production. Beef breeds typically put on more muscle faster for less food than dairy cattle do, and the meat quality is better. This makes beef calves far more valuable than male dairy calves, which are often killed immediately after birth.

Select Sires in Minnesota has trialled the implantation of beef cattle embryos and is now commercialising the technique. "It's in its infant stages," says Chris Sigurdson at Select Sires, but the company hopes the practice will become routine. "That's the vision."

If it does catch on, it would also help reduce the industry's substantial greenhouse gas emissions, says Alison Van Eenennaam at the University of California, Davis. "It really alters the sustainability metric."

Dairy cows must keep having calves to keep producing milk. Female dairy calves can be used to replace ageing cows, but male dairy calves aren't as valuable as those bred for beef production. Some farmers kill male dairy calves after birth because it often costs more to raise them than they can be sold for.

These calf deaths have been reduced by the growing use of reproductive technologies. Many dairy cows are now inseminated with semen from dairy bulls sorted to remove sperm with a Y chromosome. This means the resulting offspring are nearly all female.

But if every calf were female, there would be too many. So, about half the time, dairy cows are inseminated with semen from beef bulls. The resulting cross-breed calves are more valuable for meat production than male dairy calves.

In the US, this is standard practice on large dairy farms and it is taking off elsewhere. The problem is, demand for the cross-breed calves is falling in the US. "Their value is declining sharply," says Sigurdson.

If beef embryos are implanted instead of just using beef semen, female dairy cows can produce pure beef offspring that are worth even more than the hybrids, more than making up for the higher costs of implanting embryos.

"Some farmers kill male dairy calves after birth because it isn't economical to raise them"

Cattle are responsible for around 10 per cent of all greenhouse emissions. Having a female cow that produces milk plus a cross-breed or pure beef calf in a year is more efficient than feeding a dairy cow plus a beef cow for a year to get one beef calf, says Van Eenennaam. Dairy cows also produce less methane because they are fed richer foods, she says.

"That's a bigger impact in terms of emissions than anything that's going to happen with genome editing," she says.

Phil Brooke from Compassion in World Farming says the organisation supports the use of sexed semen because it improves welfare – by reducing the number of unwanted males – as well as production. "It ticks all the boxes," he says. But the organisation is opposed to embryo transfer, he says, because it is more invasive than insemination and the larger size of beef calves could increase the risk of dairy cows having difficulties during birth.

Van Eenennaam says the procedures are equally invasive. ▮

A herd of cows at a dairy farm in Pickett, Wisconsin

MORRY GASH/AP/SHUTTERSTOCK

Physics

Ultimate speed of sound has finally been pinned down

Leah Crane

THE maximum speed of sound in a solid or a liquid has just been calculated for the first time. It is about 36 kilometres per second, more than 8000 times slower than the speed of light.

We have known the universal speed limit of electromagnetic waves travelling through a vacuum for over a century, but the limit for sound, which requires a medium, has been elusive until now.

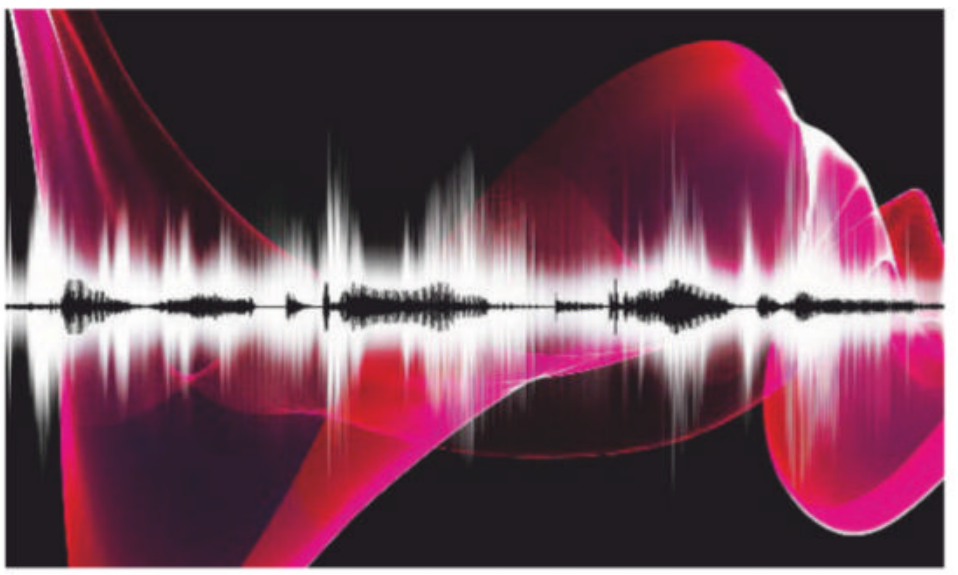
To calculate it, Kostya Trachenko at Queen Mary University of London and his colleagues started with two well-known physical constants: the ratio of proton mass to electron mass, and the fine structure constant, which characterises the strength of interactions between charged particles.

Trachenko says we have a pretty good idea of these values, because if they were changed even a bit, the universe wouldn't look at all like it does. "If you change these constants by a few per cent, then the proton might not be stable anymore, and you might not even have the processes in stars resulting in the synthesis of heavy elements, so there would be no carbon, no life," he says.

Sound is a wave that propagates by making neighbouring particles interact with one another, so its speed depends on the density of the material it travels in and how the atoms within it are bound together. Atoms can only move so fast, and the speed of sound is limited by that movement.

Trachenko and his colleagues used that fact along with the proton-electron mass ratio and the fine structure constant to calculate the maximum speed at which sound could theoretically travel in any liquid or solid. They found it was about 36 kilometres per second (*Science Advances*, doi.org/ghd8j4).

Sound waves travelling in liquids or solids top out at 36 kilometres per second



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"The common wisdom was that diamond has the highest speed of sound, because it is the hardest material, but we didn't know whether there was a theoretical fundamental limit to it," says Trachenko. The theoretical limit is about twice the speed of sound in a diamond.

The speed of sound is also dependent on the mass of the atoms in the material, so the researchers predicted that solid metallic hydrogen – a material that theoretically exists at the centre of giant planets, but for which laboratory evidence has been hotly contested – should have the highest speed of sound. They calculated that it should be close to the theoretical limit.

They also looked at experimental data for more than 130 materials and found that none of them broke the limit.

However, Graeme Ackland at the University of Edinburgh in the UK says that it isn't clear the calculations produce a speed limit. "You can use these fundamental constants to get something with units of velocity, but I can't quite see a good fundamental reason for why it is a bound. I'm not completely convinced," he says.

Ackland says that more work is necessary to find exactly how the approach applies to sound moving through heavier elements. ▮

Technology

AI can alter the timing of just one object in a video

EXPECT more startling video special effects soon. A neural network can distinguish between people and objects in footage, and speed up or slow their movements separately while ensuring they interact smoothly. This could be used to dramatise or de-emphasise motion or events caught on film.

To achieve this, a team at Google and the University of Oxford split each frame of video into separate layers and taught an AI to identify the people or objects in them.

This neural network homes in on the things in each layer by focusing on their movements. Then it further separates each object or person onto its own layer. The background is isolated into another layer.

It also tracks the way people or objects interact with the world around them in the video. "You also have to change the things in the scene that move with them – their shadows, reflections or water splashes," says team member Erika Lu at the University of Oxford.

These details are picked up by the neural network and sped up or slowed down. That is done by deep learning, associating the elements around an object with the object itself. Previously, elements had to be highlighted by hand – a time-consuming, costly process.

The AI stitches all these things back together after altering them. The result is the ability to speed up, say, one pair of ballroom dancers and slow down another in the same video, near-seamlessly masking the moment they cross over each other (arxiv.org/abs/2009.07833).

"Details like shadows, reflections and water splashes are also sped up or slowed down"

"The paper will inspire further development of such techniques for advanced video editing in the future," says Jia-Bin Huang at Virginia Tech University.

Huang points out that the method used requires training the AI on each individual video, making it time-consuming. In addition, the authors say that the neural network struggles to pick up things such as flashing lights as objects that need to be discretely animated. ▮

Chris Stokel-Walker

Archaeology

Ancient Irish genes

Stone Age people in Ireland had dark skin and were lactose-intolerant

Michael Marshall

SOME Stone Age people in Ireland left their dead to decompose in a rocky chamber on a mountain. Genetic analysis of two of these bodies shows they had darker skin, like many people in Europe at the time.

The chamber was discovered in 2016 by a hillwalker exploring Bengorm mountain in north-west Ireland. Finding human bones on the floor, he called the police. The bones turned out to be thousands of years old and the site was turned over to archaeologists led by Marion Dowd at the Institute of Technology Sligo in Ireland. "It's a Neolithic site that has been completely undisturbed for 4500 to 5000 years," she says.

THORSTEN KAHLERT

View from a chamber entrance on Bengorm mountain, Ireland

The team found a total of 4899 bone fragments, which belonged to at least eight individuals, both adults and children. However, the chamber wasn't the final resting place of some of their other bones. Instead, people carried corpses to the chamber and left them for up to 2 years to allow the flesh to decompose, then took away the skulls and other large bones.

Such elaborate funerary rites were common in the Neolithic, the last phase of the Stone Age. By this time, the first farmers had moved into western Europe from further east. In the British Isles, they largely replaced the hunter-gatherers that had been living there for millennia.

Neolithic funeral practices often lasted years and were probably tied to religious beliefs about the afterlife, says Dowd. "The physical disintegration of the body possibly mirrors the spiritual journey."

Lara Cassidy at Trinity College Dublin in Ireland obtained DNA from two of the bones, belonging to two adult males from around 3000 BC. The pair were distantly related, sharing the same amount of genetic material as second cousins, says Cassidy. "That tells us they're coming from a community that's sizeable enough that you can avoid close inbreeding."

Both Bengorm men were lactose-intolerant, so they couldn't digest the lactose in milk without discomfort. Today,

"There was diversity. You're getting a lot of gene variants circling at that time"

most adults with European ancestry can digest lactose, but the trait only evolved in the past 5000 years. Neolithic farmers probably coped by processing milk to remove most of the lactose, says Carles Lalueza-Fox at the Institute of Evolutionary Biology in Barcelona, Spain. "If you make cheese, then you get rid of the lactose problem."

The two adult males had "intermediate to dark" skin, according to the DNA analysis. Their skin was probably in a range traditionally associated with the Mediterranean or Middle East today, says Cassidy (*Oxford Journal of Archaeology*, doi.org/fct8). This is in line with other Neolithic Europeans, she says. "There was diversity. You're getting a lot of [gene] variants circling at that time."

The Bengorm population may well living ancestors in Ireland today, says Dowd. The site was used for funeral rites for at least 800 years, suggesting a long-lasting population. We have less information about the hunter-gatherer groups that lived in the British Isles before the farmers, but a 2018 study of the 10,000-year-old "Cheddar Man" skeleton from the UK found evidence that he had dark skin that was significantly darker than the Bengorm men had.

Later, genetic variants linked to lighter skin tones became much more common in Europe. but we don't know when that happened, says Cassidy, because we have little DNA from the Bronze and Iron Ages so far. ▮

Animals

Rats that hunt with whiskers are four species, not one

Jake Buehler

AN ELUSIVE type of wading rat armed with super-powered whiskers is actually four separate species, researchers have found.

African wading rats, formerly the single species *Colomys goslingi*, are truly unusual rodents. They are one of the only semi-aquatic rodents in Africa, striding into streams on stilt-like feet. There, they drape long whiskers on the water's surface, sensing the vibrations of their prey: aquatic insects, tadpoles and small fish moving underwater.

"It was known all the way from Liberia to Kenya, which is an insanely wide distribution for a really small animal," says Tom Giarla at Siena College in Loudonville, New York.

Giarla and his colleagues wondered if the territory was actually inhabited by a series of hidden species. The team examined dozens of wading rats in museum collections, and captured specimens across their wild range.

The group compared the rodents' physical features and analysed their DNA. The team also compared them with the similar Ethiopian amphibious rat (*Nilopegamys plumbeus*), of which only one specimen has ever been collected, in 1927, and which may be extinct.

Two of the wading rat populations in the Congo basin and West Africa were distinct, unrecognised species. The team named them *Colomys lumumbai* and *Colomys wologizi*, respectively. The team also discovered that a *Colomys goslingi* subspecies in Cameroon was a full species (*Zoological Journal of the Linnean Society*, doi.org/fct4).

Giarla says he is most interested in learning more about how the new species interact with their environments. Understanding the rats' habitat requirements is important because their rainforests are threatened by deforestation, mining and political strife. ▮

Reader Q&A

Your questions answered

From immunity to vaccines and face coverings, **Jessica Hamzelou**, **Graham Lawton**, **Michael Le Page**, **Donna Lu** and **Adam Vaughan** have the answers

WE HAVE now been living with SARS-CoV-2, the virus that causes covid-19, for the best part of a year. In that time, our knowledge has expanded dramatically, but there is still so much we don't know – and even when we think we know things, the science can change fast.

On 24 September, we held a live Q&A event online for subscribers about the pandemic and were inundated with questions. On the following pages, our reporters tackle some of the most common.

Transmission

How does the coronavirus spread through the air? Is aerosol transmission a possibility?
The coronavirus definitely infects people via the air. The rather confusing debate among experts is whether it is only carried by large droplets that rapidly sink to the ground or whether people can also be infected by smaller droplets that can remain airborne for hours, known as aerosols.

It is very hard to establish exactly how people have been infected, but the overall evidence does suggest that aerosol transmission is happening. To give one example, a study looking at how a passenger on a flight between London and Hanoi in Vietnam infected up to 15 others concluded: "The most likely route of transmission during the flight is aerosol or droplet transmission."

What about aerosols indoors? I'm wondering if I brave a museum visit.
The risk is thought to be greatest in crowded, poorly ventilated spaces where people don't wear masks and shout or sing, such as some pubs. In a spacious museum that isn't crowded and where everyone is wearing masks, as currently required in the UK, the risk should be lower. However, the risk also depends on the odds of encountering infectious people. If case numbers are rising, these odds rise too. How you travel to the museum will also matter.

And how about outdoors?
The risk will vary enormously depending on circumstances, such as how windy it is, how many people are around you, how close they are and if any are infectious. Time is also a factor: you might have to stay in close proximity to an infected person for some time to breathe in a high enough dose of the virus to infect you.

How long does the virus remain active on surfaces?
After reviewing the scientific literature, Emanuel Goldman at Rutgers University in New Jersey concluded that the risk of infection from surfaces is tiny for most people. "The focus should be on masks, social distancing and doing things outdoors as much as possible," he says. "Inanimate surfaces are a very minor player in all this."

Don Schaffner, also at Rutgers, says he has found only one case providing evidence of transmission via surfaces, or fomites, in the peer-reviewed literature. It was for two individuals who sat in the same seat in Singapore. But he says by all means mitigate the risk by using hand sanitiser and washing hands regularly. "I'm not telling people to not worry about surfaces," he says. "I'm saying worry first about other people."

A paper published on 7 October found that SARS-CoV-2 could remain stable for 28 days at 20°C on non-porous surfaces, such as glass touchscreens, stainless steel and paper banknotes. The Australian team behind the research agreed that the virus spreads mainly through aerosols and droplets in the air, but concluded that surfaces may be an important route too because the virus "can remain infectious for significantly longer time periods than generally considered possible". However, real-world differences in temperature, humidity and sunlight – the virus samples were tested in a lab in the dark – mean the results don't reflect real-life situations.

NINA WESTERVELT/BLOOMBERG VIA GETTY IMAGES

"The focus should be on masks, social distancing and doing things outdoors as much as possible"

Are masks an effective measure? Is there a need to wear one outdoors?
A growing number of studies suggest that face coverings reduce your chance of getting infected, make infections less severe if you do get infected – by reducing the amount of virus you are exposed to – and stop you infecting others if you have caught the virus. No single study is conclusive, but looked at as a whole, the evidence is convincing. Even when there is no requirement to wear face coverings outside, it is still a good idea in crowded places where you cannot avoid being close to others.

Visitors at the reopening of the Metropolitan Museum of Art in New York in August

Vaccines

What is the progress on developing a universal coronavirus vaccine?
Never before in vaccine history has so much progress been made in such a short time. Several vaccines are already in phase III trials to see if they actually work, and dozens more potential vaccines are being developed. Vaccine manufacturers are also being paid to prepare for making billions of doses. Hopes are high, but even if several vaccines prove effective, it will take years to roll them out worldwide.

Will the first vaccines benefit the most vulnerable?
Older people have a lower immune response to vaccines and so flu vaccines for them contain added components called adjuvants that boost the immune response. We don't know whether this will be necessary for the coronavirus, but the Novavax vaccine already in phase III trials contains an adjuvant, and several other vaccines with adjuvants are in earlier stage human trials.

If several strains of the new coronavirus emerge, can we expect any vaccine to be completely effective?
There are many reasons why vaccines might not be 100 per cent effective, unfortunately. For instance, they might not produce a strong enough immune response. The differences between coronavirus variants are small, so the hope is that any one vaccine will work against all of them. If this doesn't prove to be the case, however, it should be possible to tweak vaccines so they protect against multiple strains, just like flu vaccines typically do.

How much time would have been saved in the development of a vaccine by doing challenge trials, versus the traditional approach?
With challenge trials, healthy people are given the coronavirus to test a vaccine's efficacy. These might be able to give results in weeks instead of months or years – at least for young people. No one is proposing challenge trials involving older or vulnerable people, though, so they wouldn't tell us how well any vaccine works for these key groups.

A health worker in Brazil gives an injection as part of a coronavirus vaccine trial

Treatments

With improvements in treatment, how has the fatality rate for covid-19 changed?
We have a good idea of how many people have died in richer nations. What we don't know is how many have been infected, as the number of reported cases isn't the full story. So there is no definitive way to calculate the infection fatality rate (which estimates the proportion of deaths among infected people) or how it is changing – estimates still vary widely. Figures from the UK's Intensive Care National Audit & Research Centre suggest that 83 per cent of people admitted to intensive care units after 1 September are surviving compared with 60 per cent before this date, but these numbers must be treated cautiously. Intensive care units might have turned away more borderline cases during the first peak due to a lack of resources, for instance, making the apparent death rate higher then.

Is plasma therapy likely to be effective?
In theory, there is every reason to think that treating covid-19 patients using blood plasma taken from people who have recovered from the disease will work. And several small, early studies have reported promising results. But we need to wait for the results of large trials because the complexity of biology often confounds expectations. For example, it has just been discovered that a tenth of people with severe covid-19 produce antibodies to a key antiviral molecule made by their own bodies – a kind of autoimmune response. Plasma donated by these individuals could make the disease worse.

28 days
The amount of time the virus might remain stable on touchscreens

SILVIO AVILA/AFP VIA GETTY IMAGES

Origins

Are we any wiser about the origins of SARS-CoV-2?
We still don't know for sure where the virus came from, and we may never know. But by far the most likely source is a bat.

That is based on the virus's two closest-known genetic relatives, which are coronaviruses isolated from horseshoe bats in China. But neither virus is the direct recent ancestor of the new coronavirus. Only the discovery of a much more closely related virus in a wild bat will confirm the bat origin story.

It is also possible that the source is an intermediate species that caught the virus from a bat and then passed it on to humans. The number one suspects are pangolins, which are also known to carry coronaviruses that are genetically similar to SARS-CoV-2.

Bats and pangolins were almost certainly on sale in the live animal market in Wuhan, China, that has been identified ›

as the pandemic's ground zero. So the virus could have crossed the species barrier there, from a bat or a pangolin into a human.

But it is also possible that the market was merely the venue of a superspreader event, not where the virus jumped species. One scenario that cannot be ruled out is that a progenitor virus acquired from bats was circulating in humans for months causing only mild symptoms, but then mutated into SARS-CoV-2 and began spreading in the market.

"If the immune response fades rapidly, we would expect to have seen more cases of reinfection"

Wilder scenarios are that the virus accidentally escaped from a laboratory or that it was deliberately engineered as a bioweapon – both of which are exceedingly unlikely.

Why are bats the reservoirs for so many viruses?

Bats are clearly trouble: they also gave us the original SARS virus, plus Ebola, Nipah and more, and are by far the most prolific source of zoonotic viruses, ones originating in animals. Bats can tolerate extremely high virus loads, meaning that they are an efficient incubator of novel viruses. Humans also come into contact with bats relatively frequently, especially in parts of the world where they are a source of meat and traditional medicines.

Immunity

At least one person who had covid-19 a second time had a more severe illness. Could we have issues vaccinating people who have had it?

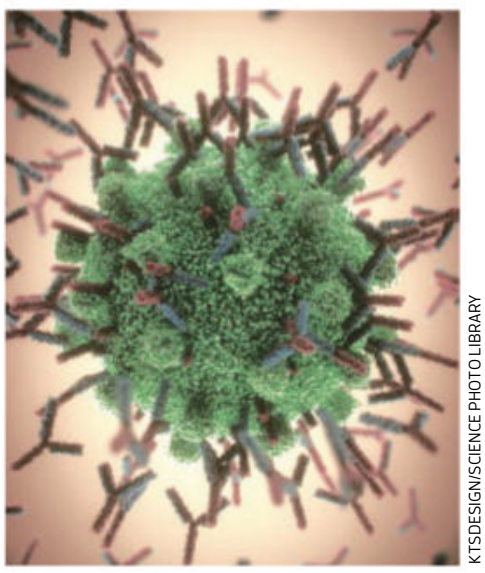
Fortunately, it is now becoming clear that exposure to the virus provokes a classic immune response that protects people against reinfection. However, we don't know how long immunity lasts. It may only be months.

There are a handful of confirmed cases of reinfection, but nowhere near as many as would be expected if the immune response always fades rapidly. It is possible that the people who got reinfected had an unusually weak response the first time or encountered a mutant virus that was biologically different enough to evade their so-called immune memory. The test results could also have been false positives.

At least one person who had covid-19 twice is reported to have become more severely ill, which raises the spectre of something called "disease enhancement". This is where a second bout of an infectious disease is worse than the first. A few viruses, most notably dengue, are known to do this, but it is too early to say whether SARS-CoV-2 does too.

There is a similar phenomenon called "vaccine-enhanced disease", where a vaccine not only doesn't protect against infection, but also makes the symptoms of the disease worse. Vaccine developers are well aware of this risk. Thankfully, it hasn't been spotted in any of the experimental vaccines so far. This also suggests that reinfections won't typically be worse.

Antibodies responding to an infection by a SARS-CoV-2 virus (green)



KTSDESIGN/SCIENCE PHOTO LIBRARY

It appears that the recent "second waves" of the virus are in different areas from those hit hardest initially. Does this suggest that there is some degree of immunity in those places?

Antibody surveys are probably not picking up the true extent of immunity to the virus. These tests look for circulating antibodies, which are known to fade quite rapidly after an infection or are hardly produced at all. One survey, for example, found that among UK doctors who had tested positive for the virus, 12 per cent had no detectable antibodies.

The T-cell response, which is the arm of the immune system that kills infected cells, seems to be much more robust. Immunologists think that if we did population surveys of T-cells, we would see higher levels of immunity. This so-called cryptic immunity may be why the second wave is hitting different areas to different extents. But we can't be sure.

Can I predict my personal risk for covid-19?

All sorts of factors, including age, race and pre-existing health conditions, determine your risk of becoming severely ill. Because it still isn't clear who will develop an asymptomatic case of covid-19, it is difficult to predict the risk to an individual who hasn't yet caught the virus. But once symptoms start, it should, in theory, be possible for an individual to calculate their own personal risk of experiencing a severe or potentially fatal case, says Tim Spector at King's College London. There isn't yet a "personal risk calculator" available, but Spector's team is working on ways to predict risk based on early symptoms and data collected from the COVID Symptom Study app.

200m

This many people may have died in the Black Death from 1331-1353

At the moment, however, there is no way to predict who is at risk of "long covid", where often debilitating symptoms can last for months.

Environment and animals

How is the pandemic related to over-exploitation of the planet?

The role our destruction of nature plays in infectious diseases spilling over into humans is something we have only begun to grasp fully in the past two decades, says Peter Daszak at the EcoHealth Alliance. He says the drivers include: rising human population density; encroachment into and road building in forests; and hitting thresholds of contact between wildlife, humans and livestock at which a disease emerges, then spreads through trade and travel networks.

Global analyses have found that the risk of zoonotic diseases emerging is highest in tropical areas where land use is changing, such as forests being cleared for cattle farms.

Daszak also says that the wildlife trade in China readily mixes legally and illegally captured and traded animals, and involves

DAVID CLIFF/NURPHOTO VIA GETTY IMAGES

Face coverings have become part of daily life for people using public transport in the UK

domestic and international commerce – and that viruses exploit those pathways.

However, it would be wrong to think that people in the West aren't also to blame. "The encroachment of people into high biodiversity regions is a global driver of emerging infectious diseases and it's largely done to supply our overconsumption in richer countries," says Daszak.

Is it possible for pets to carry and spread the coronavirus?
SARS-CoV-2 has been detected in a number of animals, including tigers, lions and rabbits. Ferrets, hamsters and cats have been shown to be able to pass the virus to others of the same species, and transmission between mink in the Netherlands has led to outbreaks at more than 40 mink farms.

However, cases of pets catching the coronavirus from their owners remain rare, and research indicates that most pets with confirmed infections only show mild symptoms.

Whether animals can pass the virus back to humans is less clear. A paper that hasn't yet been peer-reviewed suggests that mink at Dutch farms have transmitted the virus to farm workers. If confirmed, it would be the first documented case of animal-to-human transmission. To date, there are no recorded cases of domestic pets infecting humans.

Pandemics

How long do pandemics normally last for?
Covid-19 is the second pandemic of the 21st century. The H1N1 influenza outbreak of 2009-10 sickened and killed far fewer people than covid-19 already has. You could argue that there is a flu pandemic every year, yet the World Health Organization (WHO) saves the term for novel flu viruses, not slightly mutated seasonal ones.

The H1N1 pandemic lasted about a year-and-a-half, but that is no guide to how long the current pandemic or future ones will last. The duration of a pandemic depends on the biology of the disease and the measures that are used to control it. There is also the ongoing pandemic of HIV that began in the 1980s.

Other relatively recent pandemics include the 1918 flu, the flus of 1957-58 and 1968-69 and the cholera pandemic of 1961-75. However, history is littered with them, including the worst of them all, the Black Death of 1331 to 1353, which killed up to 200 million people out of a global population of about 450 million. By comparison, we could consider ourselves lucky.

Is there really any hope that the coronavirus will be defeated or will we have to live with it forever?
Many infectious disease experts believe we will have to learn to live with it. Global social inequalities and air travel imply that so long as the virus exists in people somewhere in the world, its easy transmission means it will spread.

Even if a vaccine is developed, it doesn't mean that the world is likely to "beat" or eliminate the virus. "What will a vaccine do? It certainly won't stop it becoming endemic," says David Heymann at the London School of Hygiene & Tropical Medicine. "We don't understand enough about immunity to understand what that vaccine might be and if herd immunity can be established."

> **"Despite a decade of warnings about a new pandemic, covid-19 caught the world napping"**

Do you think experience of this pandemic will help better prepare us for future ones?
Despite a decade of warnings from the WHO that a new pandemic was a certainty, covid-19 caught the world napping. Experts say there will be another pandemic sooner or later, but we are unlikely to be any better prepared for it despite our current predicament. ▮

PLEASE NOTE
We urge you to keep up to date with and follow your local guidelines. If you sent us a question that wasn't answered here, take a look at our website, where you can find a longer and more in-depth version of this article.

Infectious diseases

What to expect from viruses as winter hits northern hemisphere

Michael Le Page

MARCO BELLO/BLOOMBERG VIA GETTY IMAGES

WINTER is coming to the north. If what happened in the southern hemisphere is any guide, anti-coronavirus measures could result in fewer people than usual getting flus and colds. The respite may be brief, though. These viruses could come roaring back when measures to limit the spread of covid-19 end.

If fewer people susceptible to these viruses are infected this year, there will be more susceptible people around next year, says Daniel Yeoh at Perth Children's Hospital in Australia.

If we fall ill at the moment, we tend to worry that we have covid-19, especially if we have a fever or a cough. But such illness is more likely to be due to cold or flu viruses than to the coronavirus.

"Colds and flus still dominate over the coronavirus overall," says Claire Steves at King's College London, a member of the team behind the COVID Symptom Study app. The app's users in the UK, US and Sweden report daily whether they are well or have symptoms.

"The social distancing that limits the spread of coronavirus works for other viruses too"

Between 8 and 21 August, for instance, just 0.4 per cent of UK app users who reported symptoms of illness tested positive for the coronavirus, says Steves. People reporting a runny nose and swollen glands were unlikely to test positive, but 90 per cent of those who did have a positive test had severe headaches and fatigue.

Another study of key workers in the UK found that only half of the people who thought their symptoms indicated covid-19 actually had the disease.

Measures being taken to try to stop the spread of the coronavirus are also making it harder for other respiratory viruses to spread. "The social distancing works for other viruses as well," says Steves.

In some places, the effect has been dramatic. Normally the number of people who go to hospital with an illness diagnosed as flu or respiratory syncytial virus climbs sharply every winter. This winter, in Western Australia, the number of reported cases instead fell to zero most weeks, Yeoh's team has reported.

In fact, Australia, Chile and South Africa have reported just 51 positive results for flu out of 80,000 tests done during the southern hemisphere winter. In the previous three winters, these countries reported 25,000 positive results out of about 180,000 tests.

Fewer flu cases than normal were also reported in the northern hemisphere summer. "The numbers are low," says John McCauley at the World Health Organization. He says that many resources usually dedicated to monitoring flu are now monitoring coronavirus instead. "We could be underestimating prevalence," he says.

It is less clear what is happening with other respiratory viruses such as rhinovirus, adenovirus and parainfluenza virus as they seldom cause serious illnesses so there is no systemic surveillance in most countries. However, the US Centers for Disease Control and Prevention (CDC) monitors them.

"Positive detections of non-influenza respiratory viruses have been lower than we would expect in August and September with the exception of rhinovirus/enterovirus," says a CDC spokesperson.

What matters is what happens during the northern hemisphere's winter, when the number of cold and flu infections usually peaks. Flu cases add to the pressure on healthcare systems, which is why it is more important than normal that people get the flu vaccine this year. Fewer flu cases than usual may occur where anti-coronavirus measures are in place, but not as few as in Australia. "There are a couple of key differences in Australia that may have combined to lead to the very low numbers seen here," says Yeoh.

Flu vaccinations are key to limiting the burden on hospitals in a pandemic

Australia imposed its lockdown just before winter in the southern hemisphere, whereas most northern hemisphere countries don't have lockdowns in place now. Australia also instituted strict travel restrictions that remain in place, limiting the odds of flu being reintroduced from other countries, says Yeoh.

Indeed, in the UK, the number of people reporting symptoms of illness between 8 and 21 September is up by 74 per cent compared with the same period in August, says Steves. The percentage testing positive for covid-19 is up too, at 2.8 per cent.

She says that viruses other than the coronavirus were probably largely responsible for this surge after schools reopened, but within this there was a concerning rise in covid-19 cases too. As coronavirus restrictions lift, and with potentially more susceptible people next year, we could see a spike in future colds and flus. ▮

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Space exploration

An asteroid's watery past

The parent body of the asteroid Bennu probably had flowing water on its surface

Leah Crane

THE asteroid Bennu is a strange little place, but data from NASA's OSIRIS-REx mission is starting to unravel its mysteries. The spacecraft, which has been orbiting Bennu since December 2018, is gearing up to take a sample from the asteroid's surface later this month. In preparation, it has gathered a smorgasbord of information, including hints that Bennu's parent asteroid may have had flowing water.

Bennu is a rubble pile, formed when something smashed into a larger asteroid billions of years ago and the bits coalesced into many smaller asteroids. By studying Bennu, which is about 500 metres wide, we can learn more about this parent asteroid, which was probably a few hundred kilometres across.

When OSIRIS-REx reached Bennu, it spotted something strange: some of its boulders had bright veins up to 150 centimetres long and 14 centimetres thick. These are too large to have formed on Bennu itself, says Hannah Kaplan at NASA's Goddard Space Flight Center in Maryland, so they were probably portions of larger cracks on Bennu's parent that were up to several kilometres long.

"They suggest that there was fluid flowing on fairly large scales on Bennu's parent asteroid," says Kaplan. That is because the veins are made of carbonates, a type of compound that generally forms due to interactions between water and rocks (*Science*, doi.org/fctb).

Over 98 per cent of Bennu's surface seems to be coated in carbonates and organic molecules, complex carbon-bearing compounds seen as precursors to life. Yet despite probably having both water and organic molecules, Bennu's parent was unlikely to be teeming with life.

"You're in the vacuum of space, there's no atmosphere, you're looking at a lot of irradiation, it's cold – you wouldn't want to sit on the surface," says Kaplan. "It's not a favourable environment per se, but it does have a lot of the factors that make a place technically habitable."

One of the main goals of OSIRIS-REx is to investigate the carbon on Bennu because Earth was probably built from rocks similar to it, and these may have brought the ingredients for life here. "These same types of organics may have been delivered to early Earth and may have been the start of some of the organic chemistry that led to life as we know it," says Kaplan.

55%

Some boulders on Bennu are made of this much empty space

There are also differences across the surface of Bennu that are hard to explain. It is covered in boulders, but the largest ones are mostly in its southern hemisphere. The boulders themselves are strange too, with some being so porous that empty space appears to comprise up to 55 per cent of them, more than any meteorite we have ever recovered.

There seem to be two populations of rocks: porous, darker-coloured ones and denser, lighter-coloured ones that often have carbonate veins. These differences aren't obvious to the human eye – the surface would seem to be a fairly uniform dark-grey to us – but they could be critical in helping us figure out how Bennu formed. They may have come from two different areas in Bennu's parent body, with the denser rocks coming from deeper underground.

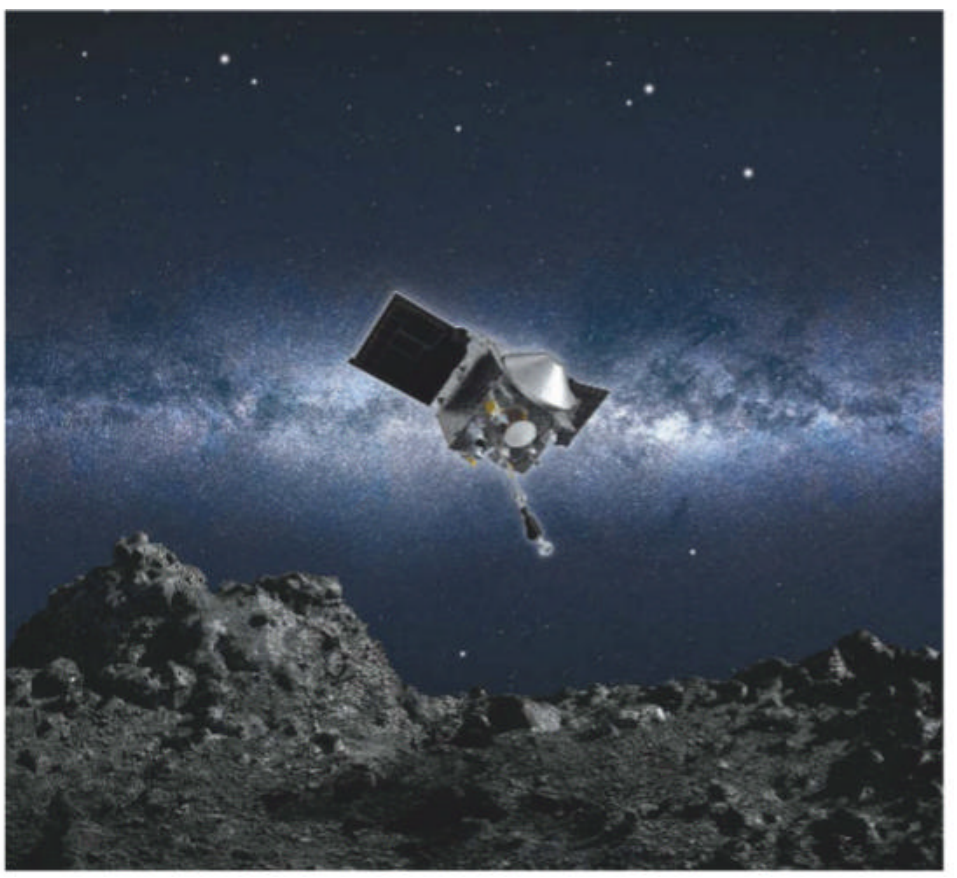
That wouldn't answer all of Bennu's mysteries, though, because some relate to the asteroid's evolution after it was chipped off its parent. "The way Bennu's colour changes over time is quite a bit different than what we have seen on other planetary surfaces like the moon or other asteroids that we've visited," says Daniella DellaGiustina at the University of Arizona.

Ageing an asteroid

Astronomers can date different areas of Bennu by comparing fresher regions with more weathered ones, revealing how they change over time. Rocks on Bennu seem to become more blue, whereas those on other space rocks tend to become more red. This may be because those carbonate-filled rocks interact with the solar wind and micrometeorites differently to rocks without carbonates, says DellaGiustina.

On 20 October, OSIRIS-REx will take a small sample from Bennu's surface before heading back towards Earth. When the sample gets here in 2023, researchers will hopefully be able to answer many of these questions. "All the characterisation work we've done for Bennu basically puts this return sample into context," says Benjamin Rozitis at the Open University in the UK. If we can study the sample thoroughly and understand how it relates to the different rocks on Bennu, that makes it easier to compare with other asteroids and small bodies.

"We can't do a sample return from every interesting place in the solar system, but by studying Bennu globally and trying to understand it as a small world, we get a much better sense of how Bennu relates to other objects in our solar system that we might never be able to sample," says DellaGiustina.



NASA/GODDARD/UNIVERSITY OF ARIZONA

OSIRIS-REx will take a sample from asteroid Bennu later this month

RICHARD BAKER/IN PICTURES VIA GETTY IMAGES

Psychology

Strangers get more help in wealthier neighbourhoods

CITY and country folk are just as helpful as each other. In fact, the chance of people assisting a stranger in the UK by posting an envelope seems to depend only on a neighbourhood's relative wealth.

From 2014 to 2017, Nichola Raihani and Elena Zwirner at University College London carried out tests in 37 areas in cities, towns and villages across the country.

One involved dropping a stamped, addressed envelope on the ground to see if people picked it up and posted it. In a variant, a letter was put on a car windscreen with a note asking the finder to post it.

In another test, Zwirner dropped some cards on the pavement when she was 5 metres from another pedestrian to see if they would help her pick them up. Sometimes she asked for assistance, other times she just began picking up the cards. In a third test, Zwirner started crossing the road when a car was approaching to see if it would stop.

The pair found that people living in less urban neighbourhoods were no more likely to help than those in cities. However, people were much less likely to help if they were in deprived areas, as defined by income and employment.

In relatively wealthy areas in both cities and towns, around three-quarters of the letters were posted. In poorer neighbourhoods in cities, half were posted. In poorer parts of towns or villages, only a third were posted (*Proceedings of the Royal Society B*, doi.org/ghd2gt).

The findings go against studies suggesting that wealthier people are less helpful, but these tend to be lab tests. **Michael Le Page**

Technology

Squad of bots may lend artists a hand

SWARMS of robots could help artists paint pictures, rushing across a canvas to lay down colours in the right places.

María Santos at the Georgia Institute of Technology and her team designed a system that would allow an artist to select regions of a canvas to be painted in certain hues. These are then created in real time by 12 robots that cross the canvas leaving trails of colour behind them.

Currently, the robots don't carry real paint. Instead, the researchers tested their ability to work together using projectors that simulated coloured paint trails behind the robots. Each of the machines can produce three primary colours – magenta, cyan and yellow – which can also be combined to make other shades.

Santos and her team found that the robots were able to work together effectively by varying the colours of the trails they laid down, while also considering the colours laid down by neighbouring robots (*Frontiers in Robotics and AI*, DOI: 10.3389/frobt.2020.580415).

Santos says the next step will be to develop robots that can handle real liquid paint. "This step involves not only developing the hardware necessary to manage paint, but also studying the painting release mechanism needed to achieve appropriate colour mixing."

Vanessa Sanchez at Harvard University says another challenge with using liquid paints will be the drying time, as the robots currently run on wheels, which could result in them streaking paint across the canvas before it has dried. One way to avoid this might be to use different types of robot, such as drones, she says. "You wouldn't have to worry about tracking of the wheels." **Layal Liverpool**

Botany

Super vine grows its own greenhouses

A VOLUNTEER nature guide in Japan has discovered that a type of vine creates mini-greenhouses to warm its developing fruits.

Schizopepon bryoniifolius (pictured) is an annual vine that grows throughout east Asia, often on the edges of forests. It belongs to the same family as cucumbers, pumpkins and squashes. In the autumn of 2008, guide Nobuyuki Nagaoka noticed that some leaves on a *S. bryoniifolius* plant had expanded and overlapped to form enclosures. Inside these were many developing fruits.

SHOKO SAKAI

He eventually contacted Shoko Sakai at Kyoto University, whose team has now studied these vines on Mount Gassan in the Dewa Sanzan mountains in Yamagata prefecture. The researchers monitored the temperatures in leaf enclosures and in places where the leaves were removed. They found the temperatures in the enclosures were up to 5°C higher at noon on sunny days.

They think the leaf structures also protect developing fruits from frost damage, but they haven't shown this. Far fewer fruits grew well when the enclosures were removed. Plants at higher, colder sites also grew thicker enclosures (*Proceedings of the Royal Society B*, doi.org/fctm).

This isn't the only plant that makes its own greenhouses. A species of Himalayan rhubarb does something similar. **MLP**

Really brief

RIZA AZHARI/ALAMY

Something smells a little less fishy

If you don't find the smell of fish particularly off-putting, you may have an olfactory gene mutation that makes these odours seem less disagreeable. Researchers have identified a gene, *TAAR5*, that affects the perception of odours containing trimethylamine, a compound found in rotten and fermented fish (*Current Biology*, doi.org/fctn).

Plastic waste to fuel hydrogen economy?

Chemists have used microwaves to get hydrogen from plastic waste. Researchers mixed plastic with a catalyst of iron oxide and aluminium oxide. When blasted with microwaves, the catalyst created hot spots in the plastic and stripped out hydrogen (*Nature Catalysis*, DOI: 10.1038/s41929-020-00518-5).

The AI doctor will see you now

A robot that can perform colonoscopies may make the procedure simpler and less unpleasant. The robot uses a machine-learning algorithm to move a flexible probe along the colon via the rectum (*Nature Machine Intelligence*, DOI: 10.1038/s42256-020-00231-9).

Medical devices

New technique may alleviate tinnitus

A GADGET that stimulates the ears and tongue may curb the severity of tinnitus, a hearing disorder involving phantom noises.

The approach uses headphones that play a sequence of tones and white noise in the wearer's ears, as well as a small mouthpiece that simultaneously provides electrical stimulation to the tongue.

Around 13 per cent of people in the UK live with persistent tinnitus and about 30 per cent of people will experience it at some point in their lives. Treatments such as cognitive behavioural therapy and counselling are often used to help, but there is no cure.

Hubert Lim at Neuromod Devices, which developed the device, and his colleagues tested it in a trial including 326 people with tinnitus. Over a 12-week period, three groups of participants used it twice a day for 30 minutes.

The researchers found that this significantly reduced the severity of tinnitus symptoms for between 75 and 89 per cent of participants, with improvements persisting for up to a year (*Science Translational Medicine*, doi.org/fctr).

The researchers believe the device works by making the auditory brain more sensitive to many inputs and acoustic stimuli, so it becomes distracted and less sensitive or aware of tinnitus.

A second trial is ongoing, says Lim. It will be vital to separate the device's effects from those that might have been observed anyway. "There is a strong placebo effect when assessing interventions for tinnitus," says John Phillips at Norfolk and Norwich University Hospital in the UK. **LL**

Palaeontology

GREGORY FUNSTON

Dinosaurs that lost a finger show evolution in action

A TWO-FINGERED dinosaur may help researchers better understand how animals evolve to lose digits.

Oviraptorids, a group of bird-like dinosaurs, usually had three fingers on each hand. But a set of juvenile skeletons have two-fingered hands, suggesting an adaptation.

Gregory Funston at the University of Edinburgh, UK, and his team have named the dinosaur, which was probably ostrich-like, *Oksoko avarsan*. Unlike its three-fingered relatives, the new species had shorter forearms and only two functional, stout fingers with a limited range of motion (*Royal Society Open Science*, doi.org/fcth).

That means it may have used its hands for nest-building instead of grabbing prey, says Funston.

Over millions of generations, animals evolve away body parts that become less useful – including fingers and toes, says Funston. It is akin to the loss of the tail in humans after they evolved to walk upright.

The researchers acquired the skeletons (pictured) after Mongolian customs officials confiscated them from black market fossil traders. While this was enough to confirm the discovery of a new species, the illegal nature of the excavation has prevented a full investigation of their origins. Christa Lesté-Lasserre

Sports science

Get your marathon time before you run it

PLANNING to do a marathon? A new way of analysing data from a smartwatch could more accurately forecast how you will perform.

Currently, most smartwatches estimate your VO_2 max – the maximum rate at which you use oxygen during exercise – via heart rate measurements. They use this estimate to predict race times. But relying on this single parameter can result in errors of up to 20 per cent, says Thorsten Emig at the French National Centre for Scientific Research (CNRS). So he and his colleagues have developed a more accurate mathematical model to do the job.

It uses smartwatch data to calculate two physiological parameters: the speed a runner has at maximum oxygen uptake and the rate they lose power during a race. The first is directly related to a person's VO_2 max; the latter is linked to their endurance.

The model was tested using smartwatch data from about 14,000 people, from recreational runners to elite athletes. It was able to predict marathon times to within 10 per cent of actual times, on average, and to within less than 5 per cent of finish times for elite athletes (*Nature Communications*, doi.org/ghd3q8). **LL**

Views

Comment

Hidden killers

Catastrophic events hog the climate limelight but there are more subtle effects that demand attention too, says **Hannah Cloke**

SOME climate crises are big, noisy and obvious: think hurricanes, typhoons, floods and wildfires. But there are other climate crises that tend to be overlooked. These are quieter and more insidious, and we often fail to properly recognise them.

Take the example of when the UK's Office for National Statistics reported that, in the second week of August, deaths from covid-19 had reached the lowest weekly levels for five months. Among a flurry of coronavirus statistics, the statisticians were keen to point out, presumably to avoid any panic, that the spike in deaths that occurred that week – 9392 deaths in total, 447 more than the previous week – was probably due to a heatwave rather than the coronavirus.

Let's be clear: an unusually hot week in the UK, which we know is made much more likely by climate change, probably killed a jumbo jet full of people in just a few days. The heatwave may have killed three times as many people that week than died with covid-19. Yet there was very little outcry and few calls for a public enquiry.

After record-breaking heat in the first half of August in the UK, the second half of the month brought torrential downpours. In Scotland – where world leaders will meet next year to discuss actions to slow down climate change – a deluge-induced landslide derailed a train, killing three people.

The UK's climate death toll is rising. But faced with non-stop pandemic news, public concern about environmental issues is falling, according to polling company YouGov. It found that environmental concern in the country peaked towards the beginning of this year.

A person worried about inaction on climate change might despair. But there is good news. When facing a foe that can strike anyone – including the rich and powerful – we have shown that we are willing to spend big to save lives.

In the UK, measures to prevent the transmission of the coronavirus, and to support people and businesses in the economic crash that has resulted, will probably cost more than £300 billion this year, according to the government's spending watchdog. That is nearly £5000 for every person in the country, just in one year.

Convincing taxpayers that their governments ought to make big payments and rack up huge debts to save the lives of people in far-off lands, or far-off times, is a difficult sell. But show that the danger is here and now, threatening us all in our homes, and governments suddenly feel compelled to act on our behalf.

So much for the cost. What about the inconvenience?

One of the great barriers to effective climate action is the scale of the lifestyle changes that are involved, including changing diets, driving less and taking fewer flights. The past six months have shown that all those things are possible when people are motivated enough to change.

In the past, we could be forgiven for not knowing how our present activities could affect the future climate. We could also be forgiven for putting people in harm's way, purely because we didn't know that a hazard was approaching. Now, our eyes are open.

We can forecast both when a typhoon will hit with a few days' warning and the impacts of raised greenhouse gas levels in a few decades. We have the capability, the technology and more than enough precedent to spend money to save people's lives. We just need the leaders with the boldness to see it through. ▮

For more on climate change, turn to page 34

Hannah Cloke is at the University of Reading, UK
@hancloke

MICHELLE D'URBANO

No planet B

It's the economy, stupid

Finance will play a huge role in how we tackle climate change. Reassessing your own investments could be a good place to start, writes **Graham Lawton**

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

MANY of us at *New Scientist* have specialist areas of weakness. Mine is physics. In the grand scheme of things, they are actually considered a strength: if I can understand an article about, say, quantum theory, then anyone can. But recently, it has dawned on me that I have a more serious weakness in my understanding of the world. One which, as I write about environmental issues, I ought to fill. The subject? Finance.

Ugh. I skim past those pages in the newspaper. As soon as somebody mentions bonds or derivatives, my brain seizes up. Frankly, I am an snob about it. I think there are higher-minded and more important things to think about than money.

But I have come to realise that finance ignorance, or f-wittery if you will, isn't a useful state. If we are going to transition the world to a more sustainable future, reform of the financial system is a non-negotiable starting point.

The fine details of bonds and derivatives still elude me. But thanks to a documentary called *Our Planet: Too Big To Fail* made by the conservation group WWF and a pressure group called Make My Money Matter, I now grasp the rudiments of the global financial system and its connections to things I care about: climate change and destruction of nature.

Here's the technical bit; concentrate! In essence, finance is the business of transferring money from people who own capital to people who need it to fund expensive projects, in return for a share of the spoils. All too often, the first question that gets asked is, what's my return? The second is, how quickly can I get it? And so capital frequently flows into projects that ruthlessly squeeze profit from nature, such as fossil fuel extraction, mining and deforestation. What's more, an accounting system that greedily counts the profits, but often writes off external environmental costs, incentivises destructive practices such as dumping greenhouse gases into the atmosphere.

Since the 2015 Paris climate agreement, the financial sector has invested $1.9 trillion in fossil fuel projects. Short-term incentives have created a world economy in which, according to the World Economic Forum, half of global GDP is dependent on the destruction of nature.

It doesn't have to be this way. It would be unfair to portray all finance as rapacious, short-termist and uncaring. If that were so, we wouldn't have seen such radical advances in clean energy technology, and all of nature would be destroyed by now.

"For all I know, my pension may be adding to deforestation, fossil fuel use, factory farming or worse"

With the right incentives in place, finance can be remade as a force for good, channelling investment into sustainable businesses and technologies that help to end, rather than accelerate, the destruction of nature.

The incentives need changing and the documentary makes a convincing case that the penny has finally dropped. But change has to happen now, in this window of opportunity created by the pandemic. As we build back, decisions made by financiers – who have $300 trillion at their disposal – will decide which projects get funded and hence shape the economy for decades to come. If they default to business as usual, that will plunge the planet deeper into the red.

Happily, change is happening. Some of it is driven by outside factors, such as the escalating risks of investing in projects that could be wiped out by extreme weather. Some of it is driven by consumer sentiment, such as the reputational risk of investing in socially unacceptable sectors like coal. This latter pressure point is something that many of us can apply. About 85 per cent of adults in the UK have a savings pot that is invested on their behalf for retirement. Collectively, these pots total $3 trillion. Globally it is vastly more. Few people know what their money is invested in though.

I dread to think about mine. I vaguely remember ticking a box on a form demanding that at least part of it be put into ethical funds. But I don't know what "ethical" means in this context. For all I know, my pension may be adding to deforestation, fossil fuel use, factory farming or worse.

I intend to find out. Make My Money Matter helps small investors understand where our funds are and how to move them or use them to put pressure on companies to change. Influential institutions such as the University of Cambridge are divesting from environmentally destructive industries. It is time for individuals to do the same.

If it all sounds a bit too complicated, consider that environmentally conscious financial behaviour can have a disproportionate impact, way beyond that of other consumer choices. According to Make My Money Matter, shifting your investments can reduce your carbon footprint up to 27 times as much as giving up flying and going vegan. Money is power. Wield it. ▮

Graham's week

What I'm reading
I read and write all day, so sometimes find books hard going. I'm listening to a great podcast series called Uncivil*, all about untold stories of the American Civil War.*

What I'm watching
Charles I: Killing a king *on the BBC. What a story!*

What I'm working on
Articles about the future of the coronavirus.

This column appears monthly. Up next week: Annalee Newitz

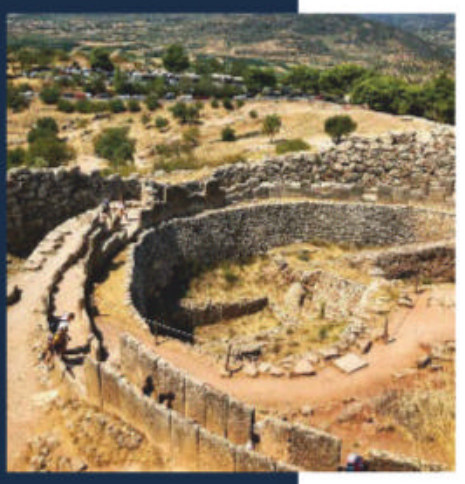
New Scientist Discovery Tours

Thinking about exploring the world again?

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

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

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



GREECE

Learn to dig Mycenaean archaeology: Greece

7 days | 14 May and 4 June 2021

An interactive tour of the key Mycenaean sites including a unique 'behind the ropes' 3-day experience at Mycenae where you will be taught how to explore, map and excavate with their resident archaeologists. Followed by visits to the hidden gems and famous sites of the ancient Peloponnese

RUSSIA

Saint Petersburg: The history of Russian science

7 days | 27 August and 8 Oct 2021

Explore the history of Russian science, from the creation of the Academy of Sciences, through to the fraught years of Soviet transformation in this stunning and vibrant city. A plethora of museums, cathedrals and cultural treasures.

FRANCE

Ancient caves: Origins of the Neanderthals: France

9 days | 1 September 2021

Step back in time on a journey to the key Neanderthal sites of southern France with Palaeolithic archaeologist Dr Rebecca Wragg Sykes. See the oldest traces left by humankind: stone tools, art objects, cave paintings and other remains.

ANTARCTICA

The science of the Antarctic: A fly-cruise expedition

17 days | 17 November 2021

A unique fly cruise expedition exploring the world's largest ocean sanctuary. Follow in the footsteps of the great explorers, whilst marvelling at imposing icebergs, ancient glaciers and ice floes onto volcanic beaches.

Editor's pick

On the great hunt for life beyond our planet

3 October, p 36

From Martin Jenkins, London, UK

I should like to add some nuance to Dan Falk's fascinating article on the possibility of advanced civilisations beyond Earth. The assumption behind the search for extraterrestrial intelligence is that such intellect is likely to be used to develop technology, but this isn't inevitable.

The cultures of both classical Greece and imperial China had technological capabilities, but preferred to apply intelligence to the arts. Also, in some cases, technology may not be an available option. Isaac Asimov observed that technology as we know it started from fire – in which case, intelligence that evolved in a marine environment may never develop it.

The implication is that, if there are intelligent civilisations out there, they may not be interested in developing the means of contact, or may not be able to do so. Perhaps they are sitting on their planets or under oceans thinking great thoughts and making beautiful art.

From Conrad Jones, Cynwyl Elfed, Carmarthenshire, UK

Finding what is probably a sign of life in clouds on Venus (3 October, p 12) is eye-opening for anyone seeking extraterrestrials, a hint that we may be looking in the wrong places and that we shouldn't just be targeting planets in the so-called Goldilocks zone.

From Mike Curran, Teignmouth, Devon, UK

In 1963, Donald Barber, a fellow of the Institute of Physics, the Royal Astronomy Society and the Royal Photographic Society, submitted a paper to a photographic journal detailing a 25-year investigation into unusual bacterial infections of photographic plates at a UK observatory. The bacteria were tolerant of this silver/gelatine environment, normally deadly to terrestrial bacteria.

The infections coincided with specific conditions: the alignment of Venus between the sun and Earth, a solar storm and a northerly airflow from the Arctic. In the absence of any other rational explanation, Barber's suggestion was that the solar wind may have stripped bacteria from the clouds of Venus, carrying them to Earth and depositing them in the Arctic to blow south to the UK.

From Andrew Smyth, Los Angeles, California, US

If advanced ETs do exist in our galaxy, we have the technology to find them: 1000 radio receivers of the same size as the Arecibo telescope may be able to detect an Earth-like civilisation up to 13,000 light years away. The real challenge for us – and perhaps for ETs – may be to persuade our leaders to fund such large projects.

From Eric Kvaalen, Les Essarts-le-Roi, France

In your leader (3 October), you say that because there are so many planets, "even if the odds of life arising on a particular world are tiny, there is a good chance it has happened many times". Let's assume that there are 10^{12} planets in our galaxy and 10^{12} galaxies in the visible universe, making a total of 10^{24} planets. If the chance of life arising on any planet is tiny, say 10^{-27}, the chance of another planet with life in the whole visible universe is just one in 1000. I just picked 10^{-27} out of the blue. Itcould be 10^{-100}.

Only people power will get this job done

26 September, p 22

From Roger Taylor, Meols, Wirral, UK

Annalee Newitz is right to conclude that "we are going to need better political systems" to deal with climate change, but I would go further. To deal with it, we will require unprecedented cooperation between people, industry and governments.

The latter two groups will do nothing until they see which way the people are moving, and so we must stop looking to others and move ourselves if we want the issue dealt with. When many of us act it becomes a substantial force. Interrogating politicians about their decisions and providing them with reasoned argument and positive suggestions, all coupled with relentless persistence, is as important as any personal "green" behaviour we might be adopting.

Just as you reported it, so it happened

26 September, p 14

From David Aldred, Elloughton, East Yorkshire, UK

After reading the rather worrying story "US science coverage is biased against people with names not of British origin", I found myself doing exactly what the article predicted: the only name I could remember was that of the Birmingham City University expert, Marcus Ryder. I had to re-read the article in order to find the author of the actual study: Hao Peng at the University of Michigan.

One part of diet science is a bit chicken and egg

12 September, p 34

From Prakash Virkar, Bangalore, India

I read your article on precision nutrition with great interest. It suggests that dietary response is, in part, associated with microbiome composition. Yet surely this is a catch-22, since microbiome composition is modified by dietary intake. It would seem that robust conclusions can only be drawn after long-term studies in which changes in the microbiome with time are also accounted for.

I was always a fan of the polyculture argument

3 October, p 24

From Oliver Arditi, Stoke-by-Nayland, Suffolk, UK

James Wong makes the oft-repeated claim that monocultures give greater crop yields from a given plot of land. As I understand it, and as past research indicated, monocultures enable the highest yield of a single crop from a given plot, but polyculture can generate a higher overall yield, spread across a variety of crops, from the same piece of productive land.

This was the primary basis of the arguments that I originally heard 30 years ago for preferring multi-crop systems of agricultural production, plus the subsidiary environmental and food security reasons that Wong mentions. I am not an agronomist and I haven't stayed abreast of the latest research, however, so I would be interested to know if it has now been shown that polyculture is less productive overall.

So nice to finally meet you all

From Andrew Clegg, Martock, Somerset, UK

I have just watched your online event on *New Scientist*'s coverage of the pandemic. What a pleasure to meet you all. More please.

The editor writes:
For more virtual events, see newscientist.com/science-events

For the record

A picture in our exposé on the plight of giant river fish was mislabelled (3 October, p 41). Both fish on page 43 were actually American paddlefish.

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters
Letters sent to New Scientist, 25 Bedford Street, London WC2E 9ES will be delayed

Signal Boost

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

Are you concerned about climate change and biodiversity? Could you help Ripple Africa make a real and lasting difference in one of the poorest countries in the world?

Ripple Africa is a UK registered charity working with communities in Malawi to help them manage their natural resources in a more sustainable way. We believe that by inspiring and empowering local people, we can help them secure a sustainable future and help the planet at the same time. However, in these difficult economic times, we are hoping that we can also inspire you to support our projects in Malawi:

REDUCING CARBON EMISSIONS
40,000 households are using fuel-efficient cookstoves, each saving three tonnes of carbon emissions a year. Our projects are registered with the United Nations Clean Development Mechanism enabling us to sell carbon credits.

TREE PLANTING We have helped community groups and farmers plant 15 million trees so far and expect to plant a further two to three million each year. By planting fast-growing and commercially valuable species, there is a financial incentive for the growers to care for them as they will provide a vital source of income when the trees mature.

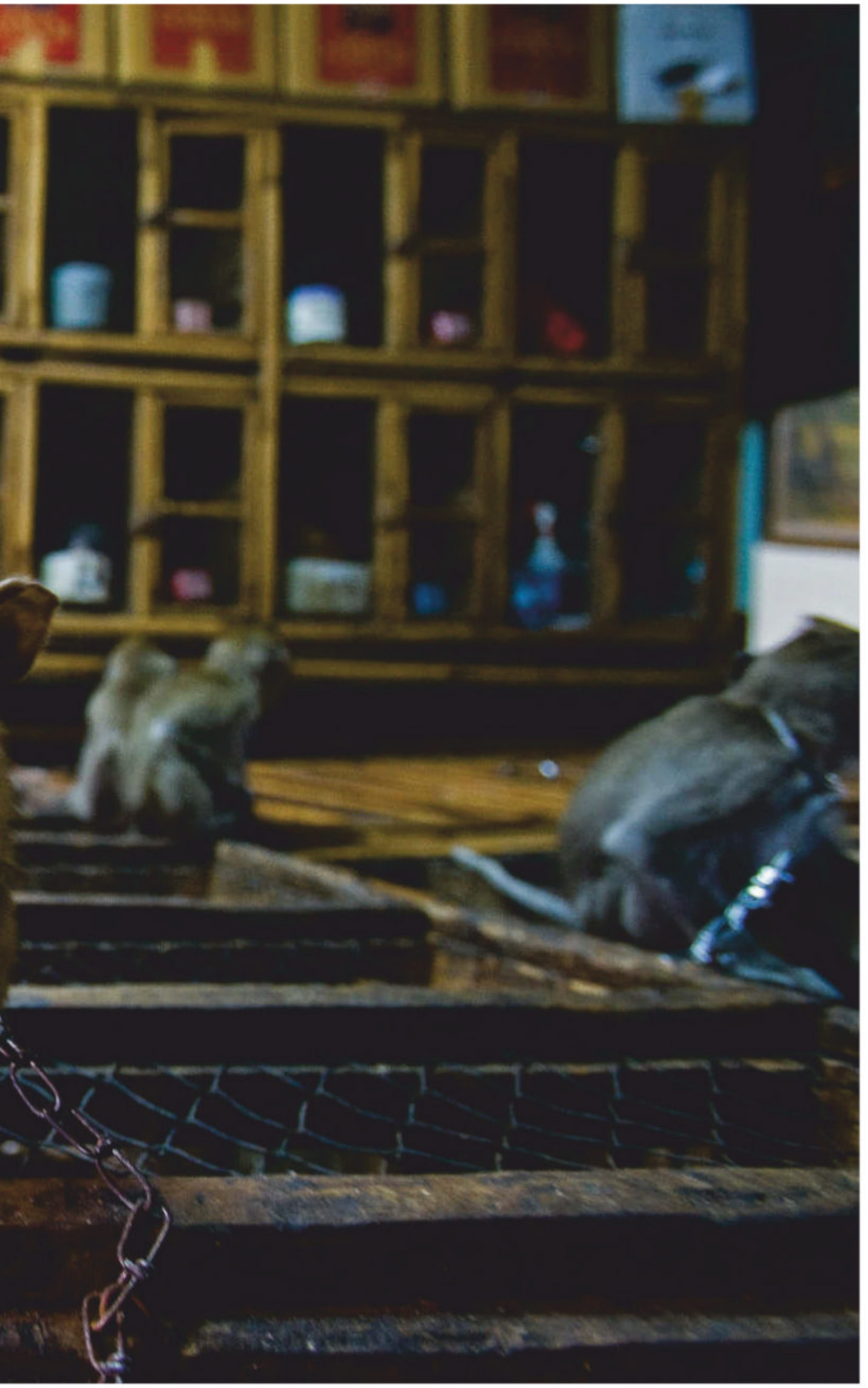
PROTECTING INDIGENOUS FORESTS We are helping 200 communities protect their few remaining forests through bylaws owned and managed by local people that ensure that charcoal production and deforestation are reduced.

SUSTAINABLE FISHING Lake Malawi is the ninth largest and most biodiverse lake in the world. We are empowering people living along 300km of the shoreline to adopt sustainable fishing practices and help stocks of critically endangered fish species to recover. New bylaws ban the use of mosquito nets for fishing - which catch baby fish before they can grow and breed - and protect key breeding areas.

We need your help to enable us to keep these projects going and growing.

Want to help?

If you would like to make a donation or offset your carbon footprint by buying carbon credits, please visit our website at **rippleafrica.org**



Macaque misery

Photographer Paul Hilton/ Wildlife Photographer of the Year

ORPHANED and alone, this young pig-tailed macaque has a bleak future ahead. It is one of many captured primates on sale at this open-air bird market in Bali, Indonesia, where it will either become someone's pet or be sold to a zoo or laboratory for biomedical research.

Conservation photojournalist Paul Hilton feigned interest in purchasing the macaque in order to gain access to the market's back room to take this shot of it chained to its cage, amid a backdrop of other young macaques in the same situation. Titled *Backroom Business*, the image won the Wildlife Photojournalist Story Award in this year's Wildlife Photographer of the Year competition, developed and produced by the Natural History Museum in London.

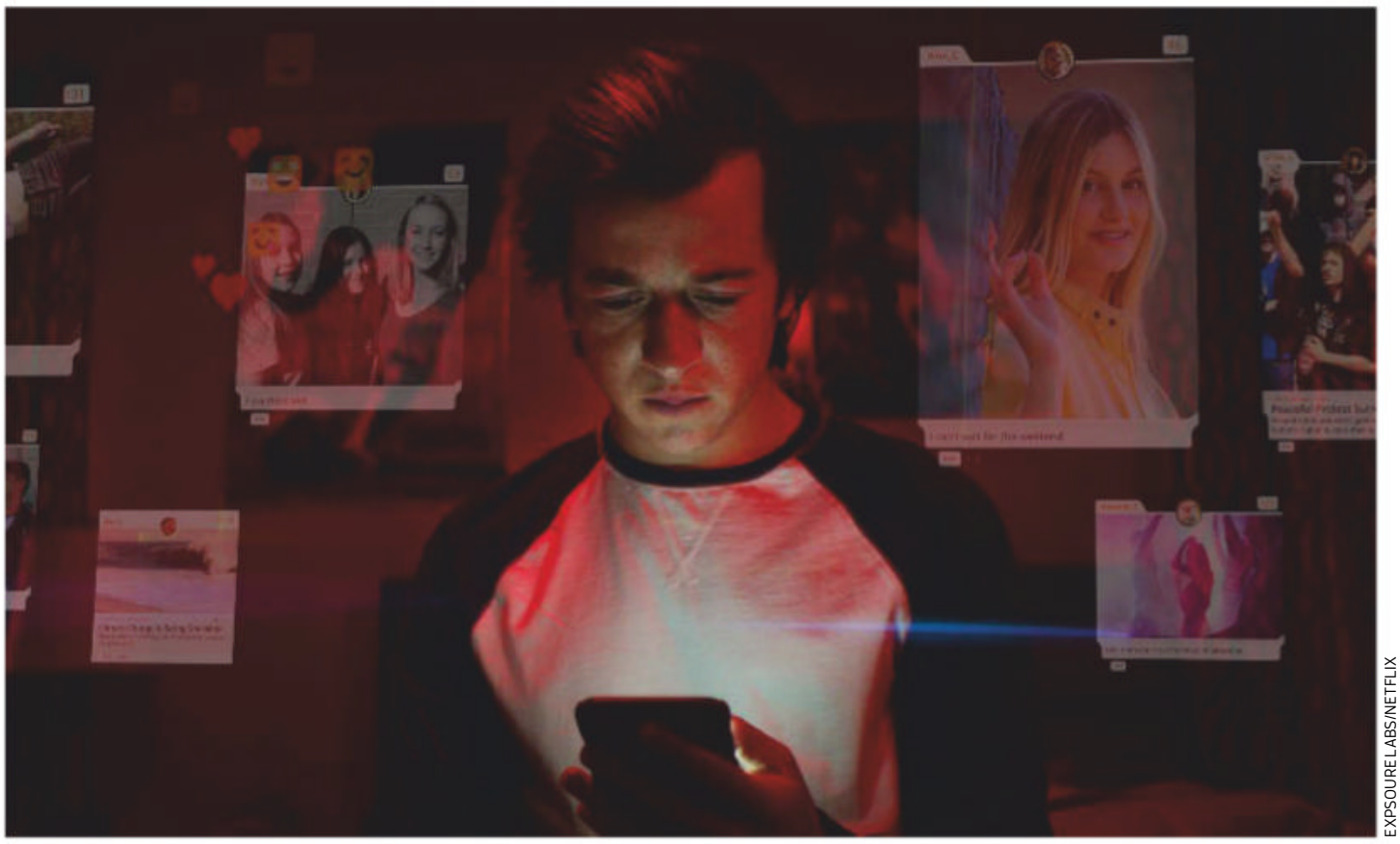
Pig-tailed macaques live in large social groups in the wild, but as deforestation drives them out of their habitat, more and more are being shot as pests when they raid crops for food. Those that are caught are packed closely together in their cages, encouraging the spread of disease. Hilton's work raises awareness of the plight of these monkeys and other wildlife in international commerce, as well as the critical role animal markets play in enabling illegal trade in endangered species.

The Wildlife Photographer of the Year exhibition is on at the Natural History Museum from 16 October to 6 June 2021.

Gege Li

We are the product

Former big tech employees are rounding on the companies they helped create and that now have us in their grip, finds **Donna Lu**



EXPOSURE LABS/NETFLIX

Film

The Social Dilemma
Jeff Orlowski
Netflix

THERE is a telling phrase that has been around in some form or another since the 1970s: "If you're not paying for the product, then you are the product." Applied to internet companies, it means that even though some services appear free, they make money by selling their users' data.

It is an idea discussed at length in new Netflix documentary *The Social Dilemma*. The film examines the ways big tech manipulates human attention for profit. Very little will be eye-opening to anyone with even a passing interest in tech, but the documentary makes for interesting viewing nonetheless because of who it features.

The Social Dilemma interviews tech insiders – former execs and employees of Google, Facebook, Twitter, Instagram and so on – including the inventors of Facebook's "Like" button, YouTube's recommendation algorithm and the now-ubiquitous infinite scroll feature.

These people, mostly male, young and white, express reservations about the platforms that they helped turn into "the richest companies in the history of humanity", as academic Shoshana Zuboff says in the film.

The result is both compelling and hard to swallow. There is a bitter irony in hearing from the people who have profited from the very companies they now claim are eroding the fabric of society. Curiously absent is recognition of complicity, let alone regret.

One of the interviewees, Tim Kendall, for example, was the director of monetisation at Facebook for five years and was directly responsible for developing its advertising model. This is the same model that has driven the decline of traditional media companies and been used for spreading misinformation and undermining democracies, all while Facebook made billions.

Many of the participants recall

"It is plausible that many tech moguls had good intentions, but were blinkered by the allure of rapid growth"

a bright-eyed enthusiasm, verging on naivety, that they felt in their years working for big tech. "When I was there, I always felt like, fundamentally, it was a force for good," says a former Twitter executive. "I don't know if I feel that way anymore."

These about-turns aren't wholly convincing. The comedy writer Rachel Wenitsky recently lampooned this in a sketch that went viral. "I thought we were doing a good thing," she deadpans in character. "After we altered the course of US politics and I made enough money to retire at 27, I realised I was wrong."

The tech interviews are interspersed with fictional scenes of a family: one daughter is a Luddite, while her two siblings are unable to get through a few minutes of dinner without checking their phones.

If one were to be generous, some of the problems faced by the tech sector today could be explained by the law of unintended consequences. It is plausible that many tech moguls had good intentions, but were too blinkered by the allure of rapid growth to foresee that their networks and algorithms would be used to radicalise people and spread unscientific propaganda that hinders efforts to tackle covid-19 and climate change. On the other hand, tech companies have deliberately used insights from behavioural psychology to make their platforms as hard to put down as possible.

A new documentary explores the negative impact of online media

Though human minds are perhaps not entirely powerless in the face of shadowy algorithms conspiring to exploit us for money, as *The Social Dilemma* suggests, the film does a good job of comprehensively covering big tech's troubling aspects.

While we can individually take steps to use technology more consciously, this documentary asks us to look at the wider societal implications of social media too. Platforms that were created to connect us have mutated into ones that can now divide us. Regulation, the film argues, has never been more pressing.

Build your own network

When nobody would build a phone network for people in a rural Mexican village, they decided to go it alone, finds **Simon Ings**

Book

Connected: How a Mexican village built its own cell phone network
Roberto J. González
University of California Press

IN 2013, the world's news media fell in love with Talea de Castro, a Mexican village (population around 2400) in a remote corner of northern Oaxaca. América Móvil, the telecommunications giant that ostensibly served their area, had refused to provide them with a mobile phone service, so the Taleans built their own.

Imagine it: an embattled, predominantly indigenous community besting and embarrassing Carlos Slim, América Móvil's owner and the richest person in the world at the time. The full story of that short-lived, home-grown network is more complicated, says Roberto J. González in his fascinating account of rural innovation.

Talea de Castro was never a backwater. A community that survived Spanish conquest and has resisted 500 years of interference by centralised government may become many things, but "backward" isn't one of them.

Globalisation is a homogenising whirlwind of technology, finance and bureaucracy that brings with it new roads, hospitals, schools, entertainment, jobs and medicine. Yet for every outside opportunity seized, indigenous skills are watered down or forgotten. Talea de Castro's farmers can now export coffee and other cash crops, but many fields lie abandoned as its youth migrate to the US. The village still tries to run its affairs – indeed, the entire Oaxaca region staged an uprising against centralised Mexican authority in 2006.

Some traditional Mexican buildings are built partially of mud. It is much easier and cheaper to use – not to mention a more repairable and more ecologically sensitive material – than the imported alternatives. Despite this, almost every new building in Talea de Castro is made of concrete.

The village backed another piece of imported tech in 2013: a DIY phone network, assembled by US-born rural development specialist Peter Bloom and Erick Huerta, a Mexican telecoms lawyer. Both considered access to mobile phone networks and the internet to be a human right. Also involved were "Kino", a hacker who helped indigenous communities evade state controls, and Minerva Cuevas, an artist best known for hacking supermarket barcodes.

Talea de Castro's network ran off an open-source mobile phone network program called OpenBTS. Mobiles within range of a base station could communicate with each other and connect globally over the internet.

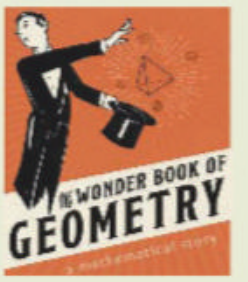
Yet the network never worked very well. Whenever the internet went down, the whole place lost its mobile coverage. Recently, the phone company Movistar has moved in with an aggressive plan to provide the region with regular (if costly) coverage. The idea of an autonomous network in Talea de Castro lives on, however, in a cooperative organisation of community cell phone networks that represents nearly 70 villages across several regions in Oaxaca.

***Connected* is an account of how a rural community takes control over the forces that threaten its existence. The people of Talea de Castro are dispersing ever more quickly across continents and platforms in search of a better life. The "virtual Talea" they create on Facebook and other sites to remember their origins are touching, but the fact remains: 50 years of development have done more to unravel a local culture than 500 years of conquest.**

Talea de Castro's DIY mobile network had global reach – when it worked

CARLOS SALINAS/AFP VIA GETTY IMAGES

Don't miss



Read

The Wonder Book of Geometry by David Acheson takes us on an illustrated tour through the history of the field, from ancient Greece to the present day, and uncovers some of the prettiest surprises in mathematics on the way.

Watch

Max Winslow and the House of Secrets finds a lacrosse player, a social media influencer, a gamer, a bully and a computer hacker competing to win an eccentric billionaire's mansion. Alas, the building's resident AI has other ideas.

Read

Arctic: Culture and climate opens at London's British Museum on 22 October. The wealth of objects and artworks on display in this beautiful exhibition guide reflect the region's 30,000-year history of habitation.

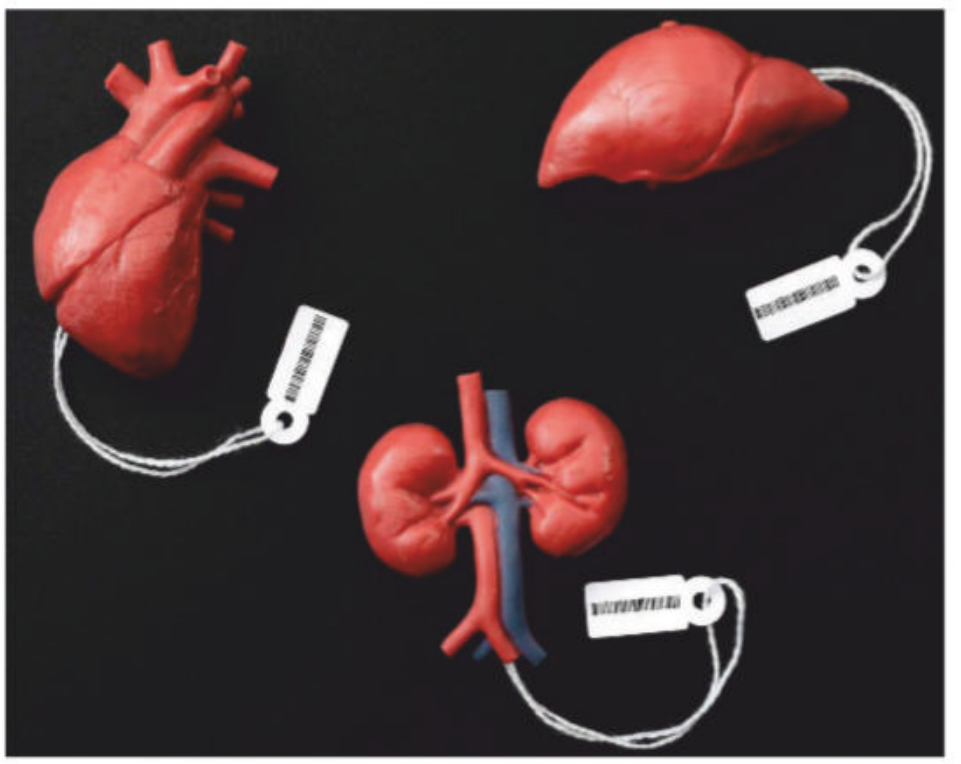
SKIPSTONE PICTURES; TRUSTEES OF THE BRITISH MUSEUM

The science fiction column

A world of redemption

The unfolding story of what happens to a young man whose tongue has been cut out during a brutal civil war provides an unmissable but hard to read lesson about the morality of forgiveness, says Sally Adee

Sally Adee is a technology and science writer based in London. Follow her on Twitter @sally_adee



VICTOR MOUSSA/ALAMY

Body parts are key to a tale of inhumanity and forgiveness

THE main problem with this book is you aren't going to want to read it. But it's good and you should.

Malachi Dakwaa, the eponymous character in T. C. Farren's novel, is a young man whose tongue was cut out in a brutal civil war. In the years since, he has eked out a half-life as a quality control manager at a chicken processing plant, ensuring the uniform compliance of shrink-wrapped body parts.

One day, he gets an offer for a job he didn't apply for, with a payment he could never have hoped for. Do six months at a secret facility run by a pharmaceutical multinational that does research that isn't supposed to exist and he walks away with a new, perfectly grafted tongue. The NDA is particularly tough: if he ever discusses what he saw in the facility, the company can repossess his payment.

At the facility, he finds a body-horror experiment, but one a strict utilitarian might find morally uncomplicated: the people deemed the worst in the world (like "the monsters" his boss labels those who took Malachi's tongue) have been spirited to the place to become incubators for organs. Here, some life-saving good is forcibly extracted from existences that only made the world a worse place. Fitting penance, the boss argues, and as overseers go, Malachi is ideal. To receive his tongue, he needs to make sure he never makes the mistake of seeing the people as anything other than inhuman lest he try to save them from their grisly fate.

"Sci-fi can put you at a slight remove that may actually improve your ability to engage with difficult material"

The book is thrilling, high-stakes world-building, but it took me a couple of months to finally commit to reading it. This is no grand escape from reality, but a searing overexposure to the worst things that can happen to people who may or may not deserve them.

This isn't why we read science fiction, or at least, not to judge by a recent dust-up when researchers claimed sci-fi turns you into a credulous, uncritical reader who isn't able to fully inhabit the mind of the characters. A more recent study takes issue with this, arguing that what happens is more complicated: sci-fi can put you at a slight remove that may actually improve your ability to engage with difficult material.

I thought of these studies often as Farren's beautiful, spare prose dragged me on. I did cry, but the tense plot kept the characters distant enough that I didn't drown in their darkest moments.

It does leave an imprint, though. In the original, biblical Book of Malachi, Malachi isn't a real person but a "messenger". Farren's mute messenger tells us a lot about our world. The book may be near-future sci-fi, but it doesn't seem implausible when prisoners in China are reportedly killed for their organs and inmates in the US are used as firefighters.

Withdrawing empathy by categorising people into cases outside our moral responsibility makes it easy to let them suffer. How readily we turn each other and the natural world into things to be consumed.

This book shows how a small tear in the label you give a person can reveal shared humanity. Once you see it, the tear can only get bigger and let in the possibility of unexpected redemption and maybe a whole new world.

This grace and hope elevate *The Book of Malachi* from the foundations of its sci-fi action-thriller narrative. The questions Farren asks about who controls our ideas of forgiveness, who deserves it and why could stay with you for a long time. ▮

Book

The Book of Malachi

T. C. Farren

Titan

Sally recommends...

Book

The Ministry for the Future

Kim Stanley Robinson

A blueprint for the future that is as obsessively researched as his Mars trilogy. Instead of colonising Mars, The Ministry for the Future *is about recalibrating humanity to live properly on and with Earth rather than terraforming it into a climate hell.*

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Climate's make or break year

Throughout 2020, climate change has played second fiddle to the coronavirus crisis – but decisions we are taking now will seal the fate of our warming planet, says **Adam Vaughan**

THE orange skies looked more like a smoking hellscape from the film *Blade Runner 2049*, but this was California 2020. The images of the huge wildfires there, and in Australia earlier in the year, are perhaps as emblematic of 2020 as those of queues of people wearing face masks.

Climate change hasn't stopped because of a global pandemic. Yet our turbocharged heating of Earth has become an almost forgotten crisis. "Climate change has been put on the back burner," says climate scientist Corinne Le Quéré at the University of East Anglia, UK, who advises the UK and French governments.

In the meantime, the world has seen a welter of uncomfortable records or near-records this year on measures related to climate change, from global temperatures to Arctic sea ice loss, with ever-clearer consequences for global health, wealth and happiness.

"It's understood the covid crisis is a short-term public health crisis and an economic crisis for a few years," says Petteri Taalas at the World Meteorological Organization. "But it's very well understood that the magnitude of crisis we face if we fail with climate mitigation would be something very different."

Coronavirus is far from over. But it is time to think what we want the world to look like 10, 20 and 30 years down the line. What has been happening with the climate crisis while the world's attention has been diverted? How has the pandemic changed the game, and what can and must we do now to avoid catastrophic warming? Read on to find out.

2019: THE CLIMATE PRE-COVID-19

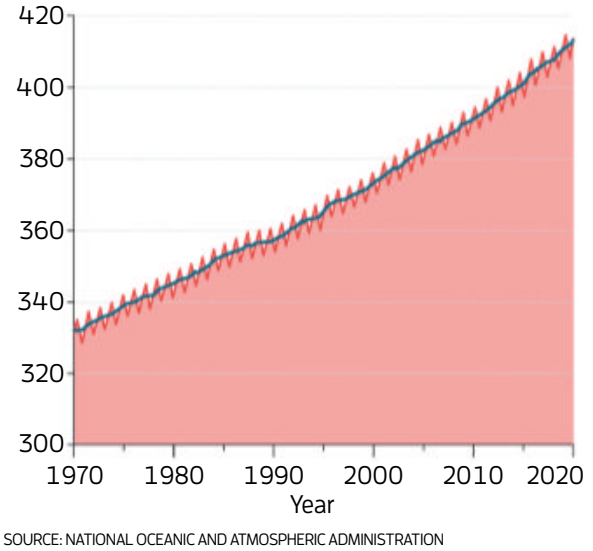
First, a recap. Humanity's reliance on fossil fuels has driven atmospheric carbon dioxide levels from about 280 parts per million before the industrial revolution to an average of 409.8 ppm last year, with that figure now rising by more than 2 ppm year on year. The culprit is mainly CO_2 we emit by fossil fuel burning and land use change, such as converting forest to farmland. Despite briefly flatlining from 2014 to 2016, emissions have grown again, reaching 43.1 billion tonnes in 2019. The world has now already warmed about 1°C since the pre-industrial age.

This is the backdrop that spurred nearly 200 governments to agree to "pursue efforts" to hold warming to 1.5°C, with a backstop limit of 2°C, as part of the 2015 Paris climate agreement. Emissions-curbing plans under the Paris agreement leave Earth on track for warming of 3°C. If we are to hit a 1.5°C path, our remaining "carbon budget" is now highly constrained: roughly speaking, the world needs to halve emissions by 2030 and reduce them to net zero by around 2050. That's where we were.

RAY CHAVEZ/MEDIANEWS GROUP/THE MERCURY NEWS VIA GETTY IMAGES

Wildfires light the sky over the San Francisco-Oakland Bay Bridge on 9 September

Atmospheric carbon dioxide abundance (ppm)



SOURCE: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

2020: A YEAR OF NEW CLIMATE EXTREMES

The past year has been a reminder that, however much coronavirus has distracted us, time is running out for climate change action. California's sepia skies are just the most recent physical signal of this. Australia's record bush fire season, from June 2019 to March 2020, wreathed cities in the planet's worst air pollution, killed an estimated 3 billion land vertebrates and burned an area of forest unprecedented since records began.

Siberia has also been exceptionally warm. It was 10°C above average in May, with one town north of the Arctic Circle, Verkhoyansk, baking in 38°C heat on a record June day. Most striking wasn't the temperature highs, however, but how long the heat lasted. "It's extreme, but it's also very persistent, persisting since January," says Samantha Burgess at the EU-sponsored Copernicus Climate Change Service (C3S). Arctic fires released a record amount of CO_2, breaking last year's record. Arctic sea ice extent hit an all-time low for July, and cover for the summer ranked second lowest ever, after 2012. ›

Europe experienced some excess deaths linked to early August heatwaves, but this was unremarkable compared with last year, when the continent baked in extreme temperatures. The US is another story. Adam Smith at the US National Oceanic and Atmospheric Administration (NOAA) says the country has seen extraordinary extreme weather and events. "Unfortunately, we are starting to get used to this," he says.

California wildfires, many of which were unusually triggered by lightning in August, have burned almost as much land in the state in one year as across the whole of the 1990s. This year has seen five of California's six largest wildfires on record. In Oregon, hundreds of thousands of people were told to evacuate, while blazes took hold in areas usually too wet to burn.

The climate change link isn't complex. Warmer temperatures mean drier, easy-burning trees and vegetation. California's fires have their roots in the historic 2011-2017 drought there. The state has been hit by major wildfires for four years in a row since, although 2019's were less severe.

Here and now

The US also smashed temperature records this year. Death Valley in California recorded an air temperature of 54.4°C, the hottest such temperature ever recorded in the world, if verified. Phoenix in Arizona saw 53 days with highs of 43.3°C (110°F) or more. The previous record was 33 days in 2011. Such a leap shows that, with the climate, change isn't always linear. "That's an example of this step function: an exponential jump, not a little creep.

All but one of the 10 hottest years on record have been in the 21st century, most in the past decade

(Excess temperature over the 1901–2000 average, rolling average September–August)

2015-2016	1.06°C
2019-2020	1.01°C
2018-2019	0.91°C
2016-2117	0.91°C
2014-2015	0.84°C
2017-2018	0.82°C
2009-2010	0.75°C
2013-2014	0.73°C
1997-1998	0.69°C
2006-2007	0.67°C

SOURCE: NOAA

Meanwhile, the US hurricane season may break the record for the number of named tropical cyclones in a year, currently 28 in 2005. That may yet just be cyclical variation, rather than anything to do with global warming, but hurricane intensity is thought to grow in a warming world. Hurricanes Laura and Sally brought destructive rain, wind and storm surges to the US, while in the US Midwest region a derecho storm – a large system of fast-moving thunderstorms that can whip up very strong winds – caused billions of dollars of crop damage. Smith says

REUTERS/MOHAMMAD PONIR HOSSAIN

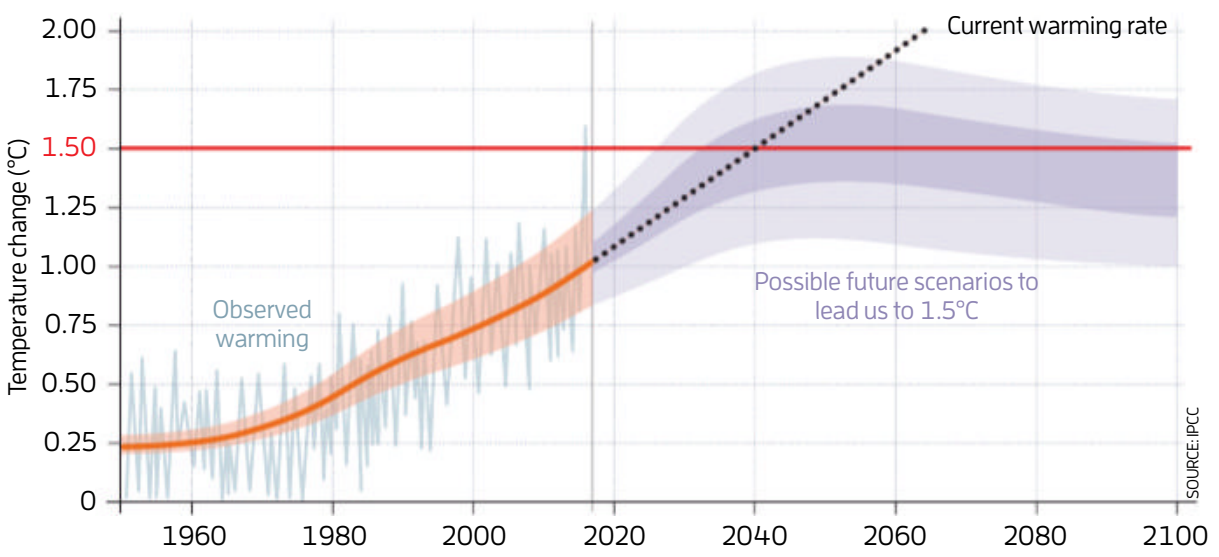
We've seen that with wildfires, damages, and now with temperature extremes and consecutive days of extremes," says Smith. 2020 may bring the biggest financial losses yet attributable to extreme events, partly because more people in the US now live near forests and coastlines, but also undeniably because of climate change, he says.

Extreme flooding has hit many parts of the world, too, from China and Bangladesh to West Africa. "It's a warning call that climate change impacts are here now. We can say with confidence the world is warmer than it would otherwise have been without anthropogenic emissions. And because it's warmer, it makes these events more likely," says Burgess. Attribution studies have already made the links explicit for Siberia's heat and Australia's bush fires.

Globally, this year is likely to be the second warmest on record, says Taalas. According to NOAA figures, the 12 months to the end of August 2020 were 1.01°C above the 1901-2000 baseline figure, second only to a 1.06°C excess recorded ending in August 2016 (see table, above). Figures from the C3S indicate this past September was the hottest globally on record.

Who cares about second? Well, 2016's record was boosted by the natural warming of the El Niño climate phenomenon; 2020 has been incredibly warm without it. "The biggest change we see from climate change is on temperature, and there climate is an absolute game changer," says Friederike Otto at the University of Oxford. "Even at 1°C warming, climate change is bringing us to the edge, or even over the edge, of what we are able to cope with."

Meeting the Paris agreement goal of limiting global warming to 1.5°C means taking action to move from our current trajectory now



Residents walk flooded streets in Munshiganj District near Dhaka, Bangladesh, on 25 July

HOW HAS THE PANDEMIC AFFECTED CARBON EMISSIONS?

Initially, the response to the coronavirus pandemic looked as if it would also be a game changer for greenhouse gas emissions. Government-imposed restrictions on movement and activity worldwide saw global emissions drop 17 per cent in April. Most of the decline was from less road and air travel, and from industry shutting down, especially in China.

The latest estimates are for an annual emissions decline of between 4 and 7 per cent. Emissions had crept back closer to normal by June, but nonetheless any fall in that range would be a dramatic break from decades of rising emissions – the biggest annual decline since the second world war. "It's really huge," says Le Quéré.

But then the bad news

As Le Quéré notes, however, the higher figure is roughly, but not quite, the annual decrease of 7.6 per cent needed to check warming at 1.5°C – this year, and every year, until 2030. That is because climate change is a cumulative affair. Richard Betts at the UK Met Office likens atmospheric CO_2 to the water in a bath and our CO_2 emissions to a running tap. If the tap keeps running, the bath water continues to rise.

In May, expecting a slower-running tap because of coronavirus, Betts made revised predictions for fractionally lower atmospheric CO_2 levels at the Mauna Loa monitoring station in Hawaii. Observations for May, June and July tracked close to his downgraded forecasts, whereas August was closer to his pre-pandemic forecast.

Betts is cautious about reading too much into one month's data and measurements at just one site. Regardless, atmospheric CO_2 levels in May hit a record monthly high of 417.1 ppm, a level unseen for several million years. The figure for May 2019 was 414.7 ppm. "We were correct in saying [lockdown] wouldn't make much difference to atmospheric CO_2," says Betts. To change things, we need to turn the tap off fully and start actively draining the bath too.

Piers Forster at the University of Leeds in the UK has estimated that this year's covid-19 restrictions will have a global cooling effect of just 0.01°C by 2030, if we return to business as usual. Staying at home and grounding planes only goes so far without simultaneous systemic change to industry, transport and power generation. "To make a real difference to CO_2 we can't just make a short-term cut, we have to get to net zero [emissions]," he says. "We aren't going to make the necessary changes without much longer infrastructure change and the whole structural changes to the way economies work."

WILL COVID-19 HAVE ANY LASTING CLIMATE IMPACT?

The dip in emissions due to the coronavirus has at least bought time for countries with legally binding climate targets such as the UK, which since 2008 has had five-year "carbon budgets". "What covid will deliver generally is a bit of extra breathing space in the carbon budget," says Chris Stark at the Committee on Climate Change, which advises the UK government. "I hope they use it wisely." The pandemic slightly delayed the committee's advice on the UK's next budget to be set, for 2033-2037, which will now consider covid-19's impacts. Stark says the report, now due out on 6 December, will probably forecast that shipping and aviation emissions won't return to pre-pandemic levels for many years.

Others are also looking at the pandemic's longer-term impacts. Oil giant BP's response is to cut oil production 40 per cent by 2030. Its rival Shell sees three ways things could play out: a world in which wealth is prioritised and emissions keep growing; one where public health comes first and emissions start falling towards the late 2020s; and one where economies falter amid renewed coronavirus outbreaks, social and geopolitical tensions grow, and while emissions stall in this scenario, so does climate action.

"The pandemic's emissions reduction is what we need this year, and every year until 2030"

Leaving this bleak picture aside, David Hone at Shell says the emissions path the world takes now will depend on how long public health concerns necessitate continued large-scale social shifts, such as lots of people working remotely. A year may not be enough to cement lasting change on that front, but things could be different after three or four years of this, he says: "People might even do renovation for a home office, then they'd ›

say I'm not leaving because I've spent money. The whole system starts to change." City authorities could be forced to address empty urban centres, potentially rezoning them as residential districts. Pre-pandemic, Hone thought there was some "wishful thinking" about meeting the Paris agreement goals. Today, he sees the health crisis as a possible trigger for the necessary structural change.

"We are in a rupture phase," says Le Quéré. She thinks there are two reasons global emissions could change radically. One is car use, which in the EU accounts for 44 per cent of all transport-related emissions. Curbs on driving and measures to encourage home working, cycling and walking could immediately cut car emissions. Equally, health concerns may see people opt for cars over public transport; there is already evidence of this happening in London.

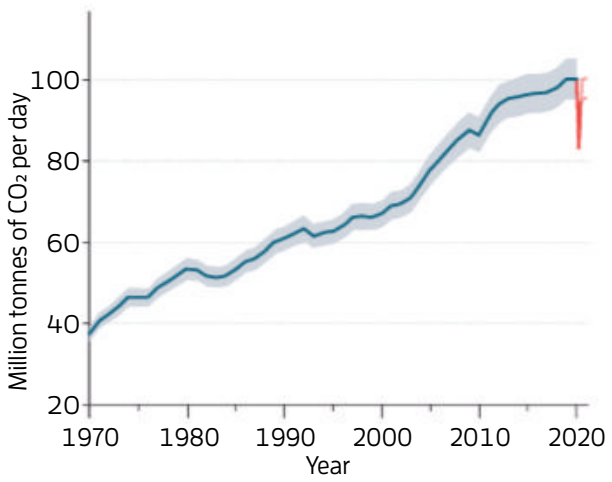
The second, bigger reason is governments' post-virus financial stimulus. How much is for green infrastructure – electrification of cars rather than road-building projects, say – will dictate how much we cook the planet.

The past offers some lessons. The 2008-2009 financial crash was followed by a stimulus that drove emissions up almost 6 per cent in 2010, entirely offsetting the brief emissions downturn the crisis had brought about. Fortunately, history looks unlikely to repeat itself. "The climate stuff really was buried in 2008, we didn't really have a green stimulus package," says Stark. "I do think this time it's different. The changing climate is much more in the forefront of people's minds around the world." Green tech has also matured rapidly. In the UK, renewable sources generated 6.7 per cent of electricity in 2009; in 2019, it was 36.9 per cent.

"One thing that is an improvement on 2008 is there is less of a discussion of whether investment in green stuff is needed, less debate over whether climate change is a thing," says Victoria Cuming at Bloomberg New Energy Finance. She and her colleagues have noted $159 billion of government investment announcements mentioning emissions-cutting technology since the start of the pandemic, with electrification of transport scooping up about a quarter of that.

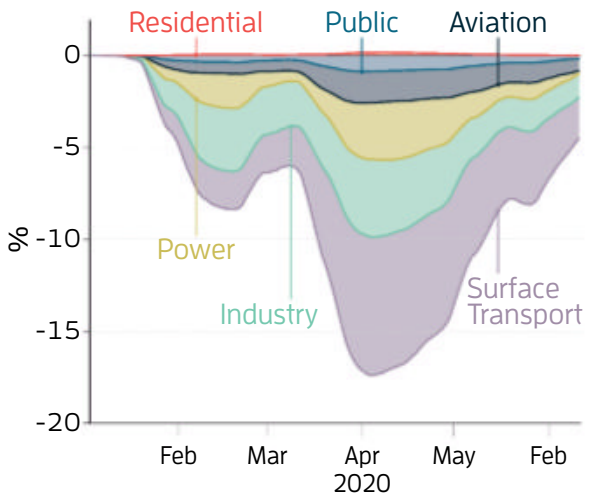
Yet three countries – France, Germany and South Korea – account for three-quarters of this money, and the $159 billion is only about 1 per cent of all the stimulus. Increasing that percentage would offer significant rewards. Forster found a strong green recovery now would avoid 0.3°C of warming by 2050 – a huge step in the right direction.

Global daily fossil CO_2 emissions



SOURCE: LE QUÉRÉ ET AL. NATURE CLIMATE CHANGE (2020); GLOBAL CARBON PROJECT; FIGURE: @JONES_MATTW

Change in global daily fossil CO_2 emissions



SOURCE: LE QUÉRÉ ET AL. NATURE CLIMATE CHANGE (2020); GLOBAL CARBON PROJECT; FIGURE: @JONES_MATTW

A floating solar panel array at a copper mine outside Santiago, Chile, in 2019

REUTERS/RODRIGO GARRIDO

WHAT'S HAPPENING WITH GLOBAL CLIMATE ACTION?

This year should have been crowned by COP26, a landmark UN climate summit hosted by the UK in Glasgow in November. At it, the world was to thrash out concrete plans to limit global warming to 1.5°C. It was postponed by a year. While no one argues with delaying a 30,000-person conference amid a pandemic, it does mean preparatory meetings were deferred. A diplomatic drive of the sort that helped the 2015 Paris summit make progress has been hampered.

This year is also the deadline for countries to submit carbon-cutting plans known as nationally determined contributions, or NDCs, to narrow the gap between current pledges and what needs to happen to meet the Paris climate goals. Only 12 of almost 200 nations have done this, and none is a major economy. In September, however, China surprised the world by pledging to achieve "carbon neutrality" by 2060 and promising a new NDC. The European Union is signalling it will have an enhanced NDC before the year's end, and the UK announced a summit for 12 December, the five-year anniversary of the Paris deal being agreed, to encourage leaders to announce new NDCs then.

Silver lining

The delay to COP26 could actually be a good thing. Stark says it will allow the UK to put in place domestic policies needed to hit its target of net-zero emissions by 2050, such as bringing forward a ban on sales of new petrol and diesel cars. Momentum is also growing from businesses, city mayors and other sub-national leaders for stronger emissions cuts, says Nigel Topping, the UK government's High Level Climate Action Champion. Meanwhile, Greta Thunberg and other campaigners are maintaining the pressure.

Work on basic climate science is one thing coronavirus hasn't stopped. Three major new climate science reports are expected from the UN's Intergovernmental Panel on Climate Change (IPCC) next year: one on the physical science of climate change, one on its impacts and how we adapt, and one on how we stem warming. A fourth report, a synthesis of the others, is due out in 2022. Together they will comprise the sixth

REUTERS/KACPER PEMPEL

Climate protesters in Warsaw, Poland, on 25 September

assessment report (AR6), a new gold standard in our understanding of climate change.

The headline news in these reports may be new estimates of climate sensitivity, a measure of how much Earth warms in response to a doubling of atmospheric CO_2 – in other words, just how bad this is likely to get. The new, more sophisticated computer models being used for AR6 put the likely range of warming at between 1.8 and 5.6°C, up from 1.5 to 4.5°C previously. "The general perception is [the models] are running hot. I think most people are expecting it to be no more optimistic than [the last generation of models], and possibly worse," says Michael Meredith at the British Antarctic Survey.

The reports will also look in more detail at climate change on a regional level, and there will be a greater focus on low-likelihood, high-impact changes such as extra sea level rise from ice mass loss in Antarctica and Greenland. There will be a new chapter dedicated to attributing extreme weather events to climate change and detecting humanity's fingerprint on Earth systems. In addition, the global warming potential of methane, an atmospheric pollutant that is shorter-lived than CO_2 but with a stronger greenhouse effect, is expected to be upgraded.

All of that means more hard science for a delayed summit to respond to. "I actually think it's a positive. We'll lose a year on the negotiations, but gain way more than a year in terms of ramping up ambition," says Topping.

WHAT DO WE NEED TO HAPPEN NEXT?

In one sense, the events of 2020 have changed nothing about climate change; in another, they have changed everything. "From a policy perspective, 2020 was not the year we expected," says Burgess. And while the response to covid-19 has shown that deep emissions cuts can be made quickly, it also highlights the challenge of making change last and the limits of individual action.

Significantly, covid-19 has been a reminder that we will have to deal with shorter-term crises as we race to tackle the big one that will play out over centuries, and that these may be intertwined. The toxic smoke from the US West Coast fires, for example, exacerbated the pneumonia that covid-19 can cause, while coronavirus social distancing complicated housing thousands of people fleeing the blazes in sports halls and schools.

One big factor in how things play out is the outcome of the US elections on 3 November. Whoever wins, Donald Trump's pledge to take the US out of the Paris agreement will become reality the day after. Joe Biden has promised a climate plan working towards net-zero emissions by 2050, and pledged to return the US to being a constructive player in UN climate talks. "We're either going to have four more years of the 'bring back coal fantasy' or a very ambitious climate presidency, and that will change the geopolitics massively," says Topping.

Regardless of the result, the wider world has the technology and the tools to halve emissions by 2030 and reach net zero by 2050. The UK's statutory climate advisers said last year that the country's 2050 goal is feasible. It will cost about 1 to 2 per cent of GDP with existing technology and without radical behavioural changes. Governments need the political will, and businesses, which will pay for a lot of it, will be vital. Economic shifts well under way, such as the falling costs of renewable energy and batteries, will make some decisions easy. Citizens, meanwhile, who can only do so much by insulating their homes or buying an electric car, need to pressure their political representatives, in writing, in elections and where necessary on the streets.

When covid-19 has become just a Wikipedia page, climate change will still be shaping all our lives, says Meredith. "Whilst our attention is on covid, and rightly so, the fact we are losing attention on climate change really does hamper our ability to do what we need to do, and the time we've got is dwindling." That is the reality of climate change in 2020. ▮

Adam Vaughan is *New Scientist*'s chief reporter

How to build a higher dimension

We have begun to cook up extra dimensions in the lab and explore what lurks within. **Jon Cartwright** investigates

CHRIS MALBON

YOU are running through an open field with the wind in your hair. Or you are diving into the ocean, feeling the cool water surround you. At moments like these we feel free, liberated. Few of us stop to consider the truth – that we are trapped in an invisible prison.

Up-down, left-right, forward-back: these are the three dimensions in which we eat and breathe, make friends and grow old. As prisons go, it could be worse. Then again, we have never known anything else. Despite some imaginary claims to the contrary, no one has ever really experienced a higher dimension.

But now, in some of the world's most sophisticated labs, we are building our own synthetic extra dimensions. The concept is so far removed from our experience that it is hard to imagine what they could be like. We have, however, already seen the ghostly effects of four-dimensional space touch on our own and wired up electric circuits with an extra dimension. It is unlikely to stop there. Now we have got the hang of it, there is talk of creating five, six or even more dimensions, and even suggestions that exotica such as new particles might lurk in the extra-dimensional wilderness.

This is a frontier that we are barred from exploring directly. We are forced instead to look for the subtle imprints that extra dimensions make on the three dimensions we are confined to. Even so, we could be about to extend the boundaries of reality in ways that come close to the limits of our descriptive powers.

Talk of extra dimensions might sound a bit mystical, but spatial dimensions have a clear definition. They are a way of describing our possible range of movement. In normal space, you only need three of them – usually labelled x, y and z. True, time is sometimes referred to as the fourth dimension, and physics tells us that it is married to space in the union known as space-time. But that is as far as we conventionally go. Even the majority of physicists seem to be resigned to just three dimensions. If they were seriously expecting more, they might not have chosen their labels from the end of the alphabet. Our struggle to grasp extra dimensions is nicely captured in

"Physicists seem resigned to just three dimensions. If they were expecting more, they might not have chosen their labels from the end of the alphabet"

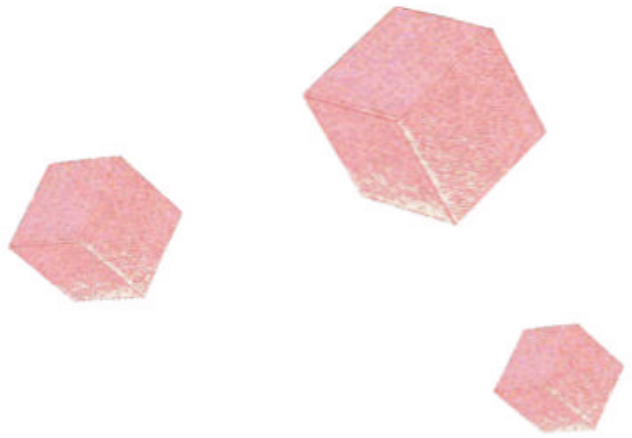
Edwin A. Abbott's 1884 novella *Flatland*, which set out to criticise the small-mindedness of Victorian England by portraying a flat world inhabited by two-dimensional shapes. When the square-shaped narrator is visited by a sphere, he has great difficulty believing in the existence of a third dimension. All he can perceive of the visitor is the shape created by its intersection with his familiar two dimensions – a circle. Likewise, when the narrator has a dream in which he visits a one-dimensional world, Lineland, the locals reject his tales of the second dimension: all they can see are the dots he casts on their narrow path.

Life on the edge

The story of synthetic dimensions also begins in a flatland, in materials that are wafer-thin and therefore, to all intents and purposes, two dimensional. If you apply a magnetic field to such a wafer, it makes all the electrons inside it want to move in tiny circles. And that is just what happens – except at the edges, where there isn't enough space and the electrons' trajectories are chopped off into semicircles. But instead of stopping in their tracks, these electrons zip along the edge, forming a conducting periphery. This is called the quantum Hall effect, and it creates a material that is electrically insulating in the middle but conducting on the sides.

This unusual duality depends on the one-dimensional edge feeling the effects of a higher dimension. To see how this works, imagine a one-dimensional line, much like Lineland in the novella, with electrons sitting on it. If you apply a magnetic field to this, the electrons can't move in circles; that isn't possible in one dimension, so they remain fixed in place. If this line is the edge of a wafer, however, the electrons can skip through the two-dimensional plane. This edge conductivity is known as a topological state.

If a one-dimensional line can pull neat tricks when it feels the imprint of another dimension, can higher dimensions do the same? The answer is yes. In 2008, decades after the original discovery of the quantum ›



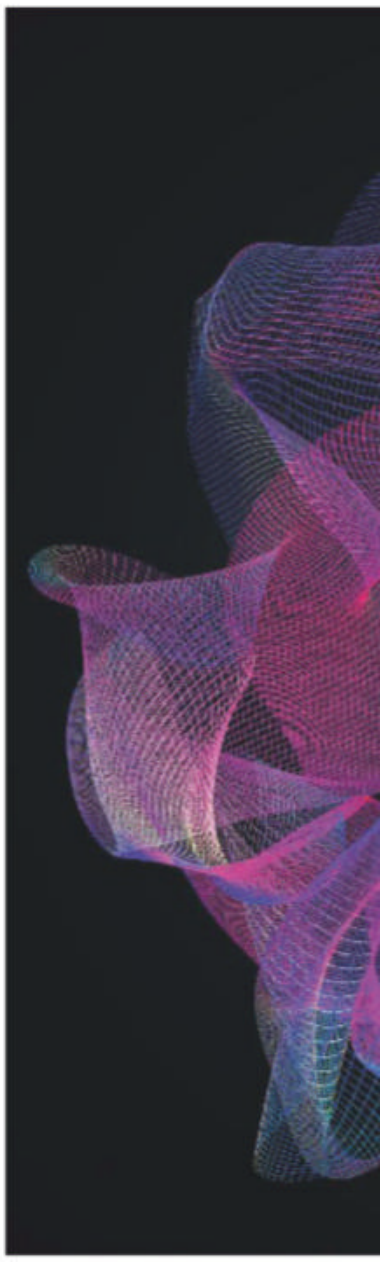
Hall effect, physicists discovered a similar phenomenon in which the electrons on a 2D surface skip through the 3D innards of a material. Like all topological states, these materials have a useful characteristic. It turns out that any impurities on the surface won't impede an electron's progress because it can always skip through a higher dimension. This makes them good electrical conductors. Some physicists think they will be useful in designing superfast quantum computers.

Long before this, in 2001, the late theorist Shou-Cheng Zhang and his colleague Jiangping Hu, then both at Stanford University in California, dared to consider a wild progression. Would it be possible to create a four-dimensional analogue of the quantum Hall effect, one in which a regular three-dimensional material felt the imprint of a fourth dimension? They ended up developing the mathematics that could describe such a thing. But it seemed destined to remain theoretical – it was tough to picture how this kind of maths could be made real.

Lately, though, a few physicists have given it a go, including Hannah Price at the University of Birmingham, UK. "Trying to understand higher-dimensional physics is like crossing into a different universe. You don't know what's waiting beyond that frontier," she says. She wanted to see what new physics might be there, so set out to try to make Zhang's ideas a reality.

To see how, let's briefly return to *Flatland* once more. In the story, the sphere finally persuades the square of the existence of the third dimension by bobbing up and down, and thereby changing the size of his intersection with the square's plane of vision. He starts as a dot when he and the plane are just in contact, becomes a big circle when his equator passes through the plane, and reverts to a dot when he is all the way through (pictured, far right). The late theorist David Thouless developed a real analogue of this process in the 1980s. It is called a topological pump and entails changing the distance between particles in an array in such a way that it looks like a higher dimensional object is being "pumped" through them.

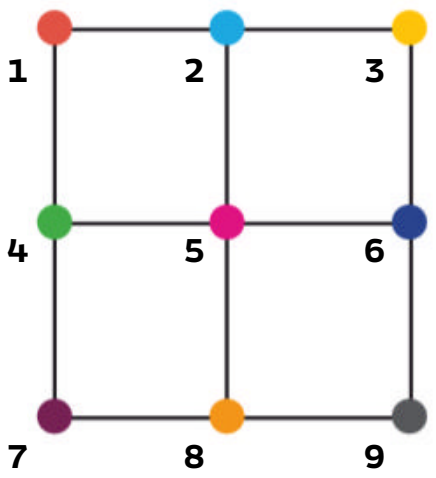
In 2018, Immanuel Bloch at the Max Planck Institute of Quantum Optics in Germany,



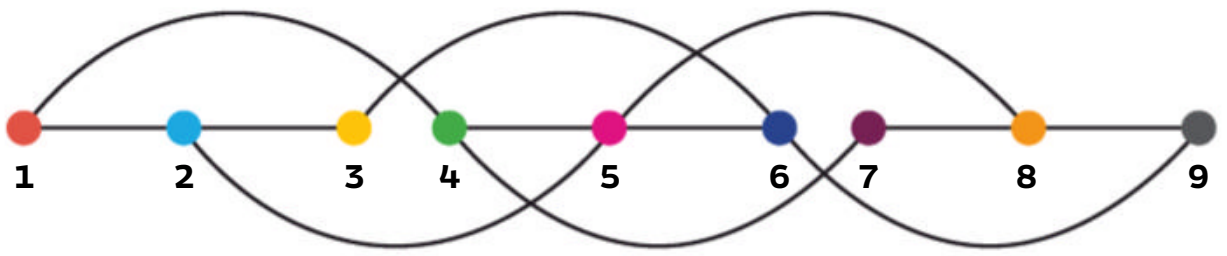
A slice of the Calabi-Yau manifold, a representation of multi-dimensional space (right)

An illustration from *Flatland* (far right) shows how a sphere would appear in a world with less than three dimensions

Two dimensions in one



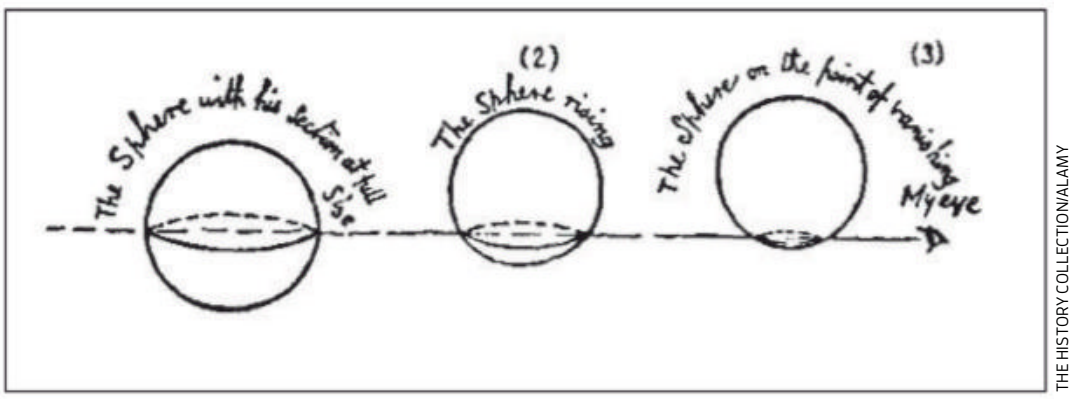
One way to build a dimension is to connect a one-dimensional line of components as if they were a two-dimensional grid. To see how it works, think of a grid connected as shown above left.



Now, arrange those points in a one-dimensional line, but have them connected in the same way as they were in the grid shown above right. You have effectively created two dimensions in one.

Researchers recently repeated this with several rows of real electrical components to create the world's first four-dimensional circuit (see main story).

VCHAL/GETTY IMAGES



THE HISTORY COLLECTION/ALAMY

"With the shackles of traditional dimensions cast off, things could quickly get wilder"

together with Price and others, created a lattice of atoms held in place by lasers. By tweaking the lasers, they could deform the lattice to generate the ghostly shimmer of a four-dimensional object. It was a real-world example of what the square had experienced with the sphere in *Flatland* – and, together with a separate experiment published at the same time, it was the first realisation of the quantum Hall effect in four dimensions. "We were a bit spooked when we wrote the papers," says co-author Oded Zilberberg at the Swiss Federal Institute of Technology in Zurich. "We thought people might think we're dealing with science fiction."

Despite Zilberberg's enthusiasm, it is hard to point to what, or where, the fourth dimension is in these experiments. It could be seen as an illusion cast on the positions of the atoms when their behaviour is viewed over time. Freeze the system at any instant and there is little sign that anything special is happening. "Our experiments weren't 4D enough," says Price.

Far better than conjuring the impression of a fourth dimension is actually building one – so that is what Price did next. To understand how it works, again picture a scenario in two dimensions. Start with a grid on a sheet of paper. Now redraw all the points on that grid in a row, and connect them up with squiggly lines – don't worry about crossing them – so that they are connected with their original neighbours. What you have just drawn, topologically speaking, is a two-dimensional grid in one dimension (see "Two dimensions in one", left). Now, replace the points with electrical components, and the lines for wires, and you have a situation like the quantum Hall effect, where electrons can skip through a higher dimension to get to where they want to go.

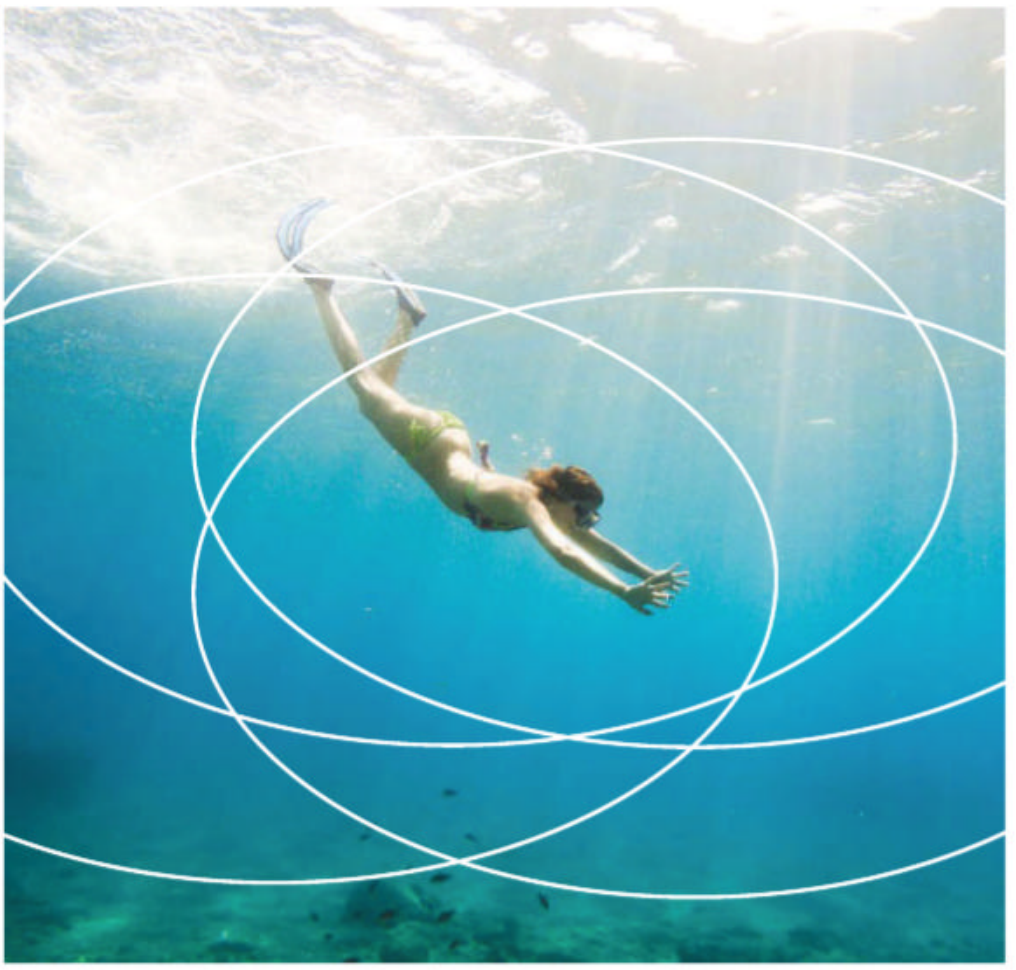
Expect fireworks

Earlier this year, based on a concept of Price's, Yidong Chong at Nanyang Technological University in Singapore and his colleagues expanded this kind of circuit to include components not just in a row, but multiple rows and layers. Applying a voltage across the edges of the stack had no effect: it didn't conduct. But when the researchers applied a voltage to the components that would have marked the edge of the four-dimensional grid, had they not been rewired into a three-dimensional space, the entire circuit conducted seamlessly like a single metallic mass. And unlike the previous experiments, the effect wasn't time-dependent. "It's a permanently four-dimensional lattice," says Price.

With the shackles of traditional dimensions cast off, things could quickly get wilder. Price, Zilberberg and others say that topological pumps could manifest the quantum Hall effect in six dimensions. Theorist Motohiko Ezawa at the University of Tokyo in Japan says that electric circuits have the potential to manifest as many dimensions as experimentalists have the patience to wire up.

But as we build experiments that are governed by more than four dimensions, the behaviour we observe from our limited three-dimensional vantage point is no longer going to be easy to make sense of. It won't be as simple as the Flatlanders discerning a sphere as a circle of changing width. Instead, we can expect a firework display of bewildering effects.

In 2018, for instance, Seiji Sugawa at Kyoto University in Japan and his colleagues laser-cooled a cloud of rubidium atoms in such a ›



MANUEL BREVA COLMEIRO/GETTY IMAGES

way that its internal states obeyed the mathematical rules of five dimensions. The signal that trickled out had the weird hallmarks of a magnetic monopole, an exotic object that, unlike any normal magnet, has only a north or south pole, not both. Zhang calculated that it might even be possible to observe a five-dimensional version of a Weyl particle, which behaves like a massless electron. It isn't clear whether these could be harnessed for a practical application though.

There is a bigger question before we get to that: are these synthetic dimensions real? In the case of Price's electric circuit, the extra dimension certainly has tangible effects. Yet there is a difference between it and the three dimensions we normally experience. We can still see the interconnects that collectively manifest the extra dimension: it is as if the fourth dimension is somehow wrapped up within the three dimensions of regular space. Experiments like this ask us to pretend that the interconnects – or the lasers, or whatever else is responsible for sustaining the extra-dimensional physics – aren't there at all, like stagehands at the theatre.

Shinsei Ryu at Princeton University raises another issue. If we take Price's four-dimensional electrical circuit, he says, the primary flow of the electrons is governed by the synthetic dimension, but their natural interactions – for example, the mutual repulsion that results from their charge – may well still be governed by the three normal dimensions. As a result, making our own dimensions might not be a reliable way to study the finer points of extra-dimensional physics. "That's my worry," says Ryu.

Even when we feel most free, we are trapped in a three-dimensional prison

"There is a more powerful way to build a synthetic dimension, one that relies upon quantum rules"

Still, the story might not end there, according to Ryu. There is a more powerful way to build a synthetic dimension, one that relies on quantum particles such as atoms having energies that go up in discrete steps. You can think of these energy states as being like a ladder, which the particle can hop up or down. This might feel like a trick because the particle itself doesn't actually move – its extra dimension is contained within a fixed position in three dimensions. But this is exactly the point. This type of extra dimension is completely independent of the regular three. Magnetic fields could be used to tune the way each particle interacts with its neighbours – whichever dimension they are in – and this would potentially allay Ryu's concern about unnatural behaviour. "This is my dream," says Price.

The dream is perhaps not far from coming true. In 2015, two independent teams of physicists created synthetic dimensions of the quantum energy-ladder variety out of atoms, making systems of two dimensions in total. That is still two dimensions short of the other implementations, but Price believes that this strategy could ultimately provide a way to explore bona fide extra-dimensional physics.

If we pull that off, then Ryu is hoping there will be new applications, such as making it easier to link up the quantum bits, or qubits, that form the basis of emerging quantum computers. The fact that topological states are protected from impurities and other sources of disruption suggests that those states could deliver high volumes of data without fear of signal loss.

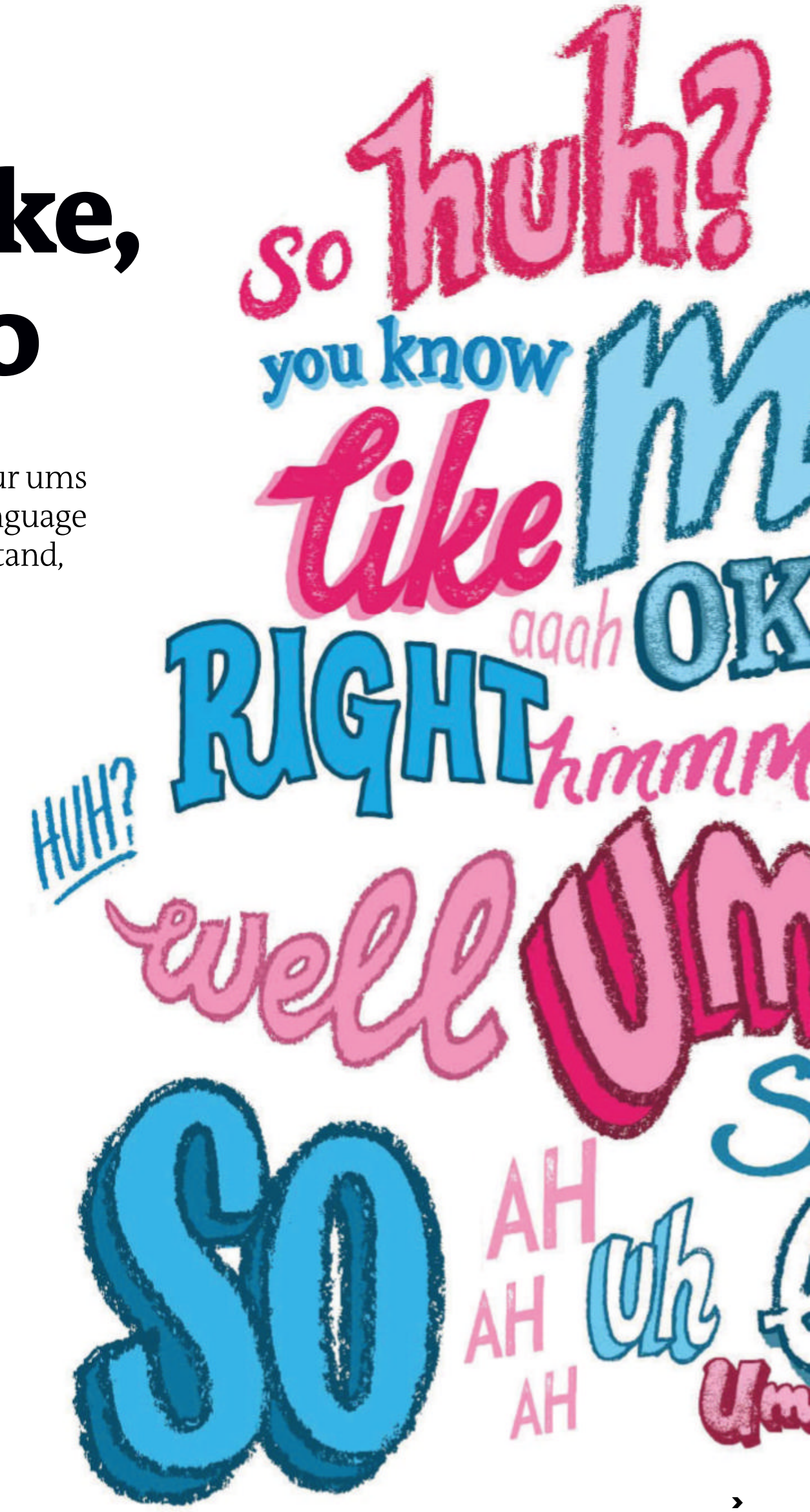
Studying the behaviour of synthetic dimensions could also help us understand the possible role of extra dimensions in fundamental physics. Thanks to Ryu and others, the theory behind topological states is so well mapped out that there exists a "periodic table" of possible extra-dimensional behaviours, dictated by how much underlying symmetry there is in the system. According to Ryu, it may be no coincidence that there are 10 classes of symmetry in the table and 10 dimensions in string theory – the most famous extra-dimensional idea in physics. "There's certainly mathematical connections between them," he says.

We are, it seems, only just realising that we have been living in our own Flatland. "It opens our minds," says Zilberberg. "We can explore things like this for real." ▮

Jon Cartwright is a freelance journalist based in Bristol, UK

Speak like, uh, a pro

Far from signalling stupidity, our ums and uhs are part of a hidden language that we subconsciously understand, finds **David Robson**



ANDY SMITH

YOU might expect it to take more than a two-letter word to sink a politician's credibility. But one did just that for Canada's prime minister, Justin Trudeau, in June 2016. With a huge wildfire burning in the province of Alberta, he had been asked about the country's capacity to cope. "Uh, certainly, I think we're, uh, all aware that, uh, uh, a prime minister, uh, showing up at Fort McMurray, when firefighters are busy trying to, uh, uh, contain a massive raging wildfire is, uh, not a particularly helpful thing," he began. Trudeau went on to use a total of 50 uhs in a statement lasting little more than a minute.

A video soon went viral, and online commentators were universally scathing. "Canada's dumbest, uh, Prime Minister" wrote one viewer. Reading the unedited transcript, you may well have questioned Trudeau's intelligence yourself. Surely such hesitation is a sign of sloppy thinking and ineloquence. Weren't we taught as children to eliminate uhs from our conversation?

Yet the latest research shows that this is an unfounded prejudice. Far from being an inarticulate waste of breath, filler words like um, uh, mmm and huh are essential for efficient communication, sending important signals about the words we are about to say so that two speakers can better understand each other. "They streamline our interactions, smooth the flow of the ›

conversation and manage our social relations," says Mark Dingemanse, who studies language and social interaction at Radboud University in the Netherlands. Indeed, he argues that the complexity of our language today couldn't have emerged without them. To which the obvious response may be, "huh?"

It is only recently that scientists have paid filler words any serious attention, with many linguists previously considering them to be mere errors in speech production with no useful function. "People were taught that they were just garbage," says Jean Fox Tree at the University of California, Santa Cruz. The few studies that were done mainly riffled through that supposed rubbish for clues to deception – with mixed results (see "I'm, uh, telling the truth", page 48).

The turning point came in 2002, with a landmark paper by Fox Tree and her colleague Herbert Clark at Stanford University. They analysed vast records of conversations spoken in English covering millions of words and concluded that, far from being mere accidents, filler words constitute a "collateral signal" or "metalanguage". In essence, this means that without changing the overall meaning of a sentence, they help us coordinate conversations with minimal confusion.

Take uhs and ums. The analysis revealed that these words don't merely replace pauses in a speech, they announce them. Intriguingly, the pauses following ums were about twice as long as those after uhs. This suggests that each filler word signals something specific to the listener, rather than arising as a processing error, argued Fox Tree and Clark. These simple "inserts" are managing the listener's expectations of what will come next, priming them to either wait patiently as the speaker collects their thoughts or dive in and help out. "You're using these words to negotiate communication in real time, with a waiting addressee who wants to communicate with you right at that moment," says Fox Tree. As an illustration, she pauses mid-sentence without an uh or an um to signal the delay – and I can confirm that it is indeed very disconcerting.

Heads up

The paper has now been cited more than 1000 times, igniting more research to explore the idea that filler words are signals that guide us through a conversation. Susan Graham at the University of Calgary, Canada, for instance, has found that these words prepare us to be surprised by something new or unfamiliar. "They are a signal that something is changing in the conversation," she says.

In a series of experiments, Graham hooked her participants up to special goggles that tracked the movements of their eyes as they

WHY WE, LIKE, SAY "LIKE"

Speakers of every language co-opt certain words to punctuate sentences in a way that often appears completely gratuitous. In English, one of these words is "like", as in: "the concert was, like, 2 hours away". It turns out that this usage may not be as random and meaningless as it seems.

When Jean Fox Tree at the University of California, Santa Cruz, asked students to recount a personal experience to two separate listeners, they often placed the extra likes in the same place in both retellings. She thinks that like acts as a form of emphasis, based on the speaker's and listener's knowledge of each other. In the example about the concert, for instance, it signals that the distance is a particularly significant detail to the speaker. "So if you know me, and you know that I like that band that's playing, when I say 'the concert was, like, 2 hours away', what I'm saying is, that's a short distance to drive to get to this band that I really like," says Fox Tree. "But if you know that I hate driving, saying 'the concert was, like, 2 hours away' would mean that's too far for me to drive to get to that band."

This makes like similar to uh and mmm (see main story). Far from being linguistic garbage, they all rely on interpreting another person's mind, which is a highly sophisticated cognitive skill.

CANADIAN PRESS/SHUTTERSTOCK

Justin Trudeau was called out for umming and uhing

heard various sentences describing pairs of images presented to them. She found that participants could more easily follow the speaker's description as it veered from one image to the other if the sentences included a filler word. For example, if they had been looking at a picture of a monkey, they were quicker to switch their gaze to the turtle in the neighbouring image if the speaker said: "Look at the, uh, turtle."

Tellingly, Graham has also found that 2-year-olds don't appear to respond to fillers like uh or um in this way, while 3-year-olds do. This suggests that our understanding of such signals develops along with other more sophisticated verbal and cognitive skills. In addition, the response is highly dependent on context. If we are led to believe that someone is especially forgetful, their ums and uhs cease to act as signals that direct our gaze to the most salient information.

By preparing us to pay closer attention to what is being said, a deftly placed filler word can even work as a memory aid, according to researchers at the University of Illinois at Urbana-Champaign. Like many linguists before them, they turned to the whimsy of Lewis Carroll for source material, asking participants to listen to summaries of *Alice's Adventures in Wonderland*. In some trials, the readers inserted a small uh before the important plot points, such as: "Meanwhile, uh, the cook keeps hurling plates and other items at the Duchess and the baby." Far from being annoying or distracting, such hesitations improved the participants' subsequent recall of these episodes by a whopping 57 per cent compared with slicker readings. That is the kind of boost you might expect with elaborate and effortful mnemonic techniques, not simply by peppering the text with a few uhs.

Of course, a slight hesitation provides listeners with increased mental processing time. To test whether this could explain the memory effect, the researchers ran additional trials in which the uhs were replaced with a cough of the same duration. Rather than boosting recall, this reduced the participants' memory of the plot by 36 per cent, confirming that there was something special about uh that primed participants ›

"These seemingly meaningless little words can even work as memory aids"

I'M, UH, TELLING THE TRUTH

to listen more carefully. Further tests revealed that speakers use these filler words selectively to signal potential conceptual difficulties, such as a turn in the plot of a story, rather than problems with pronunciation.

The way that these seemingly meaningless little words help us memorise and process speech is quite astonishing. But fillers have an additional role with truly profound consequences for human language.

Unlike a carefully crafted screenplay, spontaneous speech is often vague and full of potential for confusion – not least because people generally come to a topic with different backgrounds and levels of knowledge. As a result, speakers have to tailor their language to each other on the fly. "We're constantly working to revise our understanding as we go," says Patrick Healey at Queen Mary University of London. He believes collateral signals like huh provide some essential feedback to speakers, allowing them to clarify what they mean before a mistake gets out of hand.

The power of "huh?"

Healey has demonstrated this "conversation repair" function of filler words in an ingenious experiment. Pairs of participants in different rooms had to find a route through a complex online map by conversing through an online chat tool. Unbeknown to them, the researchers tweaked their messages before they reached each other. For example, if one participant asked "on the left?" for clarification, the researchers changed it to a word like "huh?" or "eh?" – which tersely indicates a more general confusion. With this simple manipulation, the participants soon started using more systematic ways of describing their location, for example with the invention of a coordinate system.

Spontaneous speech would be incredibly difficult without this kind of corrective process, says Fox Tree. "We would need to be able to plan everything perfectly in advance and enunciate it clearly, with the proper word choice and syntactic structure." It would be much more like a rigid computer code than a flexible, freewheeling conversation.

Given these essential roles in solving basic communicative problems, how might filler words have emerged? That's what Dingemanse is trying to work out. He has found huh in 31 mostly unrelated languages – from Cha'palaa (spoken in northern Ecuador) to Lao and Russian – suggesting that it may be a universal word. This convergence reflects the intense pressure to maintain the momentum of conversation, he says. The average switch between speakers takes just 200 milliseconds, and a short sound like huh is an incredibly efficient way of unobtrusively signalling our confusion. "We need some way to quickly indicate the problem, so that we basically pass the ball

Umming and uhing was once thought to be a sign of deception – the sound of mental cogs turning as the brain struggles to come up with a convincing story. Truth-tellers, in contrast, would have less trouble recalling a real event, so were thought to use fewer filler words.

It is an appealing idea: a clear linguistic signature of deception would allow police and courtrooms to determine who to trust. Unfortunately, it turns out not to be true. Indeed, the latest research suggests the exact opposite. Pronounced umming and uhing may signal that someone is telling the truth, perhaps because they are making less of a conscious effort to present a varnished front.

"The simplicity of these sounds reflects just how essential they are"

VISOOT UTHAIRAM/GETTY IMAGES

Filler words help our conversations flow smoothly

back into the corner of the producer and let them fix it," says Dingemanse. "And that is exactly what huh is… You barely need to do anything more than open your mouth and breathe out to make a sound."

Similar pressures to guide the course of a conversation, without prolonged interruption, will have shaped many other kinds of collateral signals, says Dingemanse. Mmm, for example, signals our intention to let the other speaker continue with their point. "And what better way to signify that you want to keep your mouth shut," he says, "than a syllable in which you actually keep your mouth shut?" Far from being a sign of impotence, then, the simplicity of these sounds reflects just how essential they are for communication across the world.

We don't know exactly when collateral signals first emerged in the history of language, but it is telling that they are unique to human speech, despite the fact that they are so easy to articulate. While other apes vocalise to each other to signal the appearance of a predator, none have the equivalent of an mmm of assent or a huh to ask for clarification. "We have no known observations of animals using this very special type of interactive repair in their communication," says Dingemanse. That is partly because of the complexity of the cognitive processing behind filler words. They rely on the speaker and listener gauging each other's understanding and responding appropriately. This is impossible to achieve without some kind of theory of mind – the ability to appreciate another person's thoughts – and a willingness to cooperate. These two traits are limited, at best, in other animals.

For this reason, Dingemanse suggests that the evolutionary history of collateral signals is deeply intertwined with that of language itself, and may go back hundreds of thousands of years. He thinks the development of some signals, like uh or huh, may even have been an important turning point in our evolutionary journey, propelling us beyond simple syntax to the sophisticated and nuanced ways of talking that we now take for granted. "To be able to produce complex sentences, we rely on the listener showing evidence of their understanding," he says. Without that, each phrase would have to be so short and simple that there would be no room for miscommunication.

Evolving complexity

This remains a hypothesis, for now. However, Dingemanse and postdoctoral researcher Marieke Woensdregt are working on computer models that simulate the evolution of different forms of communication, with and without collateral signals that can help to repair language. "We've just started doing this, but it really looks like if you don't have repair, you end up with a simpler kind of language," he says. "If you do have repair, on the other hand, then it gives you more flexibility to make your language more complex."

Meanwhile, Dingemanse's research should offer some welcome reassurance to anyone who like, uh, Justin Trudeau has been called out for umming and uhing. Far from being a sign of stupidity, these deceptively simple words may represent the pinnacle of human cognitive and linguistic sophistication. ▮

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

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The back pages

Stargazing at home

The Red Planet rules

Earth and Mars are closer together this month than they have been since 2003. Enjoy these night skies, says **Abigail Beall**

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

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Enthusiasm for Mars
Good eyesight
A light pair of binoculars, say 7x50

Stargazing at home appears every four weeks

Next week

Citizen science

FOR a few weeks this October, Mars overtakes Jupiter to become the third brightest object in the night sky. The only brighter things at this time will be the moon and Venus, which appears in the early hours of the morning. This means that during the evenings, the Red Planet will dominate the skies.

The elliptical orbits of Earth and Mars now bring the planets closer than they have been since 2003. On 6 October, when Mars was closest to Earth, there were about 62 million kilometres between it and us – 163 million kilometres closer than the average distance.

A week later, on 13 October, Mars reached opposition: Earth sat directly between Mars and the sun, meaning Mars was fully illuminated. Although that was a week after its closest approach, this is when the Red Planet seemed brightest because of an effect called opposition surge, which makes objects brighten when they are illuminated from directly behind the observer.

On 16 October, a new moon meant there was no moonlight, so Mars was the brightest object that night. But all of October is a great time to look at the planet because it will be shining more brightly than during the rest of the year.

You won't need any equipment to look at Mars: it is bright enough to see with the naked eye, even in places with a lot of light pollution. Just look towards the east after sunset or the west before sunrise and identify the brightest "star" that you can see, with a red glow. This will be Mars.

DIANA ROBINSON PHOTOGRAPHY/GETTY IMAGES

Throughout October, the planet will appear around the time of sunset and stay visible all night, in both the southern and northern hemispheres. It will rise in the east, tracing the path the sun takes across the sky during the day.

Jupiter and Saturn will also shine brightly, but you will find these by looking south after sunset. If you are uncertain, using a stargazing app can confirm whether you have identified Mars.

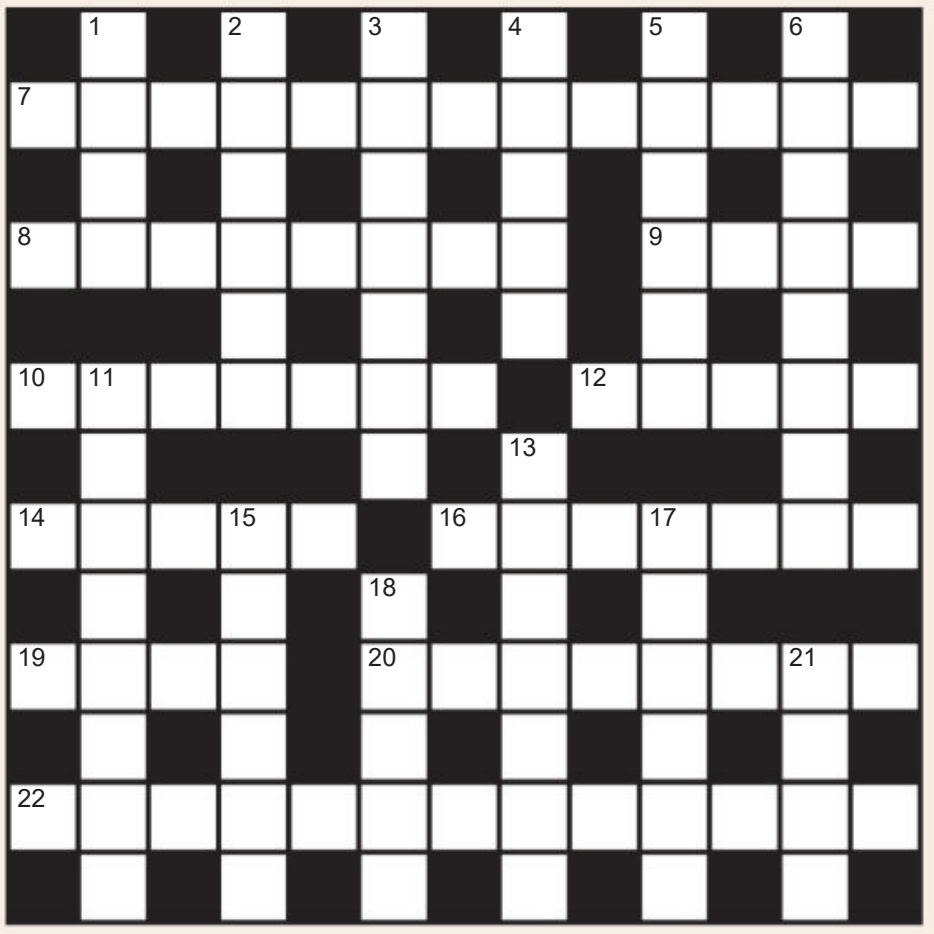
Once you find the planet, grab a pair of binoculars. They are usually described by two numbers: the magnification and the size of the lens. A 7x50, for instance, is a small pair of binoculars that will make any object look seven times bigger. Binoculars of this magnification can be used for birdwatching, but are also great for beginner's astronomy because they are small and light enough that whatever you are looking at won't wobble.

For more detailed stargazing, such as looking at asteroids or Jupiter's moons, you will probably need a larger pair. But unless you mount them on a tripod, it will be almost impossible to hold them steady enough to see the objects.

If you have a pair of binoculars of any magnification, using them to look at Mars will enhance its colour. Since the planets travel independently compared with the stars, if you study Mars for long enough, you may be able to spot it moving relative to a nearby star. ▮

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

Cryptic crossword #42 *Set by Wingding*



Scribble zone

Answers and the next quick crossword next week

ACROSS

7 Over time, Shelley hoped to animate creature created by scientists (5,3,5)
8/11 (Down) Marinate roll with acid mixture; this will make it go brown (8,8)
9 18's relative taking head off criminal (4)
10 Trick to get over slope: climbing equipment (7)
12 Quit extracting gas and amber, perhaps (5)
14 Physicist overtaking Tesla in competition (5)
16 Accumulate across Greek island (7)
19 Shock caused by snack going the wrong way (4)
20 Pascal returns with little desire (8)
22 Shift in tone changes feel of PPE, with doctor deprived of oxygen (7,6)

DOWN

1 Rising trouble with solid Na_2CO_3 (4)
2 Lion oddly involved in crash in race (6)
3 Man with cold heart making psychoactive chemical (7)
4 Animal carer carrying leopard's skin in grassland (5)
5 Positive or negative cost (6)
6 High-fat regimen provides kinetic energy to pass on time (4,4)
11 See 8 Across
13 Dinner containing carbon sink (7)
15 One subsumed by reproduction in high branches (6)
17 Give consent to rodent providing last of taxidermy (6)
18 Part of brave new bird (5)
21 Parasite is a positive sign (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #73

1 Debris from Halley's comet is responsible for which meteor shower that arrives each October?

2 The supercontinent Pangea was surrounded by which superocean?

3 Name the chemical element with the highest boiling point

4 The Nobel prize ceremony is held on 10 December each year because this is the anniversary of what?

5 What is the correct term for a baby llama?

Answers on page 55

Puzzle
set by David Bedford

#81 A bridge too far

"Finally, we always test our candidates with a puzzle about four students crossing a bridge with a torch," said the interviewer at Microsoogle.

"Oh goody, I've heard this one before!" thought Sam, smugly.

"The rickety bridge is only strong enough to take two people at a time, and the torch is needed for each crossing, walking at the pace of the slower student. The most timid student, Tim, needs 10 minutes to cross the bridge. Tom can cross faster than Tim, and the other two are quicker still. All of them take a different whole number of minutes to cross."

"Yeah, yeah," smiled Sam.

"All four students get across the bridge in 17 minutes. What is the longest time that it could take for Tom to cross the bridge on his own?"

"Wait – that's not the normal puzzle!" blurted Sam.

Can you help?

Answer next week

New Scientist Podcast

"Very well informed... delivered in an unfussy, well presented and accessible way... Definitely news you can use."
Press Gazette

The New Scientist Weekly podcast

Episode 38 out Friday 16 October

Our weekly podcast has become the must-listen science show, bringing you the most important, surprising or just plain weird events and discoveries of the week. If you missed the earlier episodes you can still listen in to hear about:

Episode 37
Black holes and CRISPR gene editing spring Nobel surprises, climate change and indigenous people in the Arctic and symptom clusters identified for covid-19

Episode 36
Hunt for life on Venus and Mars, how the paleo diet affects your age, strategy for the second wave of coronavirus and species extinction crisis

Episode 35
The first woman on the moon, evolution special, a deep-water mystery and the purpose of sleep and dreams

Episode 34
Race to find life on Venus, coronavirus claims lives of one million people, extinction crisis and how the brain slows time

Hosted by *New Scientist*'s Rowan Hooper and Valerie Jamieson, new episodes are out each Friday. Follow us on Twitter **@newscientistpod**

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Patchy cabbage

Why do cabbages exist? What is the point of having a tight bundle of leaves that don't attract pollinators and shield each other from the sun? Does its structure affect its ability to photosynthesise?

Jan Horton
West Launceston, Tasmania, Australia
Cabbages exist because humans domesticated them long ago due to them being easy to grow in many climates and keeping well, especially when fermented. To me, and to many others, they also taste delicious, but not all my family agree.

Humans have bred the cabbage so that the juvenile stage is prolonged, because the light inner leaves are sweeter and more digestible than the tough, protective, dark green outer leaves. Once picked, they can be stored for a long time in a cool place, which is all to the good of humans and livestock. However, for the good of the plant, just leave it

"The cliffs are covered in wild cabbages descended from garden escapes, and you can smell them far out at sea"

in the ground and keep watering it. In due course, it will develop a flowering stalk, then masses of flowers followed by lots of seeds.

Some relatives of the cabbage are grown for their seed, including canola, which is bred for its high seed oil content.

Jonathan Wallace
Fenham, Newcastle upon Tyne, UK
The tight rolled-up "head" of cabbage leaves doesn't confer an advantage to the plant, any more than vines "benefit" from having seedless grapes. It has been bred to have characteristics desirable to the grower and consumer.

As to whether the structure of the cabbage affects its ability to photosynthesise, leaves that are inside the head and not exposed to sunlight can't photosynthesise. But cabbages are able to grow to a large size, so the leaves that are exposed to the sun must be able to make enough carbohydrate to meet the needs of the whole plant.

Chris Warman
Hinderwell, North Yorkshire, UK
Cabbages exist to be eaten, as do cauliflower, broccoli, kale and Brussels sprouts. They are all cultivars of *Brassica oleracea*, a plant that grows wild on the sea cliffs of southern Europe.

Cabbages with a "heart" – the capitata type, as described by the questioner – are just one of seven main groups of cabbages, which in their turn contain innumerable varieties.

Selective breeding of cabbages may go back for as long as 4000 years and classical writers such as Theophrastus and Pliny the Elder described cultivated varieties, probably loose bundles of leaves resembling collard greens or what the British know as "spring greens". Hearted cabbages were first developed in the Middle Ages.

The original attraction of cabbage is that its thick leaves stored carbohydrates and vitamins through the winter. Wild cabbage is tough and bitter, but natural variations enabled breeders to select for a softer, sweeter leaf. Breeders could also develop curly leaves (kale) and colours ranging from near black (cavalo nero) to near white.

Features that make cabbages desirable to humans would not be advantageous in the wild. This is true of most of our domesticated plants and animals, which are vulnerable to predators and adverse conditions. The modern cabbage needs continual protection from encroaching weeds, ravenous birds and cabbage white butterflies.

The tight heart of capitata cabbages exists because it is supported by the original loose cluster of green leaves that are trimmed away in harvesting. This can be seen in all its glory in exhibition cabbages, which can exceed a metre wide and be as heavy as a small person.

Wild cabbage is a slow-growing biennial or perennial with leathery leaves, sometimes tinged with violet, and masses of yellow flowers. It doesn't compete well with faster growing plants, but it tolerates salt and finds a niche on chalk and limestone cliffs. The cliffs at Whitby and Staithes in the UK are bright with their flowers and you can smell them far out at sea. Genetic analysis shows these aren't the original species. Instead, they are apparently descended from garden escapes.

Incidentally, lettuce has followed a similar course of development to cabbage, although only in the growth of its leaves, which may form heads or be curly and brightly coloured. It was adored by the ancient Egyptians and dedicated to Min, the god of fertility and harvest.

David Muir
Edinburgh, UK
The cabbage as we know it isn't a natural thing. Over thousands of years, inventive farmers have altered various structures of the wild cabbage.

Selective breeding for specific parts of the plant's structure has given us particular vegetables: development of the terminal bud gave us cabbages; the lateral buds,

JOHAN SWANEPOEL/ALAMY

This week's new questions

Information loss **It is a rule of physics that information can't disappear. So what happens to the information in my brain when I die?** ***Max Davies,*** *Irvine, California, US*

A healthy spread **If you eat three meals a day, does it make a difference if they are taken within, say, an 8-hour window or a 14- hour one?** ***Manyando Milupi,*** *Doncaster, UK*

Where does the brain's information go after a person dies?

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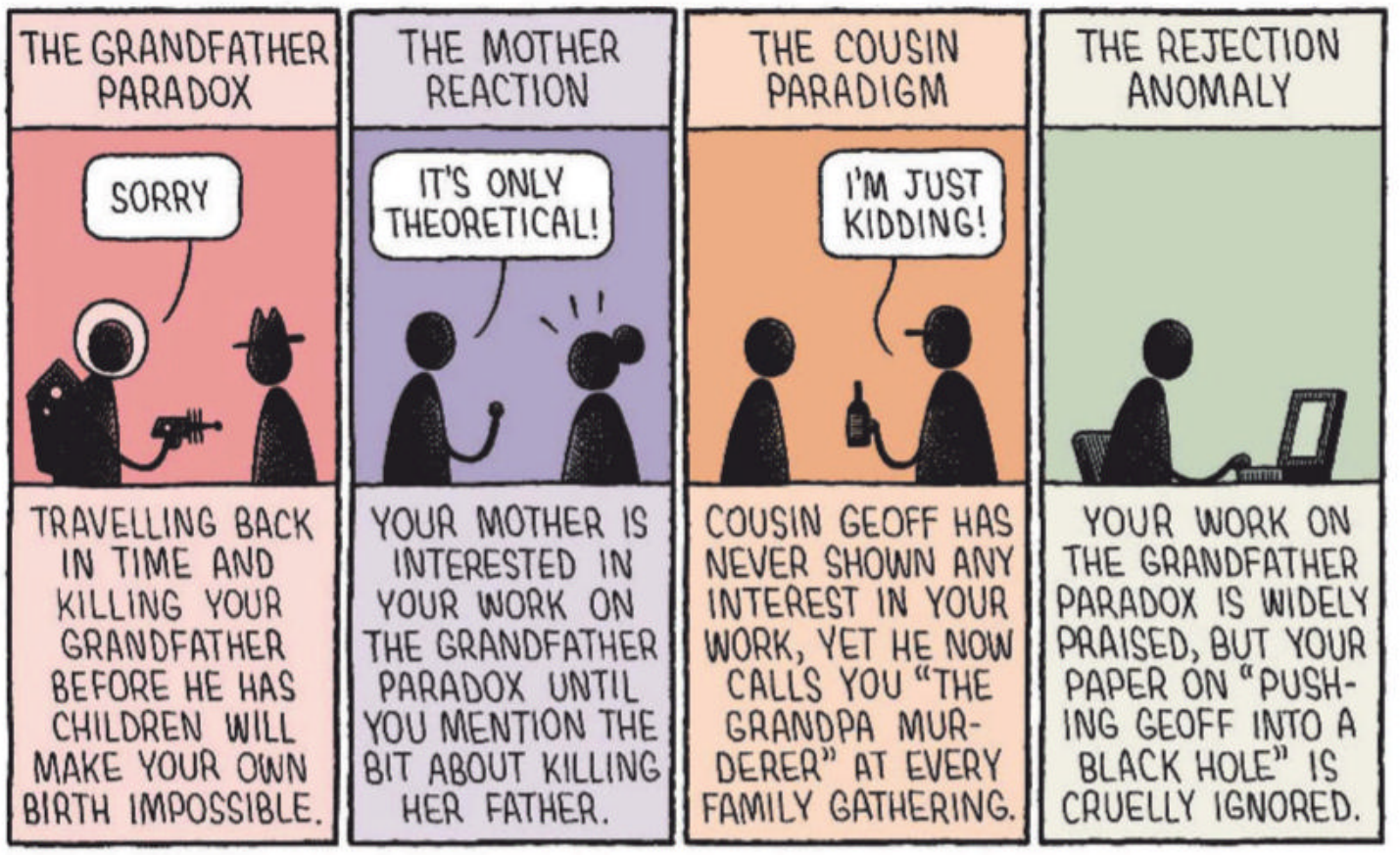
Tom Gauld
for New Scientist



Brussels sprouts; the flowers, cauliflower and broccoli; the leaves, kale and collard greens; and the stem, kohlrabi.

Some cultivars of *Brassica oleracea* may be of medical benefit. Brussels sprouts and broccoli contain sinigrin, a chemical shown to have anti-cancer, antibacterial, antifungal, antioxidant and anti-inflammatory properties. The bits of the plant that aren't so green also contain valuable nutrients, even if they lack the green chlorophyll required for photosynthesis. Eat your greens!

Jackie Jones
Brighton, East Sussex, UK

These plants provide a breeding ground for cabbage white butterflies, which lay their bright yellow eggs in neat patches all over the underside of the leaves during summer months until October.

The caterpillars that hatch from these eggs eat large holes in the leaves. Only close-mesh net will protect the members of the cabbage family from the butterfly; they are attracted by the smell of the plant and will travel a long distance to find them.

"When a photon of light collides with the atoms in a pane of glass, it doesn't have enough energy to interact with them"

I made the mistake of growing a summer-harvesting broccoli once and spent ages picking out these pesky caterpillars. I now only grow winter greens; by this time the butterflies have long gone.

Seeing the light

Why does light reflect in a mirror but go straight through glass?

Thomas Fox
Fortrose, Highland, UK

Mirrors such as those found in a bathroom tend to be made from a sheet of transparent glass or plastic and a layer of smooth, polished aluminium (or in older mirrors, silver).

The reason why light goes straight through glass but bounces off metal lies within the individual structure of these materials.

Glass is an amorphous solid, which means it has cooled too quickly to form a regular crystalline structure. As a consequence, when a photon of light collides with the atoms in a pane of glass, it doesn't have enough energy to interact with them and hence become absorbed or reflected.

Instead, the photon passes straight through. This makes the glass transparent.

In contrast, the aluminium atoms are arranged in a regular crystal lattice structure and have free "delocalised" electrons whizzing round the material. This is why metals can conduct electricity.

These electrons are free to interact with photons of light and reflect the photons that have similar frequencies to their own. This is what makes metals shiny and, when smoothed, reflective. ▮

Answers

Quick quiz #73
Answer

1 The Orionids, which peak late in the month

2 Panthalassa

3 Tungsten, which boils at 5555°C

4 Alfred Nobel's death

5 A cria

Quick Crossword #68 *Answers*

ACROSS **1** Fuchsia, **4** Machine, **8** Onager, **9** Rawlplug, **11** Ergo, **12** Recurrence, **14** Cardiac veins, **17** Undetectable, **20** Blueprints, **21** X-Men, **23** Urbanite, **24** Nessie, **25** Estuary, **26** Grommet

DOWN **1** Florence, **2** Clangers, **3** Stem, **4** Measurements, **5** Chlorinate, **6** Idling, **7** Eaglet, **10** Geochemistry, **13** Giant panda, **15** Abomasum, **16** Reinvent, **18** Obtuse, **19** Numbat, **22** Zero

#80 Vive la difference
Solution

Swapping seats 3 and 5 (to give the order 1 2 5 4 3 6 7) increases the discount on the bill to 24 euros. This is the maximum possible discount, and although there are several other ways of arranging the chairs to get the same discount, this is the only one that involves swapping just two chairs.

Purely for research

"Dr Alexa Ashingtonford stared at the test tube between her fingers, her perfectly pink manicured nails clashing with the pale, bubbling liquid inside. She recognised the power she had in her grip, the virus which had claimed so many lives and which made her heart beat furiously, like a wild tiger thrashing in its cage."

Feedback will trouble you not to ask exactly what keyword search led us to *Kissing the Coronavirus*, a recently published ebook (tagline: "She was supposed to cure the Coronavirus. Instead... she fell in love with it"). But downloading it for the purposes of general education, we find ourselves grimly fascinated by the tale of the protagonist's vaccine development work in the lab of Dr Gurtlychund, "one of Ohio's top biochemical-neuroviral-epidemiologists" – of which one can only say, someone had to be.

The plot unfurls as the virus ("so strong, so... deadly") spreads across the globe: "Asia. Europe. Some other places. But most importantly and worryingly, America." If Dr Ashingtonford can be said to have a fault, beyond an eye-watering disregard for biosafety, it is that she takes the passion that marks out many a research scientist to an extreme, while supplementing it with a passion for the job perhaps less readily associated with the chill groves of academe.

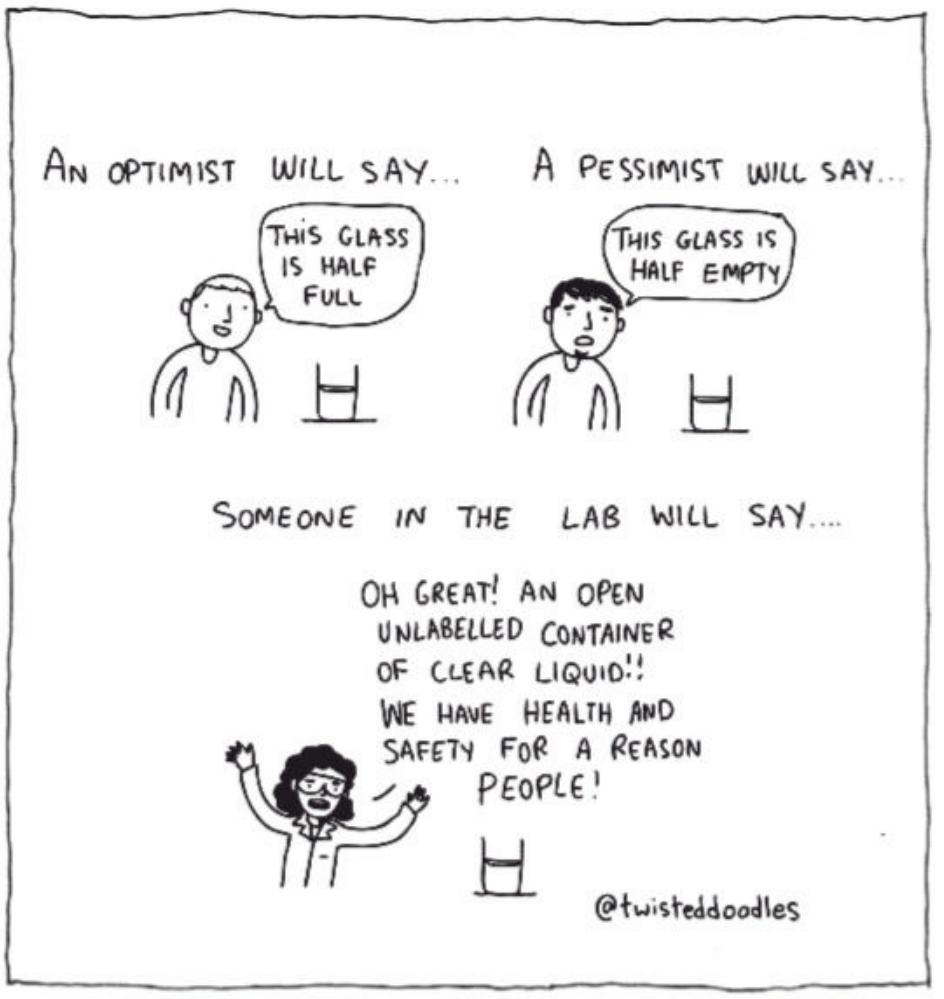
The avenues this takes her down involve some technical vocabulary with which Feedback isn't intimately familiar, and that may be beyond what is suitable for a family magazine. We nevertheless wish the book every viral success.

Captive audience

Providing a welcome opportunity to cleanse our mental palate, someone called Kiethleen from web address sellers Domain Nerdz spirals unbidden into our inbox. "We have a domain that is currently on sale that you might be interested in (Black-Hole.co)", they write excitedly. "Anytime someone types Black-Hole, Black Hole, or any other phrase with these keywords into their browser your site could be the first they see!"

Presumably the last, too, as they are sucked into the information vortex Feedback intends to construct there. If you think that is a paradox, just admire our nice shiny firewall on the way in, suckers. One for da true Nerdz.

Twisteddoodles *for New Scientist*



Got a story for Feedback?

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

More bad jobs

Our thoughts are somehow still on passion for jobs. So, undeterred by last week's stomach-churning offerings, we return to our bulging bag of undesirable occupations sent in by you, our loyal and notably long-suffering readers. Jon Sparks from Lancashire, UK, recalls a summer spent drilling holes in pepper pots by hand. The existence of such a task, we can only think, goes a long way to explaining British industry's dire productivity figures. Jon says the only thing more boring than the boring was people telling him it was boring.

Meanwhile, Michael Berkson from the original Cambridge lays claim to the award of world's worst science job (as well as the three degrees of separation prize) "on behalf of a person my Mother met at a conference many years ago". He reports that she described her work as "combing mice for lice", adding by way of elucidation that "she was a research assistant for Miriam Rothschild".

Pride of place this week, however, goes to Michael Stanford, not of Stanford. "After spending an idyllic summer as a woodsman in the Lake District, I opted for a change of scene by getting a job as a sewerman in the London Borough of Camden", he begins, showing an expert understanding of the art of the narrative hook. Dispatched to answer a distress call, he found that liquid concrete being used to line a tube tunnel had bubbled its way up through an overlying Victorian sewer, eventually manifesting itself as a hardening shard in a local resident's toilet.

With space in the sewer for only one person, and noise concerns preventing the use of power tools, it was left to Michael, hammer and chisel in hand, to chip away at the problem over several weeks. This was to little avail in the end, it seems – "I seem to remember a couple of houses had to be demolished," he says.

With interest

Feedback is glad for the reminder of the life and works of that grande dame of entomology, and much else, Miriam Rothschild.

Being a scion of the Rothschild dynasty was undoubtedly an advantageous start for someone described in one obituary on her death in 2005 as a "zoologist, naturalist, academic and eccentric". Her father Charles Rothschild had found time to describe some 500 species of flea in his days off from the banking job, while her uncle Lionel Walter Rothschild established perhaps the world's most eccentric private zoo at Tring just outside London, and is one of few people who can claim to have a subspecies of giraffe named after them.

Despite having little formal education of her own, Miriam Rothschild became "the Queen Bee of research into parasites and their hosts" – and, besides that, a wartime Bletchley Park codebreaker, a working farmer and a tireless campaigner over decades for then unfashionable causes from animal rights and mental health research to the legalisation of homosexuality. "I must say, I find everything interesting," she once said. Now that really is the last word.