New Scientist

WEEKLY March 6 – 12, 2021

FOCUS ON
CORONAVIRUS

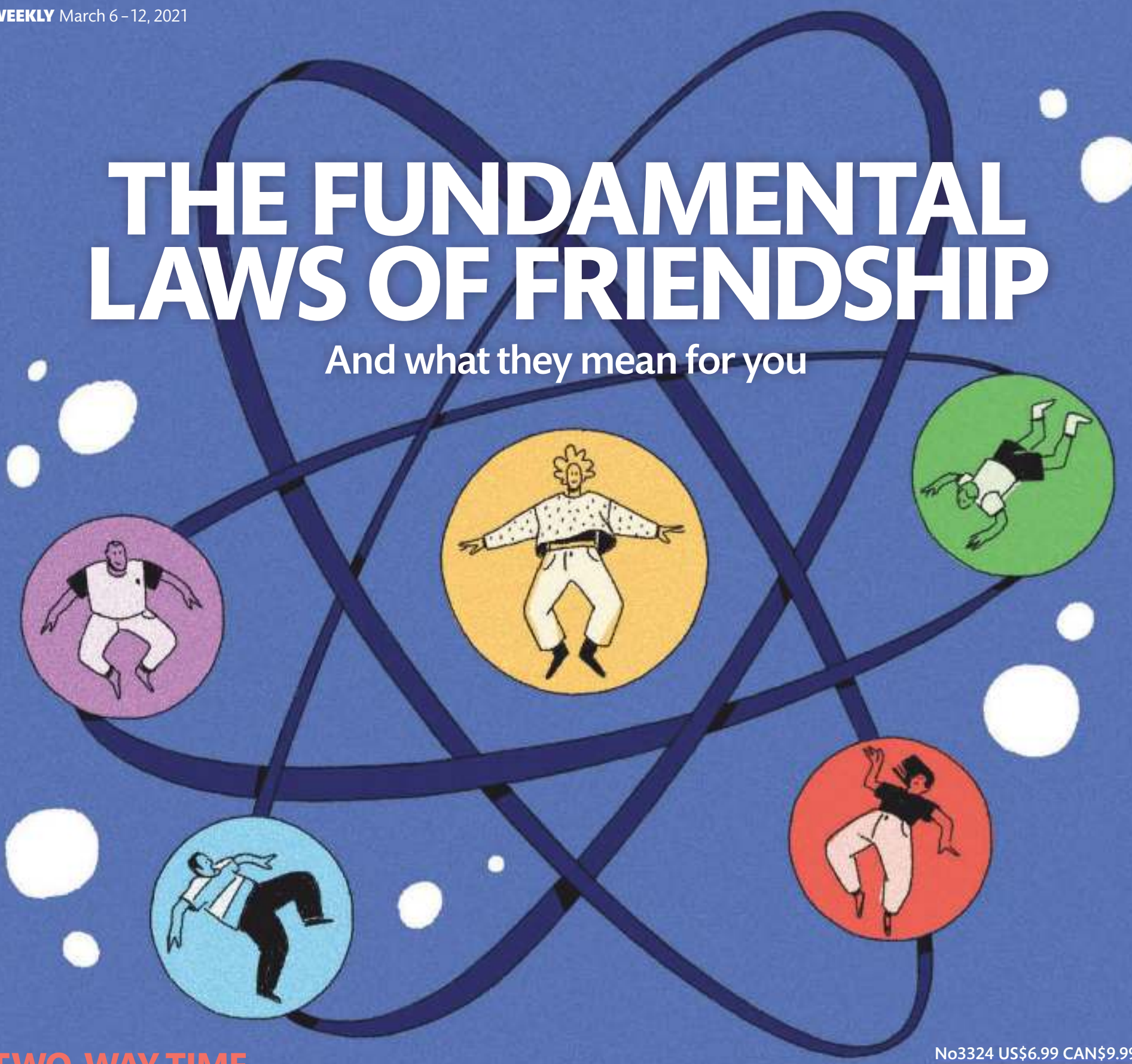
The threat from the Brazilian variant

How our abuse of nature causes pandemics

When will we be back to normal?

THE FUNDAMENTAL LAWS OF FRIENDSHIP

And what they mean for you



TWO-WAY TIME
Did time also flow backwards from the big bang?

PLUS FOR ALL MANKIND, REVIEWED / **NEANDERTHAL LANGUAGE** / **REAL-LIFE WARP DRIVES** / DATE SET FOR END OF WORLD

Science and technology news **www.newscientist.com**

No3324 US$6.99 CAN$9.99

0 72440 30690 5 09

Photo: Christina Wocintechchat

EIT Food is Europe's leading food innovation initiative

2021: A new year to rethink food

After a year of confusing and often misleading news about food, why not learn something new in 2021?

This year is a chance for the world to build back better and create a food system that works for everyone. By joining one of EIT Food's online flexible education courses, you will be empowered to 'rethink' food and make more informed food choices.

Interested? Sign up today for free:
www.futurelearn.com/connect-with-food

EIT Food

EIT Food is supported by the EIT a body of the European Union

Here's a selection of our current free online courses:

- **Superfoods: Myths and Truths**
  What is a 'superfood'? And what effect do they have on the body and society?
- **Food and Nutrition: The Truth Behind the Headlines**
  Learn how to find reliable, scientific information about food and nutrition, and understand why people are often easily influenced by the headlines.
- **An Introduction to Food Science**
  By understanding and learning more about what's in food with this course, you will be able to make smarter, more sustainable and healthier food choices.
- **The Human Microbiome**
  Discover what the microbiome is, how it changes throughout your life, and the role it plays in good human health.

This week's issue

On the cover

36 The fundamental laws of friendship
And what they mean for you

46 Two-way time
Did time also flow backwards from the big bang?

Vol 249 No 3324
Cover image: Anđela Janković

Focus on coronavirus
7 The threat from the Brazilian variant
41 How our abuse of nature causes pandemics
10 When will we be back to normal?

34 *For All Mankind*, reviewed
16 Neanderthal language
16 Real-life warp drives
12 Date set for end of the world

46 Features

"Complexity doesn't just give time its direction – it literally is time"

News

15 Efficiency paradox
Climate goals are at risk because of the rebound effect of energy efficiency

17 Think again
AI that remembers its past beats video game high scores

19 In the swing of things
Human ancestors may have swung like chimps after all

Views

25 Comment
We need better names for coronavirus variants, says Mark Pallen

26 The columnist
Chanda Prescod-Weinstein on solving a cosmic conflict

28 Letters
Saving nature is up to all of us

30 Aperture
Unexpected beauty caught in cancer research photos

32 Culture
The compelling, divided world of *Tribes of Europa*

JU HUANZONG/XINHUA NEWS AGENCY/PA IMAGES

18 Enter the biosphere Fake moon base is nearly self-sufficient

Features

36 Friendship-ology
The fundamental laws that explain why some friendships fade and others last

41 Spillover
The covid-19 pandemic was precipitated by our disruption of ecosystems. But how exactly?

46 Double time
Did time flow both forwards and backwards after the big bang?

The back pages

51 Citizen science
Find killer diseases hidden in mountains of images

52 Puzzles
Try our crossword, quick quiz and logic puzzle

54 *Almost* the last word
How long is the gap between the past and the future?

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

56 Feedback
Mint mistakes and a long covid "detox": the week in weird

Elsewhere on New Scientist

Virtual event

Making sense of quantum theory

Quantum theory has given us many startling ideas, from cats that are both dead and alive to distant objects that seem magically connected. Our understanding of the universe is based on this idea – yet it remains profoundly mysterious. In this talk, physicist Carlo Rovelli unpacks the deep meaning of quantum theory and explains how we live in a universe of relations. Join us from 6pm BST on 1 April or watch on demand later. Tickets available now.

newscientist.com/events

Podcasts

Weekly

Here's an epic thought experiment: if you had a trillion dollars, what would be the best way to spend it to safeguard humanity's future? The team also talks metabolism myths and learning Morse code in your sleep.

Escape Pod

A dose of pure escapism, with no mention of viruses! This week, the team discusses speed: the world's nippiest animals, our quickest supercomputers and the speed limit of the universe.

newscientist.com/podcasts

Newsletter

NEW

Parental Guidance

Launching this week, an evidence-based guide to parenting. In the first edition: are nightmares and other disruptions to kids' sleep on the rise during the pandemic?

newscientist.com/sign-up/parental-guidance

ALAMY

The relational universe Carlo Rovelli demystifies quantum theory

MATHIAS SCHAEF/NATUREPL.COM

Need for speed What are the fastest animals?

DEEPOL BY PLAINPICTURE

Bedtime woes Are children not sleeping as well during the pandemic?

Online

Covid-19 daily briefing

All the latest, most crucial coverage of the pandemic, with news, features and interviews. Updated each day at 6pm GMT.

newscientist.com/coronavirus-latest

This Book Could Fix Your Life

We all want to be happier, more successful and less stressed, but what really works? Award-winning *New Scientist* writer Helen Thomson guides you through the often surprising truths behind meditation, resilience, addiction, willpower, love, sleep and plenty more. Get your copy now.

shop.newscientist.com

New Scientist
Small Talk

FREE EVENT

ONLINE EVENT

THE SCIENCE OF LIVING A HEALTHY LIFE

Tuesday 9 March 2021 | 1-2pm GMT and on-demand

Actionable advice on all the big health questions: nutrition, diet, weight loss, hydration, exercise, preventative medicine, sleep and ageing.

SPEAKER:

Graham Lawton

New Scientist staff writer and living proof that you don't have to be a health and fitness fanatic to be reasonably fit and healthy

Book your free tickets at: newscientist.com/healthy-life

Regent's Place

More at: regentsplace.com

Counting the cost

The covid-19 pandemic makes plain the consequences of abusing nature

WE MAY never know for certain how the SARS-CoV-2 virus jumped from another animal to a human before upending our world. Getting a convincing answer will take some time, judging by the first results from a World Health Organization investigation into the origins of the new coronavirus. The WHO team served up more questions than answers at a press conference last month, ruling out a lab origin, but calling for more research into the possibility that it was carried via frozen food.

Most virologists regard that as unlikely. The most plausible route seems to be that the virus originated in a bat, as the closely related SARS-CoV-1 virus, which causes SARS, did two decades ago, and spread from there to people via an unidentified species.

In a sense, the details don't matter. We know enough to say that, even though these deadly pathogens originate in nature, they aren't a problem created by nature. Unbridled human consumption driving ecosystem destruction, the degradation of habitats changing the balance of species and the way we bring

"We know enough to say that these deadly pathogens aren't a problem created by nature"

species unnaturally close to one another in the wildlife trade all increase the risk of "zoonotic" diseases that jump from species to species (see page 41).

The staggering economic cost of the covid-19 pandemic – a hit to global output estimated by the International Monetary Fund at $28 trillion – should be reason enough to convince even the hardest-nosed market acolyte that cleaning up our act is a matter of economic self-interest: not a cost, but an essential investment to safeguard our future.

The pandemic is just one reason among many. The scary pace of biodiversity loss is already hurting economies as we pay more for, or no longer receive, ecosystem services that nature once provided for free, from clean air and water to fertile soils. Tackling the climate crisis, too, will be almost impossible without preserving and restoring nature. Reforestation alone could absorb about 14 per cent of annual global carbon dioxide emissions.

We don't have all the answers yet, but we don't need them to know when it is prudent to act. ▮

PUBLISHING & COMMERCIAL

Commercial and events director Adrian Newton

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

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

New Scientist Events
Tel +44 (0)20 7611 1245 **Email** live@newscientist.com
Creative director Valerie Jamieson
Sales director Jacqui McCarron
Event manager Henry Gomm
Marketing manager Emiley Partington
Events team support manager Rose Garton

New Scientist Discovery Tours
Director Kevin Currie

Marketing
Marketing director Jo Adams
Head of campaign marketing James Nicholson
Head of customer experience Emma Robinson
Email/CRM manager Rose Broomes
Digital marketing manager Craig Walker
Customer experience marketing manager Esha Bhabuta
Marketing executive Amelia Parmiter

Digital & Data
Digital product development director Laurence Taylor
Head of audience data Rachael Dunderdale
Business intelligence analyst Michael Prosser

Technology
CTO and programme director Debora Brooksbank-Taylor
Head of technology Tom McQuillan
Maria Moreno Garrido, Amardeep Sian, Ben Townsend, Piotr Walków

NewScientist

Chief executive Nina Wright
Executive assistant Lorraine Lodge

Finance & operations
Chief financial officer Amee Dixon
Financial controller Taryn Skorjenko
Management Accountant Alfred Princewill
Facilities manager Ricci Welch
Receptionist Alice Catling

Human resources
Human resources director Shirley Spencer
HR business partner Katy Le Poidevin

Non executives
Non-exec chair Bernard Gray
Senior non-exec director Louise Rogers

CONTACT US

newscientist.com/contact

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

US Newsstand **Tel** +1 973 909 5819
Distributed by Time Inc. Retail, a division of Meredith Corporation, 6 Upper Pond Road, Parsippany, NJ 07054

Syndication Tribune Content Agency
Tel 1-800-346-8798 **Email** tca-articlesales@tribpub.com

Subscriptions **newscientist.com/subscribe**
Tel 1 888 822 3242
Email subscriptions.us@newscientist.com
Post New Scientist, PO Box 3806, Chesterfield MO 63006-9953

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

EDITORIAL

Editor Emily Wilson
Executive editor Richard Webb
Creative director Craig Mackie

News
News editor Penny Sarchet
Editors Jacob Aron, Helen Thomson, Chelsea Whyte
Reporters (UK) Jessica Hamzelou, Michael Le Page, Layal Liverpool, Matthew Sparkes, Adam Vaughan, Clare Wilson
(US) Leah Crane, (Aus) Alice Klein, Donna Lu
Interns Ibrahim Sawal, Karina Shah, Krista Charles

Digital
Digital editor Conrad Quilty-Harper
Podcast editor Rowan Hooper
Web team Emily Bates, Anne Marie Conlon, Matt Hambly, Alexander McNamara, David Stock, Sam Wong

Features
Head of features Catherine de Lange and Tiffany O'Callaghan
Editors Daniel Cossins, Anna Demming, Kate Douglas, Alison George, Joshua Howgego
Feature writer Graham Lawton

Culture and Community
Comment and culture editor Timothy Revell
Liz Else

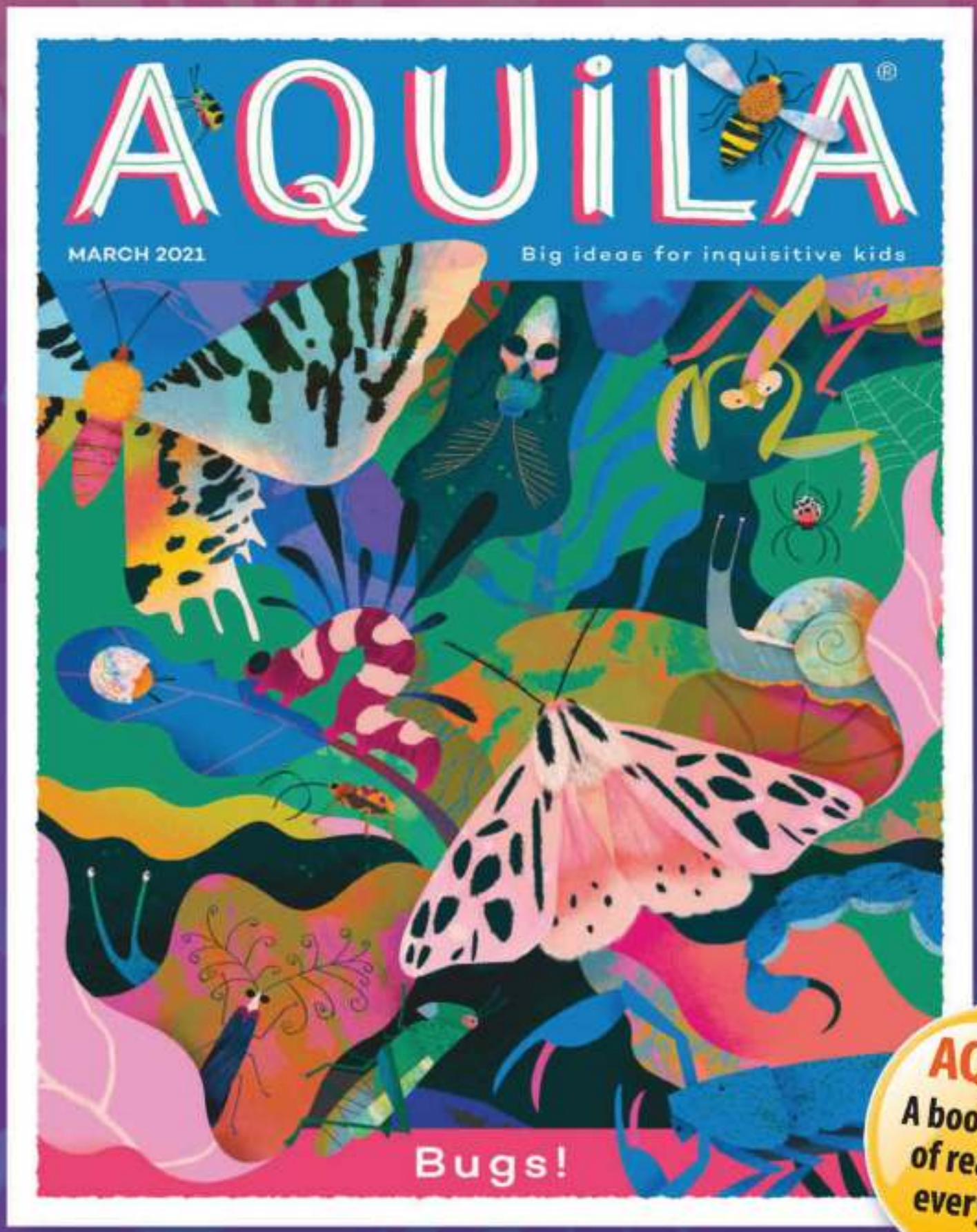
Subeditors
Chief subeditor Eleanor Parsons
Bethan Ackerley, Tom Campbell, Chris Simms, Jon White

Design
Art editor Kathryn Brazier
Joe Hetzel, Ryan Wills

Picture desk
Picture editor Helen Benians
Tim Boddy

Production
Production manager Joanne Keogh
Robin Burton

AQUILA CHILDREN'S MAGAZINE



AQUILA
A book's worth of reading in every issue!

THE MARCH ISSUE: Did you know it is estimated that there are more than 200 million insects for every human on our planet? As they whizz and buzz about their essential work, they are the unsung mini-heroes of the natural world! PLUS: The secret history of Listening Devices, and Computer 'Bugs' that spoil our fun.

AQUILA Magazine: a Brilliant Gift for curious 8 –13-year-olds. Witty and intelligent with beautifully illustrated topics, every issue is a balanced feast of Science, Arts and General Knowledge. **SUBSCRIPTION ONLY: www.AQUILA.co.uk**

"...Advanced & Philosophical, Curious & Puzzling"
Richard Robinson, Brighton Science Festival

HOLLIE ADAMS/GETTY IMAGES

People arriving in the UK from Brazil have to quarantine for 10 days

Coronavirus mutations

Brazil variant reaches UK

The P.1 variant of coronavirus could be more transmissible, but vaccines should still provide protection, reports **Michael Le Page**

SIX people in the UK have tested positive for the P.1 coronavirus variant first detected in Brazil. Five of the six either recently returned from Brazil or had close contact with someone travelling from there. Officials are trying to trace a sixth person who tested positive after sending in a home test kit without contact details. The situation has led to fears that this variant could spread more widely.

The P.1 variant seems to have emerged in Brazil last November. It caused a second wave of infections in the city of Manaus, despite up to three-quarters of its population having been infected in the first wave earlier in 2020.

A study by Nuno Faria at Imperial College London and his colleagues suggests that P.1 spread 1.4 to 2.2 times faster than other variants present in Manaus and reinfected between 25 and 61 per cent of people with immunity to these other variants.

But the researchers stress that the findings are specific to Manaus and don't necessarily mean that P.1 will spread faster in other places with different existing variants and different levels of immunity.

Indeed, while P.1 has now been detected in at least 25 countries, local transmission has been reported only in Sweden, Belgium, Mexico and Colombia.

So far, P.1 doesn't seem to be taking off in the same way as the fast-spreading B.1.1.7 variant first detected in the UK, but Faria cautions that it is too early to draw any conclusions.

While it remains unclear if P.1 is more transmissible outside Brazil, there is good evidence that both P.1 and the similar B.1.351 variant first spotted in South Africa have mutations that enable them to partly evade antibodies from vaccinations or from previous infections.

Thankfully, these variants cannot completely evade immune protection. Our bodies produce both antibodies that prevent the virus from infecting cells in the first place and T-cells that destroy infected cells to stop the virus making more copies of itself.

To prevent infection, antibodies have to bind to key sites on the spike proteins that protrude from the virus. Mutations in these sites can reduce antibody effectiveness.

By contrast, T-cells are effective as long as they recognise any part of a spike protein. This means it is much harder for a virus to mutate to evade the T-cell response. "There is no way these variants are escaping T-cell immunity," Shane Crotty at the La Jolla Institute for Immunology in California told *New Scientist* in January.

"It is likely that many coronavirus mutations have fitness costs as well as fitness benefits"

Trials of the Johnson & Johnson vaccine found that it was slightly less effective at preventing symptomatic covid-19 in South America, where P.1 is more common, than in the US. However, the difference was small – 66 per cent instead of 72 per cent – and it was still 100 per cent effective at stopping hospitalisations and deaths. This is reassuring because it means that variants like P.1 won't wipe out all the benefits of vaccination even if they do start spreading widely.

That said, there are still two worries. First, if P.1 reaches a number of vulnerable people in the UK who haven't yet been vaccinated, hospital admissions could soar again.

Second, the more widely that variants such as P.1 circulate, the more opportunity they have to evolve further. For instance, the B.1.1.7 variant appears to have now acquired the same E484K mutation that helps P.1 dodge antibodies.

However, there is a limit to what evolution can achieve. It is likely that many mutations have "fitness costs" as well as "fitness benefits", says Astrid Iversen at the University of Oxford. This might explain why other variants with the E484K mutation that appeared early in 2020 died out instead of spreading widely. ▮

Lockdown

Children of the pandemic

After a year of repeated lockdowns for many, there is a limit to children's resilience. **Michael Marshall** investigates how they are coping

MRS/GETTY IMAGES

SCHOOLS have been closed in England for about two months amid a national lockdown, and I have lost count of the number of times my daughter has cried. She is normally cheerful, but throughout this time, she has dissolved into tears most days. She misses her friends and finds Zoom lessons stressful.

In England, schools will reopen next week, but that isn't the case everywhere: in some US states, such as California, schools have been closed for almost a full year. At the start of this pandemic, many parents had a sense of solidarity, even adventure. Now many of us are grumpy and tired, and feel close to burnout. What effect has all this had on our kids?

"We need to consider children in all of this, and we're just not," says Tamsin Ford at the University of Cambridge.

England and Scotland joined Wales and Northern Ireland in the latest UK lockdown on 5 January, with schools in England closing after many children had gone back for one day. Prime Minister Boris Johnson has since announced that schools in England will reopen for all pupils on 8 March. The rest of the UK will have a staggered return to school, depending on age. But schools in some US states look set to remain closed for the foreseeable future and they are currently fully closed in 26 countries. So far, there is little data on how the closures are affecting children. But there is a lot of information about the impact the first lockdown had.

"Some kids in the US have to go sit in a parking lot in a big supermarket to get Wi-Fi for homeschooling"

On 11 January, Ford and her colleagues published a study of the mental health of 3570 children in England aged from 5 to 16, who have been tracked over several years as part of an even longer-term study. They assessed the children on their emotions, behaviour and relationships, and used that to estimate how many would be classed as having a mental health problem if they were seen by a clinician.

The researchers found that the incidence of probable mental health problems rose from 10.8 per cent in 2017 to 16 per cent in July 2020. Many children experienced disrupted sleep and loneliness in July, and they were more likely to have a problem if a parent was in psychological distress. Similar trends have been seen in other countries.

These impacts don't fall equally on everyone, says Ford. "Young women look like they're doing particularly badly, as do children in poverty."

There are clear inequalities, says Cathy Creswell at the University of Oxford, who has been tracking families month by month throughout the coronavirus pandemic in her Co-SPACE study. "We consistently see elevated levels of mental health difficulties among young people living in low-income families, as well as among children with special educational needs."

No safety net

The inequalities are worse in nations with limited social safety nets, says Megan McClelland at Oregon State University. In her state, she knows of "kids who have to go sit in a parking lot in a big supermarket in order to get Wi-Fi in order to get homeschooled".

There is also evidence that the impacts vary by age. For instance, children in the UK of primary school age, typically between 5 and 10 years old, seem to have experienced more loneliness than teenagers during lockdown, perhaps because fewer have their own phones or social media accounts. But among teenagers, there is evidence that the oldest ones have had it worse.

A study called OxWell, co-led by Mina Fazel at the University of Oxford, surveyed 19,000 children and young people in England aged from 8 to 18. A preliminary report last September found there were bigger negative impacts on well-being, and lower life satisfaction, among the oldest teenagers.

Our understanding of the situation of schoolchildren and teenagers is incomplete, says

Ford. But for preschool children, it is almost non-existent – even though they are arguably the most vulnerable because they are missing out on the transition into school and are too young to understand why.

What we do know is troubling. In May 2020, Co-SPYCE, a sister study to Co-SPACE, reported that nearly three-quarters of parents of preschool children said they couldn't balance work and their children's needs. Their biggest worry was that their kids were missing out on socialising.

Lockdown habits

In the middle of 2020, Beki Langford at the University of Bristol in the UK and her team interviewed 20 parents in England with 3 to 5-year-old children due to start school in September. During the first lockdown in March, many of the children were reported to be snacking more, being less physically active, spending more time on screens and having difficulty getting to sleep – at a time when they are forming their habits.

"They lost a huge amount of their early years education," says Langford. Now they have been taken out of school just months after starting. "They've had the double whammy, because they have been particularly affected by both of those lockdowns." Children who are turning 4 have lived a quarter of their lives in the pandemic.

There is evidence that the easing of the first UK lockdown helped children. Creswell and her colleagues found that children's mental health declined during the lockdown, but their difficulties with behaviour, emotion and attention began decreasing in July, when restrictions were easing. "Things did improve," she says.

3/4

Of parents of preschool children couldn't balance work and their kids' needs in April/May 2020

Now, however, the UK is locked down again. Anecdotally, it feels worse this time.

The new lockdown may have been particularly upsetting because it came after vaccinations began, says Creswell. "Before Christmas, everyone was excited that we were nearly at the end, and then everything's gone backwards a bit, so those things have had an impact on people and increased the uncertainty."

It will be some time before we know whether factors like these have influenced children's reactions. But there is evidence that the new lockdown is harming adults' mental health. On 13 January, an online survey by Ipsos MORI revealed that many British adults are finding it harder to stay positive from day to day. The UK Office for National Statistics regularly surveys people's reactions to the pandemic, and for 7 to 10 January – during the first week when all parts of the country were in lockdown – people's anxiety levels were the worst since April 2020.

Similarly, Creswell's team says that parental stress and depression increased during the first UK lockdown. Those with children under 10 reported more stress, particularly related to their kids' behaviour. Those with older children reported more depression.

This is critical because children's mental health is impacted by that of the adults they live with. "There is a known link between parental mental health and challenging behaviour – particularly in young boys, but also in young girls – and a strong link between parental mental health and child mental health," says Ford.

For children who are anxious, Creswell is now testing a new treatment regime in which parents can access a specially designed website and get weekly telephone sessions with a therapist. She and her team have also developed an app to help parents of primary-age children manage difficult behaviours, which they are gearing up to test.

Children's mental health was declining in the UK even before the pandemic. In 2017, Ford revealed that the likelihood of people in England aged 4 to 24 reporting a mental health condition increased sixfold between 1995 and 2014. "That was almost entirely explained by an increase in anxiety and depression disorders that seemed to be particularly marked in teenagers," says Ford.

"Before Christmas, people were excited that we were nearly at the end and then things went backwards"

This may be why a significant proportion of UK teenagers report that lockdown improved their lives. One study found that 13 and 14-year-olds with poor mental health and well-being before lockdown saw the biggest improvements during it.

It isn't just the UK where children's mental health has been declining for years. In the US, between 2007 and 2016, children's visits to emergency departments for mental health conditions rose 60 per cent. A 2019 study estimated that as many as 1 in 6 children in the US aged between 6 and 17 has a mental health condition such as depression.

"Our children were not doing well before the pandemic," says Ford, "and the pandemic is almost certainly not going to help for the vast majority of them." ▮

DAVID LEAHY/GETTY IMAGES

Younger schoolchildren are feeling the effects of loneliness the most

Need a listening ear? UK Samaritans: 116123 (samaritans.org). Visit bit.ly/SuicideHelplines for hotlines and websites for other countries

Expert poll

Face masks needed until 2022

People in the UK will protect themselves from covid-19 for years, predict disease experts

Ibrahim Sawal and Adam Vaughan

MANDATORY wearing of face coverings in shops and on public transport will probably stay in place in the UK until at least 2022, predict a majority of infectious disease experts polled by *New Scientist*.

Expectations are similar for official guidance in the UK on physical distancing, with most anticipating that 2 metre or "1 metre plus" measures will remain until 2022 or later. Opinion is split on whether the UK will hit its vaccination roll-out target.

To gather the views, *New Scientist* contacted around 200 leading UK epidemiologists, modellers, virologists and public health researchers to see when they think life in the UK will return to something resembling normality. A total of 52 responded from more than 15 universities and organisations, providing an anecdotal snapshot of expectations for the future.

Among the respondents, 23 thought guidance in the UK on face coverings would stay in place until 2022, with 12 saying 2023 or later. But even when the guidance does change, people may opt to stick with face coverings, says Mark Jit at the London School of Hygiene & Tropical Medicine (LSHTM). "It will stop being legally mandated at some point, but I think there will be a permanent culture change for people to wear face coverings in public, especially when they have respiratory symptoms. We already saw that happen in Asia following SARS," he says.

On physical distancing guidelines in the UK, the majority of experts polled expected them to stay in place until 2022, with five people predicting that they will remain until 2023. One respondent thought the guidance would always be necessary.

"We may see different rules in different regions," says Martin Michaelis at the University of Kent, UK, who is comparing the genome of the new coronavirus with that of the coronavirus that triggered the 2003 SARS outbreak. "This will not be a linear process: distancing measures may have to be repeatedly reintroduced for the foreseeable future."

People were divided on whether the UK government will meet its vaccine roll-out goal. At the time of questioning, the government had promised to offer a vaccine to every adult in the UK by September. This plan has since been accelerated, with prime minister Boris Johnson saying the UK government is now aiming to do so by the end of July.

Among respondents, 27 said the UK government would meet its old target, 19 thought not. Several of those who doubted the target would be met cited complications that might occur as second doses are administered. Around 4 per cent of those who have received a first dose have had a second one so far. Vaccine availability is also seen as a potential issue. "It will depend on vaccine producer supplies," says David Heymann at LSHTM.

The survey gives an insight into when infectious disease experts expect to resume various normal activities in their personal lives.

Most of the group anticipate taking public transport before the end of the year and, once restrictions are lifted, most expect to travel in the UK outside their local area this year. Nonetheless, 29 respondents don't anticipate travelling internationally until 2022 or later. "I think there will be little opportunity to travel in 2021 and I do not believe it is advisable in the current situation," says Mark Wass, also at the University of Kent.

Although remote working is the norm now for those who can, 32 of the respondents expect to return to a shared office this year.

Physical contact with people outside the immediate family is anticipated to take time. While the majority of respondents said they expect to invite relatives and friends into their home towards the end of the year (see table, left), 28 people said they don't anticipate hugging or shaking hands with someone outside their support bubble until 2022 or later.

And, like changing attitudes on face coverings, cultural norms may alter our physical greetings for good. "I think hugs and handshakes will be reduced so significantly that they may not be the norm any more," says Deji Oloko, also at LSHTM. ▮

TOLGA AKMEN/AFP VIA GETTY IMAGES

A woman wears a face mask while waiting for a tube train in London

Expectations of resuming normal activities

Responses of 52 disease experts to the question "When will you personally expect to do the following?"*

	Q1 2021	Q2 2021	Q3 2021	Q4 2021	2022	2023 or later	Never
Invite relatives and friends into your home	0	9	19	12	12	0	0
Eat or drink at a pub, cafe or restaurant	0	14	22	6	9	1	0
Go to cinema, theatre or other cultural venue	0	2	15	14	15	5	0

* One expert didn't give an answer for the third scenario

SOURCE: NEW SCIENTIST

18+

WHAT IS AVAXHOME?

AVAXHOME-

the biggest Internet portal, providing you various content: brand new books, trending movies, fresh magazines, hot games, recent software, latest music releases.

Unlimited satisfaction one low price
Cheap constant access to piping hot media
Protect your downloadings from Big brother
Safer, than torrent-trackers

18 years of seamless operation and our users' satisfaction

All languages
Brand new content
One site

AVXLIVE.ICU

AvaxHome - Your End Place

We have everything for all of your needs. Just open https://avxlive.icu

New Scientist
Subscriber Event

FREE FOR ALL SUBSCRIBERS

ONLINE EVENT

YOUR PHYSICS QUESTIONS ANSWERED

18 March 6-7pm GMT and on-demand

Want to know what's hot in physics, cosmology, the quantum world and more? Join a panel of *New Scientist* writers and editors as they tackle the biggest questions in the universe at our first subscriber-only event of 2021.

Michael Brooks
New Scientist
consultant and writer

Daniel Cossins
New Scientist
feature editor

Anna Demming
New Scientist
feature editor

Richard Webb
Host, *New Scientist*
executive editor

To register and submit questions visit
newscientist.com/marchevent6

You will need your 8 digit subscriber number which can be found on our customer service and event emails

Biology

Complex life's days are numbered

Earth sustains large oxygen-breathing organisms today, but in a billion years it won't

Karina Shah

ONE billion years from now, Earth's atmosphere will contain little oxygen, making it unsuitable for complex aerobic life.

Today, oxygen makes up around 21 per cent of Earth's atmosphere. Its oxygen-rich nature is ideal for large and complex organisms, like humans, that require the gas to survive. But early in Earth's history, oxygen levels were much lower – and they are likely to be low again in the distant future.

Kazumi Ozaki at Toho University in Funabashi, Japan, and Chris Reinhard at the Georgia Institute of Technology in Atlanta modelled Earth's climatic, biological and geological systems to predict how atmospheric conditions on Earth will change.

The researchers say that Earth's atmosphere will maintain high levels of oxygen for the next billion years before dramatically returning to low levels reminiscent of those that existed prior to what is known as the Great Oxidation Event of about 2.4 billion years ago.

One key reason for the shift is that, as our sun ages, it will become hotter and release more energy. The researchers calculate that this will lead to a decrease in the amount of carbon dioxide in the atmosphere as CO_2 absorbs heat and then breaks down.

Ozaki and Reinhard estimate that, in a billion years, CO_2 levels will become so low that photosynthesising organisms – including plants – will be unable to survive and produce oxygen. The mass extinction of these photosynthetic organisms will be the primary cause of the huge reduction in oxygen.

Our planet will one day lose its ability to support complex life

ALEXANDR YURTCHENKO/ALAMY

"The drop in oxygen is very, very extreme – we're talking around a million times less oxygen than there is today," says Reinhard.

Once the changes in Earth's atmosphere begin to occur, they will progress rapidly: the team's calculations suggest that the atmosphere could lose its oxygen over the course of just 10,000 years or so (*Nature Geoscience*, doi.org/fxq9).

"The biosphere cannot adapt to such a dramatic shift in environmental change," says Ozaki. Afterwards, life on Earth will be exclusively microbial, says Reinhard.

The research was conducted as part of a NASA project into planet habitability, and the predictions have implications for searching for life on other planets.

"Oxygen, in its many forms, is a very important biosignature since it is intertwined with life so fully on Earth," says Natalie Allen at Johns Hopkins University in Maryland. But Ozaki and Reinhard's new prediction shows that oxygen presence is variable and may not be permanent on a habitable planet.

"It suggests that even for planets around other stars that are very similar to Earth, large amounts of oxygen may not be detected in their atmosphere, even if they can support, or have supported, complex life," says Kevin Ortiz Ceballos at the University of Puerto Rico. Not detecting oxygen around planets doesn't mean that they are uninhabitable, he says. ▮

Internet

Wikipedia had a big spike in edits during the pandemic

BORED of the pandemic and stuck at home, many passed the time editing Wikipedia pages, according to data on the online encyclopaedia's changes over the past few years.

An analysis of 223 million edits to Wikipedia between 2018 and 2020 shows a 20 per cent increase in the number of changes made to English-language pages between January and September 2020. Similar rises were recorded on 11 other language versions.

The impact didn't happen right away: the number of edits stalled in the immediate aftermath of major pandemic milestones, such as the start of a lockdown, before rising rapidly as people sought diversions from being stuck at home.

The Italian-language version of the site saw an 80 per cent relative increase in new editors signing up to amend pages following the introduction of Italy's lockdown in March 2020. "The impact and severity of the lockdown appears to have had an effect," says Thorsten Ruprechter at Graz University of Technology in Austria, one of the team behind the research.

What Wikipedia editors turned their attention to isn't yet fully clear and is the subject of follow-up work by Ruprechter and his colleagues. Just over 1 per cent of all edits from January to September 2020 on the English-language Wikipedia were to pages about covid-19 (arxiv.org/abs/2102.10090).

"So-called edit wars may have decreased, which leads us to believe there may be higher solidarity"

"Part of the story here is what didn't happen: they don't find a correspondingly large increase in the rates of contribution removal," says Kaylea Champion at the University of Washington in Seattle.

Wikipedia is infamous for protracted so-called edit wars over small points of fact, but they may have decreased, "which leads us to believe during the crisis there might be a higher level of solidarity", says Ruprechter. ▮

Chris Stokel-Walker

New Scientist
Events

BIG THINKER SERIES
ELLA AL-SHAMAHI
THE HANDSHAKE:
AN ANTHROPOLOGIST'S GUIDE

Thursday 25 March 2021 6-7pm GMT, 1pm-2pm EST and on-demand

Anthropologist Ella Al-Shamahi explores the untold science behind one of the oldest, most familiar (and currently much missed) human gestures – the handshake.

- What is its biological purpose?
- Why has it outlasted other forms of greetings?
- How is it that even uncontacted tribes know what a handshake is?
- What are the best and worst handshakes?
- Has covid-19 pandemic killed it off for good?

Weaving together biology, evolutionary history and anthropology, Ella Al-Shamahi examines the enduring power of the handshake. She will argue that the gesture is at least 7 million years old, with origins probably embedded in our DNA - and will blow apart some myths and misconceptions about this innate human behaviour along the way.

For more information and
to book your place visit:

newscientist.com/handshake

Technology

Safer computer chips, fast

Virtual testing slashes the time to make and test computer components

Matthew Sparkes

TESTING new computer chips for security and reliability often takes longer than designing them. A new method for modelling them virtually and testing them with programs conventionally used for software instead of hardware could reduce development time.

Current hardware testing either randomly probes a chip to find flaws or seeks to formally test every single possible input and output on each computer chip. The first approach can easily miss problems and the second quickly becomes infeasible for all but the simplest designs.

Either way, testing can take months, but a single flaw in a piece of hardware can make computers unreliable or vulnerable to hacks and, unlike a software flaw, cannot be fixed with an update after shipping. Now, a team of researchers at the University of Michigan, Google and Virginia Tech has sped up the testing process by simulating computer chips and using advanced software testing tools to analyse them. Chip designs were translated into code and given a layer of software on top to make them operate as they would in real-world use.

"This could test chips faster and cheaper, but no method can guarantee a design is free of flaws"

Testing chips virtually enables engineers to use an approach called fuzzing, which watches for unexpected results or crashes that can then be examined and fixed. The problematic inputs that caused them are mutated and adapted to probe for similar problems in the rest of the chip. This covers ground more productively than purely random tests.

One problem that the team had to overcome is that chips and code work in very different ways. Chips churn through a constant stream of inputs and outputs, conducting thousands of simple operations to achieve a larger task, whereas software tests often involve submitting single inputs like text or a file and observing the output. The team had to adapt software fuzzers to run over time rather than fire off a single input and wait for the response.

"We had to trick these software fuzzers into interpreting inputs differently than they do in the software space. In a sense, what we were doing is we were taking inputs in a single dimension and extracting multiple dimensions," says Timothy Trippel at the University of Michigan.

This method reduced the time taken to test a chip design by two orders of magnitude – a chip that would usually take 100 days to test can be analysed in a single day (arxiv.org/abs/2102.02308).

The team later used the approach on an OpenTitan chip designed by Google. Within an hour, it had covered 88 per cent of the lines of code that made up the software model among three of the sections, and 65 per cent of the fourth.

Faster hardware testing could bring the next generation of chips to consumers faster, and in a more reliable and secure state, says the team.

Rob Hierons at the University of Sheffield, UK, agrees that testing hardware before production would be desirable, faster and cheaper, but cautions that no approach could ever guarantee a design is free of flaws.

"Fuzzing adds some direction to random [testing], but in the end it will often be limited," he says.

Animal behaviour

Ship noise affects dolphins that help humans catch fish

SOME dolphins help humans catch fish – but perhaps not for much longer. An uptick in noise pollution from ships is changing the way these dolphins communicate. It is possible that this may reduce the dolphins' ability to coordinate their behaviour to their – and the humans' – advantage.

Near Laguna in southern Brazil, a group of Lahille's bottlenose dolphins (*Tursiops truncatus gephyreus*) works together to drive schools of fish like mullet into the shallow water where fishers cast handheld nets, catching fish and breaking up the schools. While the water is murky, the dolphins are believed to take advantage of the chaos, snatching up disorientated fish missed by the nets.

NATURE PICTURE LIBRARY/ALAMY

The dolphins near Laguna, Brazil, have been helping people fish for a century

The relationship is at least a century old, but it might be imperilled by the increasing noise made by ships that pass nearby.

Bianca Romeu at the Federal University of Santa Catarina, Brazil, and her colleagues found that, during noisier periods, the dolphins produced fewer whistles and increased their pitch (*Animal Conservation*, doi.org/fxqp).

In other words, the dolphins were communicating differently when boats were around, which could affect the way they get organised to forage with the fishers, says Romeu.

"Probably the noise isn't interrupting the activities, but it can disturb them, can change their behaviour," says Romeu. She adds that it may make the dolphins worse at working together to drive the fish towards the fishers.

The problem isn't easily solved, but Romeu says that authorities could perhaps consider introducing rules to limit how many boats can pass nearby at any one time.

Joshua Rapp Learn

Nutrition

Dining with healthy eaters pushes you to eat better food too

Chris Stokel-Walker

WHO you eat with influences what you eat, according to a study of 38 million food purchases at a university campus over eight years.

Kristina Gligorić at the Swiss Federal Institute of Technology in Lausanne and her colleagues tracked the eating habits of 39,000 anonymised students and staff between 2010 and 2018 through smart card purchases on campus. On average, people's spending was tracked for 578 days and they visited shops, cafes, restaurants and vending machines 188 times.

After monitoring people for a year to find similarities, 830 strangers were identified as "matched pairs". Their food purchases then deviated as they respectively began to eat with different friends.

Gligorić thinks of the matched pairs as "doppelgangers whose history is the same, but one by chance happens to start eating with someone who is a healthy eating partner, and someone starts eating with an unhealthy eating partner".

Their spending was monitored for change when they ate socially, measured by when and where purchases were made, ensuring they were close enough to be in the same queue as others. The team found that people pick similar items to the person they eat with. If a new friend eats pizza, the tracked person is more likely to eat pizza.

In comparison with the other person in their matched pair, people whose eating companions ate more unhealthy foods bought an average of one additional soft drink and 0.5 extra pizzas in the six months after they buddied up. The same happened with healthier food: people who made friends with healthy eaters bought an extra 5.71 healthy items and 1.13 fewer unhealthy options on average over six months (*Proceedings of the ACM on Human-Computer Interaction*, DOI: 10.1145/3449297). ▮

Green technology

Climate targets at risk from efficiency paradox

Adam Vaughan

SEBASTIAN KAHNERT/EPA/SHUTTERSTOCK

Steel demand can rise if production is made more efficient

THE world is failing to account for a rebound effect that could wipe out more than half of the savings from energy efficiency improvements like cleaner cars, making the goals of the Paris Agreement on climate change even harder to hit.

Improvements to energy efficiency, from LED lights to better steel-making arc furnaces, are seen by many authorities as a top priority for cutting carbon emissions. Yet a growing body of research suggests that human behaviour and economics mean a major chunk of anticipated efficiency savings are lost.

A team led by Paul Brockway at the University of Leeds, UK, looked at 33 studies on the economy-wide impact of a phenomenon known as the rebound effect.

First comes the direct rebound: for instance, when someone buys a more efficient car, they may take advantage of that by driving it further. Then comes the indirect rebound: fuel savings leave the owner with more money to spend elsewhere in the economy, consuming energy. This contributes to the macro effect of growing the overall economy.

Although the 33 studies used different methods to model the rebound effect, they produced very consistent estimates of its impact, leading the team to conclude that the effect erodes,

63%

of energy savings may be wiped out by the rebound effect

on average, 63 per cent of the anticipated energy savings (*Renewable and Sustainable Energy Reviews*, in press).

"We're not saying energy efficiency doesn't work. What we're saying is rebound needs to be taken more seriously," says Brockway.

The idea that increased efficiency may not deliver the hoped-for savings dates back to the Jevons paradox, named after the economist William Stanley Jevons who, in 1865, observed that more efficient coal use led to more demand for coal.

The last review of the economy-wide rebound effect was in 2007. The new analysis is the first to pull together the explosion of research since.

Worryingly, the influential energy models that governments and companies rely on to examine how future emissions and energy demand may unfold aren't good at capturing the rebound effect.

The team looked at 17 scenarios from energy models, including ones used by the International Energy Agency, the UN climate science panel, BP, Shell and Greenpeace.

"Most of the models missed out large numbers of the channels which contribute to rebound effects," says Steve Sorrell at the University of Sussex, UK, a co-author of the new study. One scenario assumed a rebound effect of just 10 per cent.

"The message is these rebound effects do definitely need to be incorporated in any scenarios," says Roger Fouquet at the London School of Economics.

If the rebound effect does prove to be as big as suggested, it means future global energy demand will be higher than expected and the world will need far more wind and solar power and carbon-capture technology than is currently being planned for.

But that doesn't mean nothing can be done to limit the rebound effect. One answer is to double down on energy efficiency and do twice as much to achieve the same effect, says co-author Gregor Semieniuk at the University of Massachusetts Amherst. ▮

Space travel

A warp drive that doesn't break the laws of physics

Leah Crane

WARP drives may be on the road to reality. Previous ideas about how to make these hypothetical devices have required exotic forms of matter and energy that may not exist, but a new idea for a warp drive that doesn't break the laws of physics may be theoretically possible. However, it may not be practical in the foreseeable future because it requires ultra dense materials.

Contrary to what its name may suggest, a warp drive isn't really an engine. Rather, it is a bubble of space-time protected by a shell of matter in which the fundamental properties inside the shell can differ from those outside. Without an added mode of propulsion, warp drives don't move through space on their own, but, in theory, some types could break the speed of light, moving faster than this by stretching and compressing space-time around them.

"Einstein's relativity only sets limits for things moving in space-time, not the speed of space-time itself," says Sabine Hossenfelder at the Frankfurt Institute for Advanced Studies in Germany. "If you're trying to reach a certain speed by warping space-time, this limit can, in principle, be overcome."

The first method suggested to do just that was proposed by Miguel Alcubierre in 1994, but it would require strange matter with negative energy, rather than the positive energy normal matter has. There is no evidence that such matter exists, so Alexey Bobrick and Gianni Martire at Applied Physics in New York, an independent research institute, have come up with a modification that allows their warp drive to be made of real matter. Without negative energy, it can't beat the speed of light, but its effects on time could still make it useful for long space journeys.

Their idea is based on the fact that in the presence of powerful gravitational fields, the passage of time appears to slow down

"The incredibly dense materials needed for this aren't something we could produce at present"

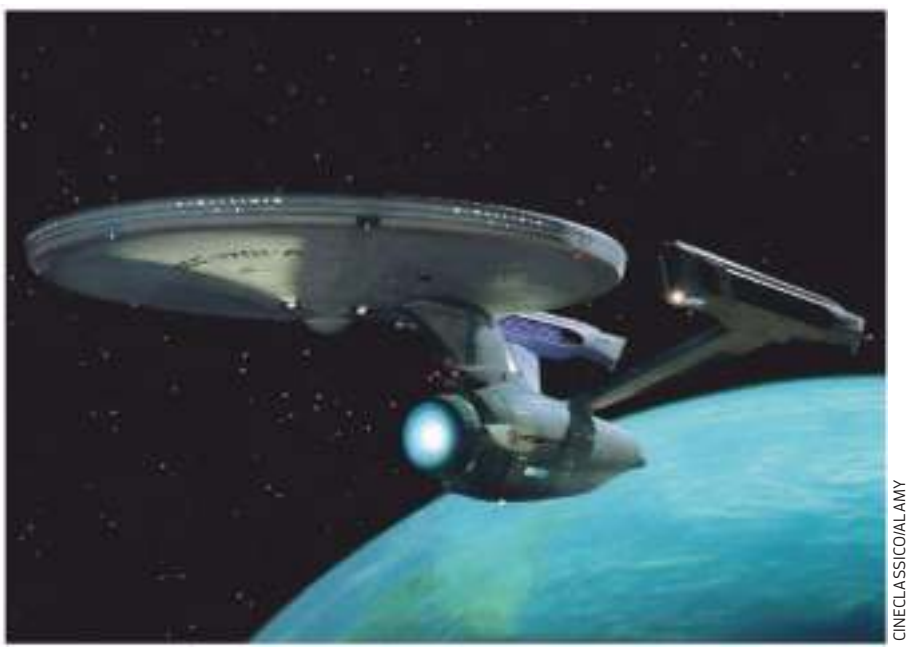
due to the effects of general relativity. In a warp drive, this effect could allow a person inside a shell of matter to travel enormous distances in what is, from their perspective, a relatively short time.

The strength of that effect is dependent on the mass of the shell – the more massive it is, the slower time moves within it relative to the outside.

"In a sense, a burrito is a warp drive, with the contents as the passenger, but it's not a very interesting one," says Bobrick. That is because the gravitational effect of the tortilla used to wrap the burrito's contents is negligible, so it doesn't deform space-time, and therefore the contents move through time in the normal way. Even if the tortilla used to make the burrito were extremely massive, it would make a far from ideal warp drive. The team found that a flat, circular shape would work best, with the largest side facing forward, like a pie sailing towards a face (*Classical and Quantum Gravity*, doi.org/fxr8).

The mass required for a measurable effect is enormous, higher than that of an entire planet. "If we take the mass of the whole planet Earth and compress it to a shell with a size of 10 metres, then the correction to the rate of time inside it is still very small, just about an extra hour in the year," says Bobrick.

So, an actual warp drive, even a tiny one, is still science fiction. "The densities that you need to get at to make this even measurable are so high that we cannot presently produce them. It's not something that's going to work in the next several hundred years," says Hossenfelder. "But maybe eventually we'll get there." ▮



CINECLASSICO/ALAMY

Warp drives are a staple of the *Star Trek* universe

Ancient humans

Neanderthal hearing was tuned for language like ours

Krista Charles

VIRTUAL reconstructions of Neanderthal ears show that our extinct cousins had the same physical capacity for hearing as modern humans. This implies they could make the sounds we can, although whether they actually spoke a language is still unknown.

"We don't know if they had a language, but at least they had all the anatomical parts needed to have the kind of speech that we have," says Mercedes Conde-Valverde at the University of Alcalá in Spain. "It's not that they had the same language, not English, not Spanish, nothing like this. But if we could hear them, we would recognise that they were humans."

Conde-Valverde and her colleagues used medical imaging software to create virtual reconstructions of Neanderthal external and middle ear cavities, based on CT scans of their skulls. With these models, they could determine the range of sounds that Neanderthals could hear, and thus probably produce as speech.

The team also did this for a group of fossils known as the Sima de los Huesos hominins that are thought to be the immediate ancestors of Neanderthals. The results showed that, unlike these ancestors, Neanderthals had the same capacity for hearing as we do (*Nature Ecology and Evolution*, doi.org/fxrg).

Neanderthal hearing was optimised towards consonants that often appear in modern human languages, such as "s", "k", "t" and "th", in the same way that ours is, says Conde-Valverde.

We don't know if this means they had the mental capacity for language development, but Conde-Valverde says recent archaeological evidence, including stone tool use, jewellery making and art, hints at complex behaviour in Neanderthals that could indicate language ability. ▮

Artificial intelligence

AI smashes video game high score

Learning from previous successes can help an artifical intelligence perform better

Matthew Sparkes

AN ARTIFICIAL intelligence that can remember its previous successes and use them to create new strategies has achieved record high scores for some of the hardest video games on classic Atari consoles.

Many AI systems use reinforcement learning, in which an algorithm is given positive or negative feedback on its progress towards a particular goal after each step it takes, encouraging it towards a particular solution. This was used by AI firm DeepMind to train AlphaGo, which beat a world champion Go player in 2016.

Adrien Ecoffet at Uber AI Labs and OpenAI in California and his colleagues hypothesised that such algorithms often stumble upon encouraging avenues but then jump to another area in the hunt for something more promising, overlooking better solutions.

"What do you do when you don't know anything about your task?" says Ecoffet. "If you just wave your arms around, it's unlikely that you're ever going to make a coffee."

ATARIAGE

An AI beat a human world record for the Atari game *Montezuma's Revenge*

To solve this problem, the team created an algorithm that remembers all the different approaches it has tried and keeps returning to moments in which it had a high score as a starting point from which to explore further.

The software stores screen grabs from a game as it plays to remember what it has tried, grouping together similar-looking images to identify points in the game it should return to as a jumping-off point. The algorithm's aim is to maximise its score, and when it reaches a new high score, it updates its record of the particular starting point it used with a new screen grab from that part of the game.

Atari games don't normally allow players to revisit any point in time, but the researchers used an emulator – software that mimicked the Atari system – with the added ability to save game states and reload them at any time. This meant the algorithm could begin from any point without having to play the game from the start.

The team set the algorithm to playing a collection of 55 Atari games that has become a standard benchmark for reinforcement learning algorithms. It beat state-of-the-art algorithms in those games 85.5 per cent of the time.

In one particularly complex game, *Montezuma's Revenge*, the algorithm scored higher than the previous record for reinforcement-learning software and also beat the human world record (*Nature*, doi.org/gh5jbc).

Once the algorithm reached a sufficiently high score, the researchers used its solution to train a neural network to play the game the same way, doing away with the need for reloading save states with an emulator.

Peter Bentley at University College London says the team's approach of combining reinforcement learning with an archive of memories could be used for more complex problems. ▮

Biodiversity

Shadow snake rediscovered in Ecuador's rainforest

AFTER a long hiatus, a mysterious reptile has slithered back into the light. Researchers working in Ecuador's tropical rainforests report that a Fugler's shadow snake (*Emmochliophis fugleri*) has been found alive after 54 years of absence from the scientific record.

In 2019, conservation biologists Ross Maynard and Scott Trageser at The Biodiversity Group in Arizona were conducting amphibian and reptile surveys in the Río Manduriacu reserve in Ecuador's Andes mountains. They were on a night hike when Trageser came across a small, dark snake wriggling next to some mossy boulders.

After catching the snake and getting a closer look, Maynard noted that despite his normally robust field identification skills, he was having trouble categorising the find. "This I definitely did not have on my radar," he says.

The snake was examined and photographed, then Maynard, Trageser and their colleagues later classified it as a Fugler's shadow snake – only the second individual known (*Check List*, doi.org/fxbd).

SCOTT J. TRAGESER

A Fugler's shadow snake has been found for the first time in more than five decades

E. fugleri and its presumed closest relatives are called shadow snakes for their dark colouration, nocturnal habits and secretive nature. They may have gone undetected for so long because they are exceptionally rare or shy, says Maynard.

"I am totally surprised and excited about the discovery," says Thaís Guedes at the State University of Maranhão in Brazil, who wasn't involved with the study. She says assessments of snake biodiversity have been neglected until recently.

"Snakes are some of the most secretive and hard to observe vertebrates out there," says Sara Ruane at Rutgers University in New Jersey, who also wasn't involved with the research. "No doubt there are other species where rediscovery awaits." ▮

Jake Buehler

Space exploration

China's self-sustaining biosphere

Crew lived a record 200 days on recycled oxygen and water, growing their own food

Michael Le Page

CHINA DAILY/REUTERS/PA IMAGES

LED lights kept plants alive inside China's Lunar Palace 1 biosphere

BIOLOGICAL life support systems, or biospheres, could now recycle enough oxygen, water and food to keep people alive for years. Two groups of four people lived in a sealed environment in China called Yuegong-1, or Lunar Palace 1, for a total of a year, with one group spending a record-setting 200 days in the facility without needing any outside materials, and they could have gone longer. The project aims to help China establish bases on the moon.

Details of the experiment, which ended in May 2018, were revealed in a study posted online. The researchers say volunteers got 98 per cent of the materials they needed to survive from recycling, with just 2 per cent coming from the outside, including seeds, toilet tissue and cleaning materials.

These are the best results achieved so far. "Now we are reaching a level of closure that is good," says Christophe Lasseur, who leads the European Space Agency's effort to develop regenerative life support systems, called the MELiSSA Project. Such systems can't yet sustain people indefinitely, he says, but they can now do it "for a long period".

"If they have accomplished what they claim to have accomplished, that would be a huge step forward," says Rob Suters at Semilla Ipstar, a Dutch company that commercialises MELiSSA technology.

There have been many efforts to create habitats that sustain people, starting with Russia's BIOS experiments from the 1960s to the 1980s. The Biosphere 2 facility in Arizona is the most famous. One of the crewed experiments done there in the 1990s lasted two years, but extra food and oxygen had to be supplied, so it is regarded as a failure. Japan also did a series of crewed experiments in the 2000s.

Lunar Palace 1 was built in 2013, with the first crewed experiment in 2014. The facility consists of a small living cabin linked to two larger cabins filled with shelves of plants growing under LED lights.

In the latest experiments, all the oxygen generation and carbon dioxide removal was done by the plants, which included wheat, potatoes, tomatoes, carrots, cucumbers and strawberries. There were some fluctuations when the crews swapped but gas levels remained within safe limits.

Waste water was treated in a bioreactor and sterilised with UV light before being used for irrigation. Drinking water was obtained by condensation and also sterilised. Some plant waste was used to grow mushrooms and then fed to mealworms, which were made into a kind of protein-rich bread. Faeces were mixed with plant waste and fermented to produce CO_2 for growing plants. Some residues left after processing urine and faeces were stored. All crew members stayed physically and mentally healthy, the study says (bioRxiv, doi.org/ghtbdd).

"A good measure of these systems is how many square metres do you need to support one crew member," says Oscar Monje at NASA's Kennedy Space Center in Florida. In Lunar Palace 1, there were 40 square metres of growing area per crew member, compared with 75 square metres in the Japanese experiments, says Monje. "That's pretty good, and matches what NASA predicted from its crop testing."

98%

Amount of key materials biosphere inhabitants got from recycling

The main aim of the research is to create life support systems for space exploration. "It would make long-term space travel much more feasible, as you would not need to bring so much mass," says Suters. But supporting people on, say, a lunar base remains an immense challenge. For starters, a moon base would have to be underground to protect it from radiation, says Monje. Then it has to be powered. "If you want to do it with solar collectors, it would be a huge area so you probably need a nuclear reactor," he says.

The moon is especially challenging because a lunar day lasts an Earth month, says Lasseur, giving it a long period of extreme cold and dark. And a system that works on Earth won't necessarily work in space. The European Space Agency is taking a different approach, focusing on testing small components on space flights rather than trying to build a complete system on Earth. But it has set up a "space greenhouse" in Antarctica.

NASA, meanwhile, has been studying how to grow plants in space, installing the Advanced Plant Habitat on the International Space Station in 2018. However, the aim of this work is just to supplement the diet of astronauts on long missions with fresh food rather than for life support. ▮

Human evolution

Our earliest human ancestors may have swung on branches like chimps

Karina Shah

THE distant forerunners of humans may have had more in common with chimpanzees than we thought. An analysis of a 4.4-million-year-old hand suggests that they swung from branches and knuckle-walked like living chimps do – challenging recent thinking that our earliest human ancestors did neither.

In popular thinking, we are often imagined to have evolved from a chimpanzee-like ape on the human lineage, members of which are known as hominins. Many researchers now challenge this idea – particularly in light of fossil evidence from the early hominin *Ardipithecus ramidus* that was published in 2009.

One well-preserved individual, nicknamed Ardi, had bones that seemed to suggest it walked along branches like a monkey rather than swinging below them like a chimp. This hinted that our last common ancestor with chimps also walked along branches, and that chimps evolved to swing and knuckle-walk after they branched off from hominins.

Thomas C. Prang at Texas A&M University and his colleagues disagree with this idea. They took the measurements of Ardi's hands reported in 2009 and compared them with 416 measurements from hands across 53 species of living primates like chimpanzees, bonobos and humans.

"The analysis of this hand, one of the earliest hands in the human fossil record, suggests that it is chimpanzee-like, implying that both humans and chimps evolved from an ancestor that was chimp-like," says Prang.

They found that Ardi's metacarpals and phalanges – the bones of the fingers and palms – were similar in size to those of living apes, with relatively large joint and knuckle dimensions. These adaptations are present in existing primates that move around forests by swinging below branches and may have helped Ardi to grasp onto branches, and even knuckle-walk.

"Ardi also has elongated, more curved finger bones, and we see this increased elongation and curvature in animals that habitually hang from branches," says Prang (*Science Advances*, doi.org/fw9v).

Larger-bodied primates tend to hang from branches and climb trees, while smaller-bodied primates, such as monkeys and many lemurs, are able to walk along the branches.

"[This study] quite convincingly demonstrates that the *Ardipithecus* hand has some suspensory adaptations, which I think makes more sense given the body size," says Tracy Kivell at the University of Kent, UK.

Ardipithecus may have swung from branches like a chimpanzee

PVE/ALAMY

This may suggest that the last common ancestor of chimpanzees and humans was relatively chimpanzee-like, before the major evolutionary shift towards bipedalism and hand dexterity.

Tim White at the University of California, Berkeley, who discovered the *A. ramidus* fossil and helped describe it in 2009, remains unconvinced.

"This is another failed resurrection of the antiquated notion that living chimpanzees are good models for our ancestors," says White. He says that the *Ardipithecus* hand, aside from having five fingers and the ability to grasp, wasn't specifically chimpanzee-like, as he and his colleagues originally reported in 2009.

Sergio Almécija at the American Museum of Natural History in New York is also largely unmoved. "We need more Miocene [epoch] ape fossils pre-dating the human-chimp split to test fundamental aspects of our last ancestor with apes," he says. ▮

Marine biology

Pufferfish pull in their eyeballs and pucker skin to blink

PUFFERFISH are the only bony fish that can close their eyes, and now we know how they do it. They sink their eyeballs deep into their sockets and then pucker the skin surrounding the eye together, like a camera's aperture closing.

The findings resolve "a great mystery hidden in the long-known behaviour of [these] familiar fish", says Keisuke Ogimoto at the Shimonoseki Marine Science Museum in Japan.

The pufferfish's eye-closing ability is something that Japanese fishers and chefs have long noticed. But scientists had never followed up on these observations until Ogimoto witnessed the behaviour with his own eyes – and fell in love with it.

"The first time I saw a pufferfish close its eyes in my aquarium, I was so moved by its cuteness that I decided to investigate," he says.

Ogimoto and his colleagues studied two fine-patterned puffers (*Takifugu flavipterus*) living in an aquarium at the Shimonoseki museum. The team took video and images of the fish's eyes as handlers gently squirted warm seawater into them, and collected ultrasound recordings of eyeball movement.

The researchers found that the skin around the fish's eye squeezes over the middle of the eyeball with a sphincter-like movement, resembling an iris constricting over a pupil in bright light. Just before the skin moves, the eyeball sinks into the head to a depth of 70 per cent of the eye's full diameter – among the greatest eye-sinking depths ever recorded in an animal (*Zoology*, doi.org/fw9x).

"The first time I saw a pufferfish close its eyes in my aquarium, I was so moved by its cuteness"

"The various aspects of this eye-closing behaviour were revealed one by one, and it was a continuous surprise," says Ogimoto. "It's exciting to ponder the mystery of the evolution of this similar-but-different eye-closing behaviour."

Manatees – or "sea cows" – also close their eyes radially, but as marine mammals they probably evolved the trait independently. ▮

Christa Lesté-Lasserre

New Scientist Academy

ONLINE COURSES TO ENLIGHTEN, ENTERTAIN AND INSPIRE

New Scientist Academy is here to feed your fascination for science. Our carefully designed courses will take you on a journey of discovery through some of the hottest research topics. Featuring an engaging mix of activities, videos, community questions, quizzes and resources to help you learn. We've brought together *New Scientist*'s trusted editorial expertise and brilliant scientists to pass on their knowledge and passion in a structured way. Each course has over 50 lessons to work through at your own pace. Review your progress, enjoy the satisfaction of learning something new. And feel confident about continuing your own scientific journey with greater confidence.

Find out more a and watch your free introductory video at **newscientist.com/courses**

- / Expert led video tutorials
- / Explainer videos, interactive diagrams, quizzes and more
- / Access to premium *New Scientist* resources
- / CPD accredited certificate
- / Community and discussion groups
- / Learn at your own pace: 6-10 hours of learning

Valerie Jamieson
CREATIVE DIRECTOR

SCIENCE COURSES FOR EVERYONE

COURSE ONE

THE BIGGEST QUESTIONS OF THE COSMOS

What happened at the big bang? What is the universe made of? Are we just part of an infinite multiverse?

If you're fascinated by the biggest questions in the cosmos, this introductory, expert-led online course from New Scientist Academy is for you. Get an overview of the hottest science at your own pace, anywhere, anytime.

MEET YOUR EXPERT COURSE TUTORS:

Dan Hooper is a senior scientist and the head of the theoretical astrophysics group at the Fermi National Accelerator Laboratory, as well as a professor of astronomy and astrophysics at the University of Chicago. His research focuses on the interface between particle physics and cosmology, and he is especially interested in questions about dark matter and the early universe.

Chris Impey is a University Distinguished Professor of Astronomy and Associate Dean of the College of Science at the University of Arizona. He has over 180 refereed publications on observational cosmology, galaxies, and quasars, and his research has been supported by $20 million in NASA and NSF grants.

Fiona Panther is a research associate at The University of Western Australia in Perth. She is a physicist and mathematician with an interest in astronomy and software development. Her expertise is primarily in microphysical astronomy: how processes that occur on the atomic and subatomic scale can influence what we observe on galactic and cosmological scales.

Find out more
newscientist.com/cosmos-course

COURSE TWO

HOW YOUR BRAIN WORKS AND HOW TO MAKE THE MOST OF IT

It's the most complex object in the known universe – but just what makes the human brain so special? How does it make thoughts, memories and conscious reality? And how can you keep yours functioning better for longer?

Get to grips with the most fascinating questions about the human brain, and some practical tips on how to take care of yours, with this introductory, expert-led online course

MEET YOUR EXPERT COURSE TUTORS:

Penny Lewis is a sleep scientist and professor of psychology at Cardiff University. She has coined the term sleep engineering to capture the spirit of her lab's work. She explores ingenious ways to enhance memory, disarm negative emotions, and combat cognitive decline through ageing during sleep. Her book, *The Secret World of Sleep* explores the latest research into the night time brain to understand the real benefits of sleep.

Sophie Scott is professor of cognitive neuroscience at University College London. As head of the speech communication group, her research focuses on how our brains process the information in speech and voices, and how our brains control the production of our voice. Her work also explores individual differences in speech perception and plasticity in speech perception, both of which are important factors for people with cochlear implants.

Anil Seth is professor of cognitive and computational neuroscience at the University of Sussex. His research seeks to understand the biological basis of consciousness by bringing together research across neuroscience, mathematics, computer science, psychology, philosophy and psychiatry.

Find out more
newscientist.com/brain-course

Animal behaviour

DANIEL VON STURMER

Bird can mimic sound of an entire defensive flock

WHEN threatened by a predator, birds often call out to encourage other birds to make noise and fly about, repelling the attacker as part of a "mobbing flock". It now seems that male lyrebirds can imitate the sound of an entire mobbing flock by themselves.

Anastasia Dalziell at Cornell University in Ithaca, New York, and her colleagues recorded 11 male superb lyrebirds (*Menura novaehollandiae*) in Australia.

They found that each lyrebird could imitate the combined alarm calls made by a mobbing flock containing birds from different species. It wasn't clear why the birds were making these noises as there was no sign of predators.

Using pretend predators in the form of a dummy snake and owl, the team recorded real alarm calls from other birds who saw the predators. Those sounds were similar to the lyrebird imitation.

The team then played recordings of the actual and imitation sounds using speakers. Both fooled birds from a range of species into mobbing flock behaviour.

The researchers suspected that the lyrebirds were making the fake alarm calls during mating after they observed two mating events while recording audio. To investigate, they set up cameras in areas that male lyrebirds prepare for mating and recorded about 1000 short videos. The footage revealed that the males also imitated mobbing flocks when the female left without mating (*Current Biology*, doi.org/fxb4).

Dalziell thinks the males did this to try to scare females into staying and mating. **Priti Parikh**

Biology

Cancer-resistance of cetaceans in the genes

WHALES, dolphins and porpoises are much better at fighting cancer than we are, and now we might be closer to understanding why.

Generally speaking, cetaceans are the most long-lived mammals, with some whale species reaching 200 years. Why is a mystery, given their bodies contain far more cells than ours "If you have more cells, that means that the risk that one... becomes cancerous increases," says Daniela Tejada-Martinez at the Austral University of Chile.

Instead, cetaceans have much lower rates of cancer than most other mammals, including us.

Vincent Lynch at the University at Buffalo, New York, says there is a "super trivial" explanation for this paradox. "They just evolved better cancer protection mechanisms." But we still need to learn more about why and how they did this.

Now, Tejada-Martinez and her colleagues have studied the evolution of 1077 tumour suppressor genes (TSGs). In all, they compared the evolution of these genes in 15 mammalian species, including seven species of cetacean.

Genes regulating DNA damage, tumour spread and the immune system were positively selected for among the cetaceans. The team also found that cetaceans gained and lost TSGs at a rate 2.4 times higher than in other mammals (*Proceedings of the Royal Society B*, doi.org/fxcz).

Such knowledge may play a role in human cancer research. "It's not like we're going to be taking whale genes and putting them into humans and making humans cancer resistant," says Lynch. "But if you can find the genes that play a role in tumour suppression in other animals, and if you could figure out what they're doing, maybe you can make a drug that mimics that for human treatment." **Krista Charles**

Materials

Electrostatic effect could defrost your car

ICE has an electrical charge, which could be exploited to create devices that easily defrost car windows and aeroplane wings.

As frost forms, its exposed surface becomes warmer than its lower layers, which are shielded from the air. This temperature difference causes positively and negatively charged ions within the frost to sink. The positive ions seem to move faster, so the bottom of the frost becomes more positively charged than the top.

ANZE FURLAN/EYEEM/GETTY IMAGES

Jonathan Boreyko at Virginia Tech and his team wanted to use this to develop a tool to remove frost. The team grew frost on a variety of surfaces, including glass, and suspended filter paper about 5 millimetres above the ice. Using a syringe to drip water onto the paper, the group found that when it became wet, ice crystals on the surface of the frost instantly began to twist and break off, jumping towards the water-soaked paper (*ACS Nano*, doi.org/gh5b6w).

This might be because the negatively charged ions on the frost's surface were attracted to positive ions in the water, producing an "electrostatic de-icing" effect, says the team.

This worked on individual ice crystals, not the entire frost sheet. Boreyko says the next step is to scale this up. Passing an electrode over frost could make removing ice from big objects, like aeroplane wings, quicker. **Ibrahim Sawal**

Really brief

SHUTTERSTOCK/MATEE NUSERM

Moth mates more often in red light

The yellow peach moth is more sexually active when bathed in red light than it is in light of another colour. The discovery came during lab experiments, and may be because red light has a long wavelength that can pass through animal tissue and stimulate cellular activity (*Frontiers in Genetics*, doi.org/fxdg).

Fossil suggests Asia was a dino hub

A *Diplodocus*-like dinosaur has been discovered in Uzbekistan – the first of its kind found in central Asia. When *Dzharatitanis* was alive about 90 million years ago, Asia might have been a geographical hub from which similar dinosaurs could have spread to other regions (*PLoS One*, doi.org/fxdt).

2.3-litre plastic bottles are greenest

We could reduce plastic waste by buying bottled products that are 2.3 litres in volume, because these provide the greatest capacity relative to the amount of plastic used. A 20 per cent shift towards bottles of this size could reduce annual US waste by 9000 tonnes (*Scientific Reports*, doi.org/fxdw).

Psychology

It is tricky to know when to stop talking

CONVERSATIONS often go on longer than we would like because people mask how they really feel.

That is the finding of Adam Mastroianni at Harvard University and his colleagues. They surveyed more than 800 people who were randomly recruited. Participants responded to questions about recent conversations with a friend or family member, including how they felt about the conversation's length and how it ended.

The team also recruited more than 250 students and non-students pooled from volunteers available for studies at Harvard's psychology department. This group took part in one-on-one conversations with another of the volunteers, who they didn't already know, in the laboratory.

Mastroianni's team recorded each conversation and asked the volunteers to talk about anything they liked for at least a minute. When the conversation had ended, both participants could leave the room. They were separately quizzed about their talk. If the chat lasted 45 minutes, someone stepped into the room to end it.

Conversations rarely ended when people wanted them to. On average, the length of a chat was off by about 50 per cent compared with how long people would have liked them to last, but there was a lack of communication between participants about this (*PNAS*, DOI: 10.1073/pnas.2011809118).

People in conversations not only want different endpoints, but also know "precious little" about what their conversational partners really want, says Mastroianni. **Christa Lesté-Lasserre**

Technology

FOURMY MARIO/ABACA/ABACA/PA IMAGES

How do you detect a deep-sea earthquake? Just ask Google

A FIBRE-OPTIC cable at the bottom of the Pacific Ocean can be used to detect earthquakes and waves.

Zhongwen Zhan at the California Institute of Technology and his team, including researchers at Google, which owns the cable, used traffic data from the 10,000-kilometre-long link to measure changes in pressure and strain in the cable. Using the data, they could detect deep-sea earthquakes and ocean waves called swells generated by storms.

Over a nine-month period, the team recorded about 30 ocean storm swell events and around 20 earthquakes over magnitude 5, strong enough to damage buildings, including the magnitude-7.4 quake near Oaxaca, Mexico, in 2020. The team had wanted to measure a tsunami, but none occurred during the study (*Science*, doi.org/fxcw).

Deploying and maintaining geophysical instruments on the sea floor is difficult and expensive, so underwater seismic stations are relatively rare. There have been efforts to use fibre-optic cables as seismic sensors, but these required specialised laser-detection kit at both ends of the cable or the use of dedicated fibres within the cables. Zhan says the new approach gets round these issues. PP

Domestication

How pets conquered the Americas with us

WE MAY have the best evidence yet that the first people in America took their dogs along for the ride.

Charlotte Lindqvist and her team at the University at Buffalo in New York extracted DNA from the oldest known dog remains found in the Americas. They found the genetic signature is consistent with the idea that domesticated dogs arrived between 17,000 and 16,000 years ago – roughly in line with the currently accepted time for the arrival of the first people.

The bone, found in the late 1990s in Lawyer's cave, Alaska, had already been dated to a little more than 10,000 years ago, but was assumed to have come from a bear. Only when the team studied DNA from it did they realise it belonged to a dog, making it the earliest evidence of dogs found so far in the Americas.

The team used mitochondrial DNA from the bone to understand the dog's genetic history. This showed that it was closely related to the lineage of domestic dogs in the Americas before European contact and colonisation. It also showed that the dog's lineage branched off from dogs living in Siberia roughly 16,700 years ago (*Proceedings of the Royal Society B*, doi.org/fxc3). **Karina Shah**

New Scientist Shop

OUT NOW!

NEW BOOK RELEASE

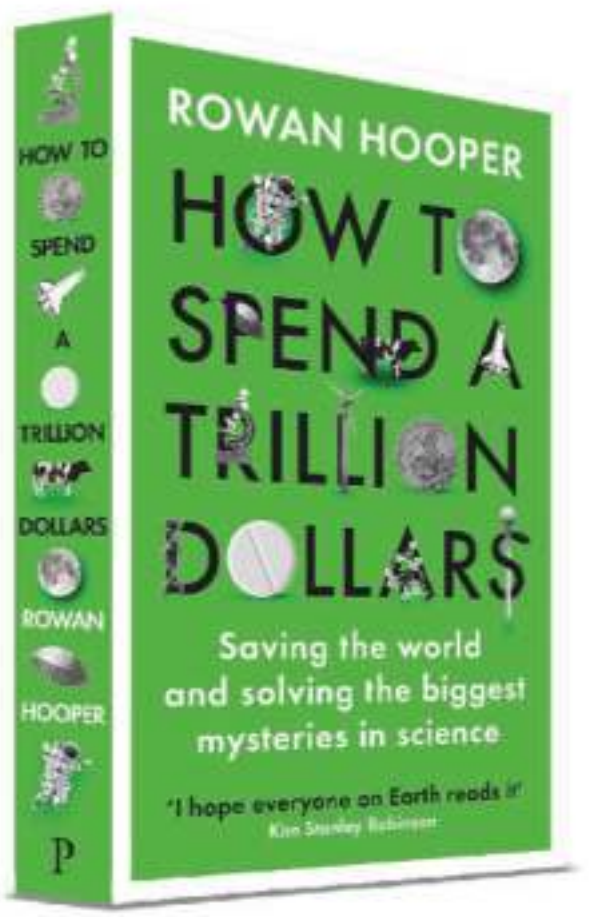
HOW TO SPEND A TRILLION DOLLARS

Saving the world and solving the biggest mysteries in science.

If you had a trillion dollars and a year to spend it for the advancement of science, what would you put it towards? Eradicating poverty, solving climate change, curing all disease – or something else entirely?

"Will someone just give Rowan Hooper a mere trillion dollars and let him, very sensibly, save the world?" Caitlin Moran

This book is the ultimate thought experiment, but also a call to arms, showing how much good humanity could achieve if we put our minds – and our money – to it.



Plus, a wide selection of books, limited-edition jigsaw puzzles, face masks and more!

shop.newscientist.com

worldwide shipping available

Views

Comment

What's in a name?

The names given to new coronavirus variants and bacteria have become too confusing, but there is a better way, says **Mark Pallen**

SOME names for microbes, like *Salmonella*, trip off the tongue. Others, like *Myxococcus llanfairpwllgwyngyll-gogerychwyrndrobwllllantysilio-gogogochensis*, aren't so easy to say. Labels for coronavirus variants fall somewhere between these two extremes, with code names like 20I/501Y.V1, B.1.429 or CAL.20C that allow coronavirus researchers to talk to peers, but leave the rest of us tongue-tied. As a result, most people find it easier to use geographical names, like the "South African variant" or the "Kent variant", which may not be accurate and unfairly places blame on the people in those locations. Can we do better?

For naming living things, we tend to use a system created in the 18th century by Swedish naturalist Carl Linnaeus, which gives each species a two-word Latin name. Examples include the name *Homo sapiens* for humans and *Escherichia coli* for a common gut bacterium. Use of a dead language nicely brings neutrality and gravitas to the process.

But, despite the millions of bacterial species out there, so far only around 20,000 have been given Latin names. This deficit is getting worse thanks to the boom in DNA sequencing, which has revealed thousands of new species in the human gut alone.

Faced with the flood of new species, most microbiologists don't have the time to come up with well-formed Latin names. Instead, they use alphanumerical placeholders such as UBA6965 or sp000063525 that are just as bad as coronavirus code names in terms of usability.

MICHELLE D'URBANO

So, how are we to cope with the need for new names, whether for bacteria or viruses? Perhaps we can learn from the way storms are named. Authorities agree on a set of arbitrary forenames each year, like Francis, which are dished out in alphabetical order for each new storm.

Last year, working with a nomenclature expert and a programmer, I hit on a similar idea for bacteria. Instead of naming each organism as it is discovered, we could create a bank of names in advance and make that available to microbiologists who discover microbes.

Although new names are conventionally handcrafted, to generate enough of them, we could automate the process using a computer program to combine word roots from Latin and Ancient Greek to create linguistically correct names.

Names for bacterial genera are typically built from two or three such roots strung together in a row. So, in naming a bacterium found in, say, chicken faeces, one might string together roots for "chicken-faeces-microbe" to create *Cottocaccomonas*.

A breakthrough came when I realised that one could apply a combinatorial approach to this problem, so 10 terms for "chicken or bird", 10 terms for "gut or faeces" and 10 terms for "microbe" used in all possible combinations could generate a thousand new names for microbes. Raiding Latin and Greek dictionaries to feed our program paid off handsomely with the creation of over a million new names for bacteria.

Which brings us back to the challenge of naming coronavirus variants. Here, I think we can follow the storm-naming approach even more closely and create a bank of names that say nothing about the properties of the variant and are unambiguous and easy-to-use.

To add gravitas, neutrality and an air of familiarity, one could raid the classical world for personal names of mythological or historical characters and then mix and match components to create an abundance of options. I am not sure whether that is going to fly with all the relevant stakeholders. But one thing is certain: we need to find a way around this problem as soon as we can and put an end to the blame game. ▮

Mark Pallen is a professor of microbial genomics at the University of East Anglia, UK

Field notes from space-time

Cosmic conflict

There is a mismatch between two ways of measuring galactic mass. Dark matter is one way to solve it, but so is rewriting the laws of gravity, writes **Chanda Prescod-Weinstein**

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

I'VE been giving a lot of talks about my research to a range of scientific audiences of late. The listeners range from groups that are mainly undergraduates to those made up of specialists in my field – in other words, people who are also searching for and trying to understand the behaviour of dark matter.

In nearly all of these presentations, I start by explaining Vera Rubin and Kent Ford's observations of galaxies. These showed that there was a mismatch between their measurements of galactic masses and what one might expect the mass to be based on how many stars are in the galaxies. I then make an explicit effort to note that there are two ways to address this inconsistency: there is either more matter than we can see in these galaxies, or we are interpreting the evidence in the wrong way – in short, that our theory of gravity is wrong.

It soon becomes obvious that, for the rest of the talk, I'm going to focus on the idea that there is more matter in galaxies and that this is comprised of so-called dark matter. But I do try to make an effort to highlight that modified gravity – revisions to our theory of gravity which would explain the mismatched data – is also an active field of research.

To better understand why these ideas arise at all, it is useful to spend more time understanding the first compelling evidence that there was a problem in need of a solution in the first place.

Specifically, Rubin and Ford found that stars were orbiting the centres of their galactic homes faster than we would expect based on how massive the galaxies are presumed to be, if we are just counting stars and adding their masses together.

At the time, astronomers measured a galaxy's mass through a combination of observations. First, they looked at the typical brightness of stars in their galaxy and used this to estimate how massive each star is. This is possible because the brightness tells us how much fuel the star has, which correlates directly with its mass. Then, by adding the masses of all of the stars together, astronomers came to an approximation for how massive the galaxy is.

By contrast, Rubin used an instrument developed by Ford to test an alternative mechanism for calculating a galaxy's mass. Looking at the speeds of stars and their distance from the centre of their galaxies, then combining them in an equation from Newtonian physics related to gravity, one can calculate mass too. By the way, that equation is one that in the US we teach to first year undergraduates – and even high school students.

"We have a problem: two ways of gauging galactic mass, based on different parts of physics, provide different answers"

However, we have a problem: these ways of measuring galactic mass, based on different parts of physics, give different answers.

Israeli physicist Mordehai Milgrom first proposed "modified Newtonian dynamics" (MOND) in the early 1980s in order to address the observational data of Rubin and Ford. He suggested that perhaps the velocities and radius were simply going into the wrong equation. How strong is his case?

There is of course precedent for thinking Newtonian gravity is wrong: we already know that in some scenarios, Albert Einstein's relativity must be used instead.

However, nearly 40 years later, the hypothesis that there is dark matter in galaxies – a type of stuff that we can't see – remains a far more popular solution to the inconsistency. The existence of dark matter was first proposed by astronomer Fritz Zwicky in the 1930s, with the idea gaining credence through the later work of Rubin and Ford.

This idea's current dominance is partly because observations made in recent decades are better explained by models of dark matter than by MOND. The most famous example is the Bullet Cluster, a set of galaxy clusters that are colliding. Observations of this are more consistent with the presence of dark matter than with a modified gravity model.

In addition, more recently, observations of the cosmic microwave background (CMB) radiation have become our strongest evidence for the existence of dark matter.

The CMB is a form of radiation that pervades all of the universe with an ambient temperature of about 2.73 kelvin (-270.4°C). It has tiny fluctuations in it on different scales that are imprints of an earlier time, when the universe wasn't transparent to light. To make our models of the CMB fit the data, we have to take dark matter into account. MOND simply isn't as successful at doing that.

For this reason, my talks proceed on the premise that we are talking about a dark matter problem. But we still haven't directly detected dark matter, and that means MOND remains – to some researchers – a compelling area of further work. It isn't an area that I work on, but I'm glad others are doing so. ▮

Chanda's week

What I'm reading
My book The Disordered Cosmos *launches in the US in the middle of March, so I'm actually looking at this a lot to make sure I haven't forgotten anything.*

What I'm watching
Well, the first season of The Real Housewives of Salt Lake City *was quite a journey.*

What I'm working on
I'm focused on the secrets of neutron stars.

This column appears monthly. Up next week: Graham Lawton

New Scientist Discovery Tours

Italy | 8 days | 1 November 2021

The science of the Renaissance

Encounter the great scientific minds and discoveries of the Renaissance on a cultural adventure across the pre-eminent cities of science - Florence, Pisa and Bologna. Led by art and architecture expert Andrew Spira and accompanied by scientific historian Professor David Wootton.

From astronomic, anatomic, architectural, medical and mathematic perspectives, the tour will look at the wondrous collections, buildings and churches that demonstrate the burgeoning of knowledge of the period whilst enjoying these beautiful cities.

Combined with the fascinating stories of polymath's such as Da Vinci and Galileo, to a wealth of lesser known Renaissance scientists and artists, who along with the patronage of families such as the Medici's, helped cement Italy's role at the forefront of scientific endeavour during this period.

Highlights

- Walking orientation tour of Florence. When in each city, most of the exploration will be done on foot without the need for coaches. We think it's a more enriching way to understand and appreciate the cities.
- Get to know the historic town of Pisa with full day of exploration including the Museo degli Strumenti per il Calcolo (Museum of Calculation Devices) that covers various scientific fields including astronomy, electromagnetism, optics, mechanics, electronics, and acoustics from the 17th century onwards.
- Time to explore the UNESCO World Heritage Site Piazza dei Miracoli with its Cathedral where Galileo is believed to have formulated his theory about the movement of pendulums by watching the swinging of an incense lamp.
- Visit the La Specola Museum of Natural History, the Tribune of Galileo and the Museo degli Argenti at the Pitti Palace in Florence.
- Explore the austere Basilica di Santa Croce, the largest Franciscan church in the world, where illustrious Italians such as Galileo, Michelangelo and Machiavelli are buried.
- Marvel in the splendour of the the Museo dell'Opera del Duomo (Cathedral Museum) a transformative experience due to the amazing housing of the Cathedrals treasures including works by Michelangelo, Brunelleschi and the original Gates of Paradise.
- Walking orientation tour around one of Italy's most under-rated but beautiful cities, Bologna, exploring the jumble of atmospheric streets leading to magnificent Renaissance period palazzis.
- While in Bologna, visit to the Cathedral of San Petronio which houses a 'hidden-in-plane-sight' solar observatory
- Go 'off the beaten track' to see the Museum of Communication

Covid-19 safety protocol includes:

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

In partnership with Travel Editions

For more information visit newscientist.com/tours

Editor's pick

Saving nature is down to every single one of us

20 February, p 34

From John Cantellow, Derby, UK

Thank you for your comprehensive article "A rescue plan for nature". The focus was biodiversity loss, but it could equally have been on climate change or pollution. These are all symptoms of the problem of our consumption, compounded by a growing population.

While the focus remains on the symptoms and we wait for others, such as governments, scientists and economists, to solve them, we shall continue to pour fuel on the problem. Only the poorest limit their consumption to their needs, while the rest of us enjoy satisfying our wants. It isn't someone else's problem to solve, it is my problem and it is your problem too – it is our problem to solve. And solve it we must, before we destroy the only planet capable of sustaining us.

I applaud UK's approach to coronavirus vaccines

6 February, p 12

From Dave Ketteridge, Hatfield, South Yorkshire, UK

Despite calls to put global interests above national interests when it comes to coronavirus vaccines, we should wave a flag for the UK's approach.

While it is well ahead in terms of vaccine supply compared with many countries thanks to its bilateral deals, it is giving £548 million to the COVAX programme to assist lower-income countries. Meanwhile, the UK's Oxford/AstraZeneca consortium is providing doses of its vaccine on a not-for-profit basis until the pandemic is under control.

The UK's early orders for vaccines enormously helped producers to have the confidence to expand their programmes, even though products weren't approved at the time – quite a gamble by the UK. No doubt any spare doses will go to other parts of the globe.

Don't eat fish on the grounds of suffering

13 February, p 36

From John Theophilus, Milkwall, Gloucestershire, UK

Graham Lawton wrote a typically interesting analysis of the environmental and sustainability issues around his decision to abstain from eating animals and birds but eat fish (largely for minimum environmental impact).

I also aim to minimise damaging the planet while trying to lead a fairly normal life. I, too, haven't gone down the path of veganism, preferring a smidgen of animal protein in my diet. But I have abandoned fish on animal husbandry grounds.

There is a long-standing cultural belief that sentience and ability to suffer decline in the order fur, feather, fin. Standard "acceptable" harvesting processes have evolved to suit. I keep reading of research indicating that fish are at least as sentient as birds and as liable to distress and pain. Viewed through this lens, "normal" fishing practices look barbaric.

I wouldn't eat chickens that had been killed by being swept up in a net and left hanging there until they suffocated. I suspect most people wouldn't either.

I get animal protein from tiny portions of animals and birds humanely and sustainably farmed and killed. I use these to flavour much larger portions of vegetables. Bon appetite!

From Marc Smith-Evans, Bagabag, Philippines

Lawton's article paints a dire picture, but offers few solutions. The contents section of the following issue shows a photo of an offshore wind farm above that of a fishmongers display. The connection between those two images is notable.

In the 1990s, I spent three years investigating the regeneration of fisheries by placing artificial reefs in areas where fishing is banned. The general conclusion was that this would generate fish stocks that migrate into fishing areas.

It seems a no-brainer to not only make offshore wind farms no-take areas, but to deploy artificial reefs there to provide structures that allow fish to feed, breed and thrive.

Just one planet will do for an alien megastructure

Letters, 20 February

From Robin Pratt, Glasgow, UK

Craig Hutton writes that to build a Dyson sphere, a civilisation would have to raid a vast number of star systems for materials.

However, according to my rudimentary maths, just one small planet may do the job. Mercury is almost entirely made of metal. If you flattened it into a sheet and then made it into a sphere around our sun at Mercury's orbital distance, then the resulting foil would be around 85 times as thick as the foil in my kitchen.

I wonder what any civilisation would do with such a vast power source. If you tap a star's entire output, it is enough to move whole planets. Two possibilities come to mind: a game of intergalactic snooker or... a death star.

Electric vehicles are a gain even without a green grid

Letters, 6 February

From Hazel Russman, London, UK

Nick Baker makes a good point about the carbon footprint of electric vehicles in the absence of sufficient renewable electricity. However, anything that reduces carbon emissions can be considered green(ish).

Steam-powered electricity generators are far more efficient converters of chemical energy into mechanical energy than the internal combustion engine, so the switch to batteries in cars reduces emissions even when the energy to charge them is produced by gas-fired power stations. It also eliminates non-carbon exhaust emissions, such as NOx and particulates. The efficiency becomes even greater if waste heat from the power station is used for district heating, thus reducing emissions from domestic boilers.

If carbon capture and storage ever becomes widespread, it will work on power stations, not cars.

Could conflict explain the mystery of Stonehenge?

20 February, p 16

From Martin Jenkins, London, UK

It is suggested that Stonehenge may be a Welsh stone circle that was transferred to Salisbury plain. However, the researchers overlook one explanation for why this may have happened: that the Salisbury plain people were successful in a war with the people of the Preseli hills in Wales and decided to mark their victory by stealing the Preseli ritual centre. This would also explain why Preseli people were interred at Stonehenge: they were forced by the victors to do the work of moving the stone circle, and in some cases this killed them.

Try two swats if you really want to get a fly

Letters, 13 February

From James Goding, Melbourne, Australia

Following up on readers' tips for beating pesky flies. If you swat a fly simultaneously from two different directions, its on-board computer experiences data overload and the fly remains fixed to the spot.

Want to get in touch?

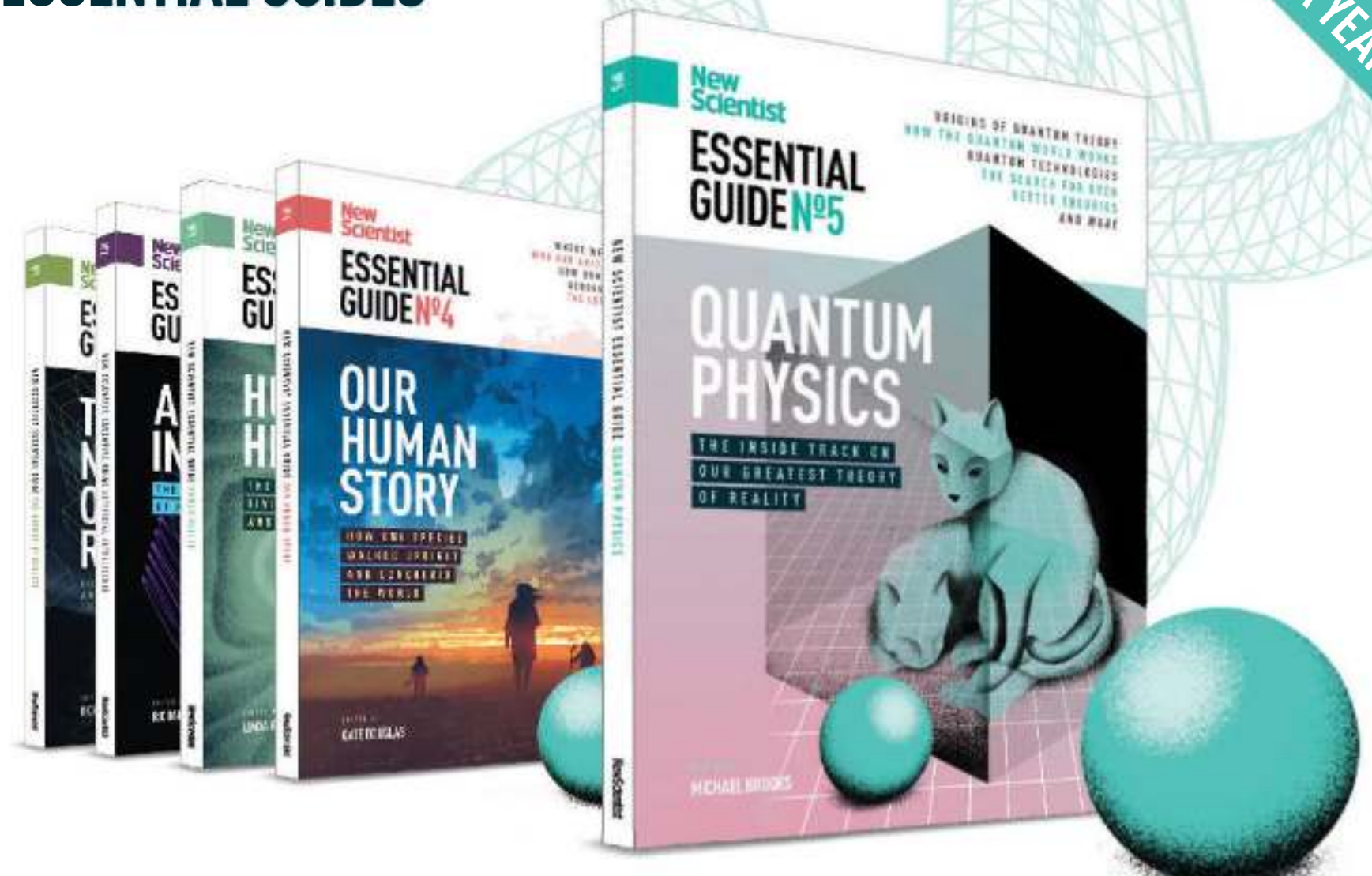
Send letters to letters@newscientist.com; see terms at newscientist.com/letters

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

For the record

Researcher Haruka Osaki at Kyushu University in Japan is female (20 February, p 17).

NewScientist
ESSENTIAL GUIDES



SUBSCRIBE FOR ONLY $65 A YEAR

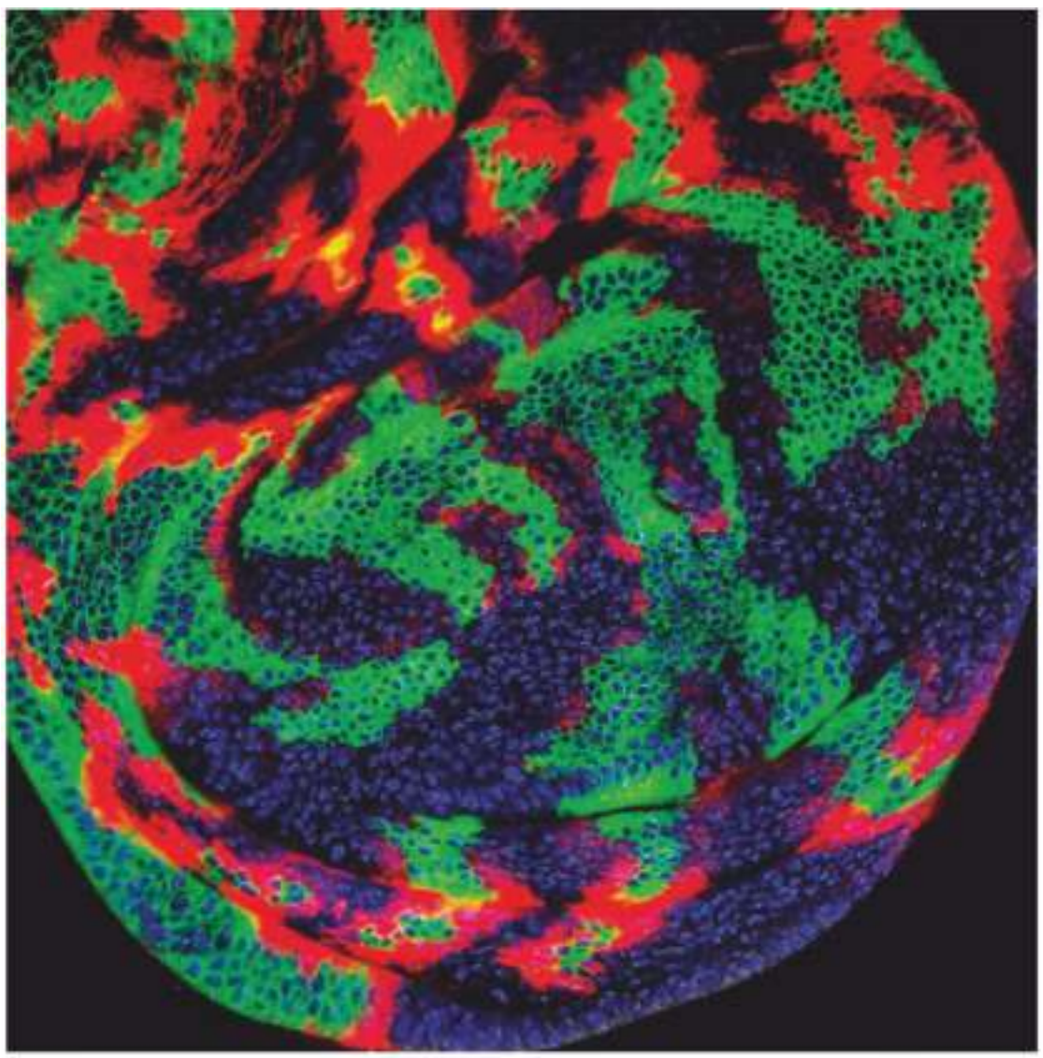
NEW SCIENTIST ESSENTIAL GUIDES
DELIVERED DIRECT TO YOUR DOOR

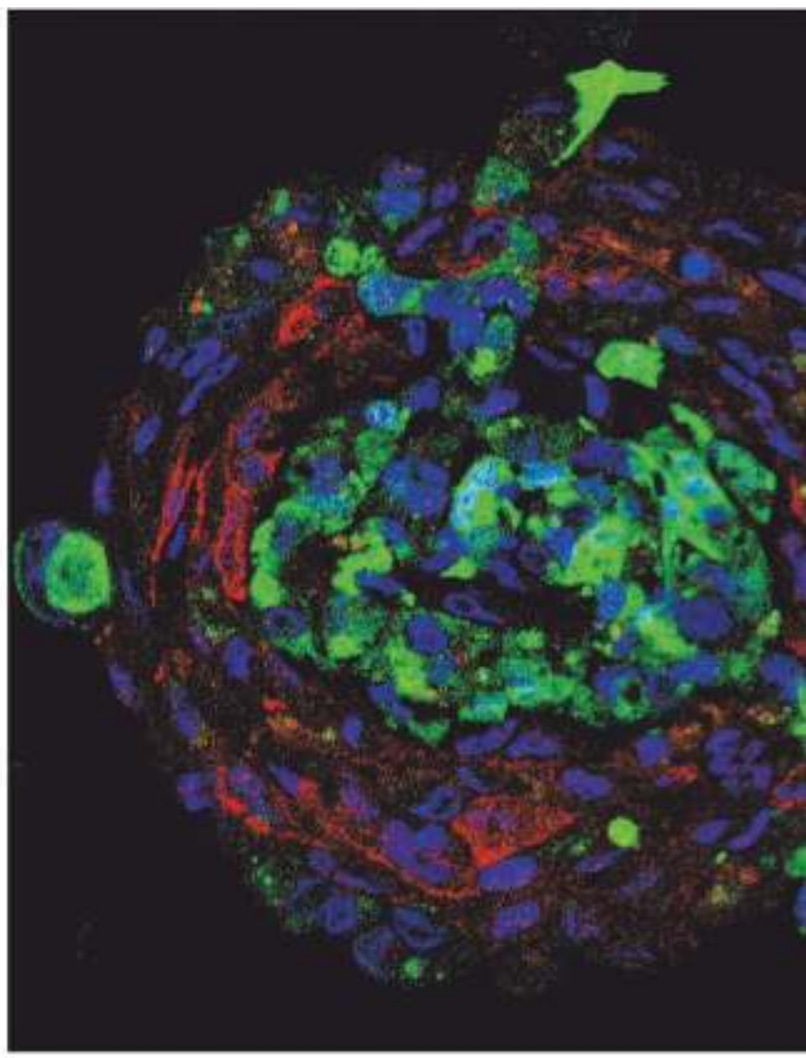
Based on the best coverage from *New Scientist*, the *Essential Guides* are comprehensive, need-to-know compendiums covering the most exciting themes in science and technology today.

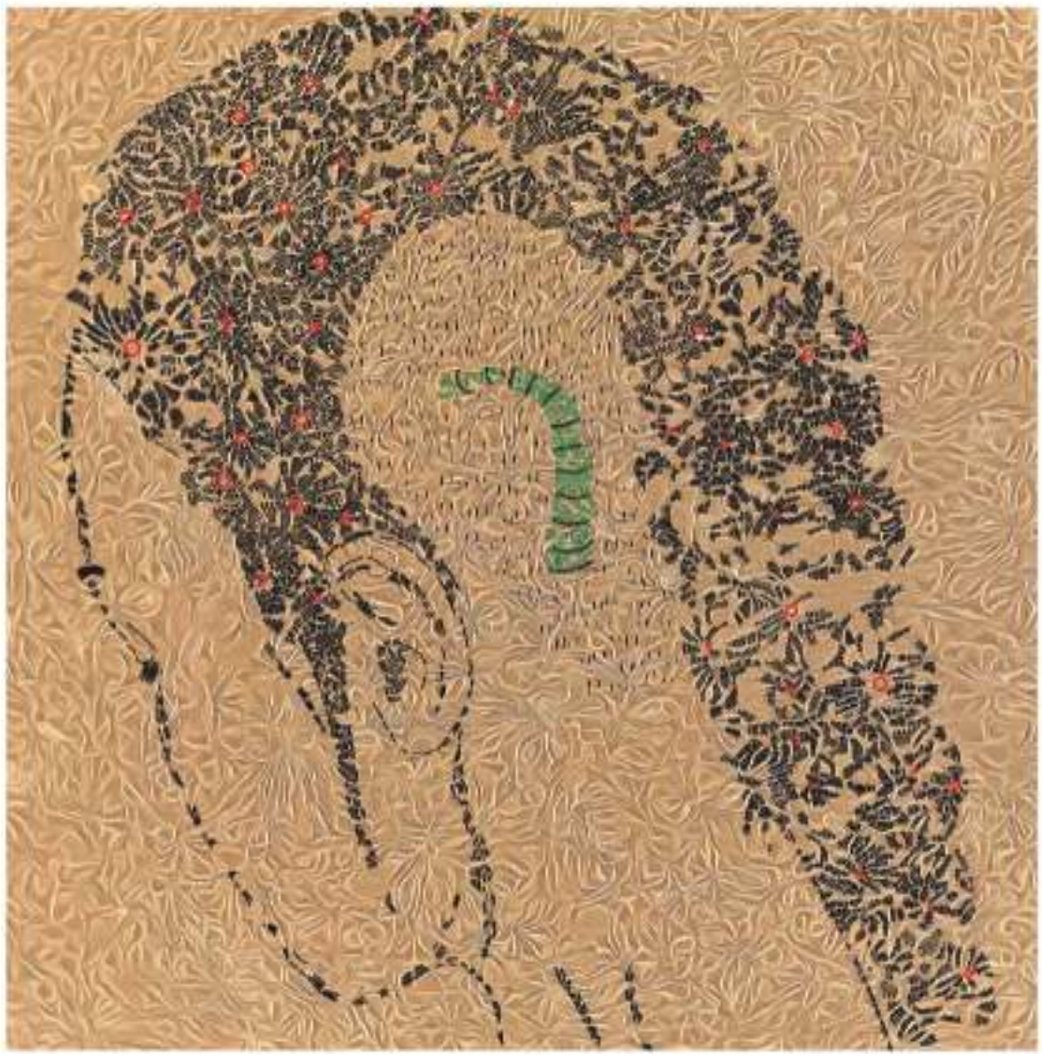
Get the series, including the recently published issue on Quantum Physics, with an *Essential Guides* subscription. It means you don't have to search for issues in the shops – we can deliver them direct to your door.

FOR MORE INFORMATION ON FUTURE ISSUES AND SUBSCRIPTION OFFERS, VISIT:

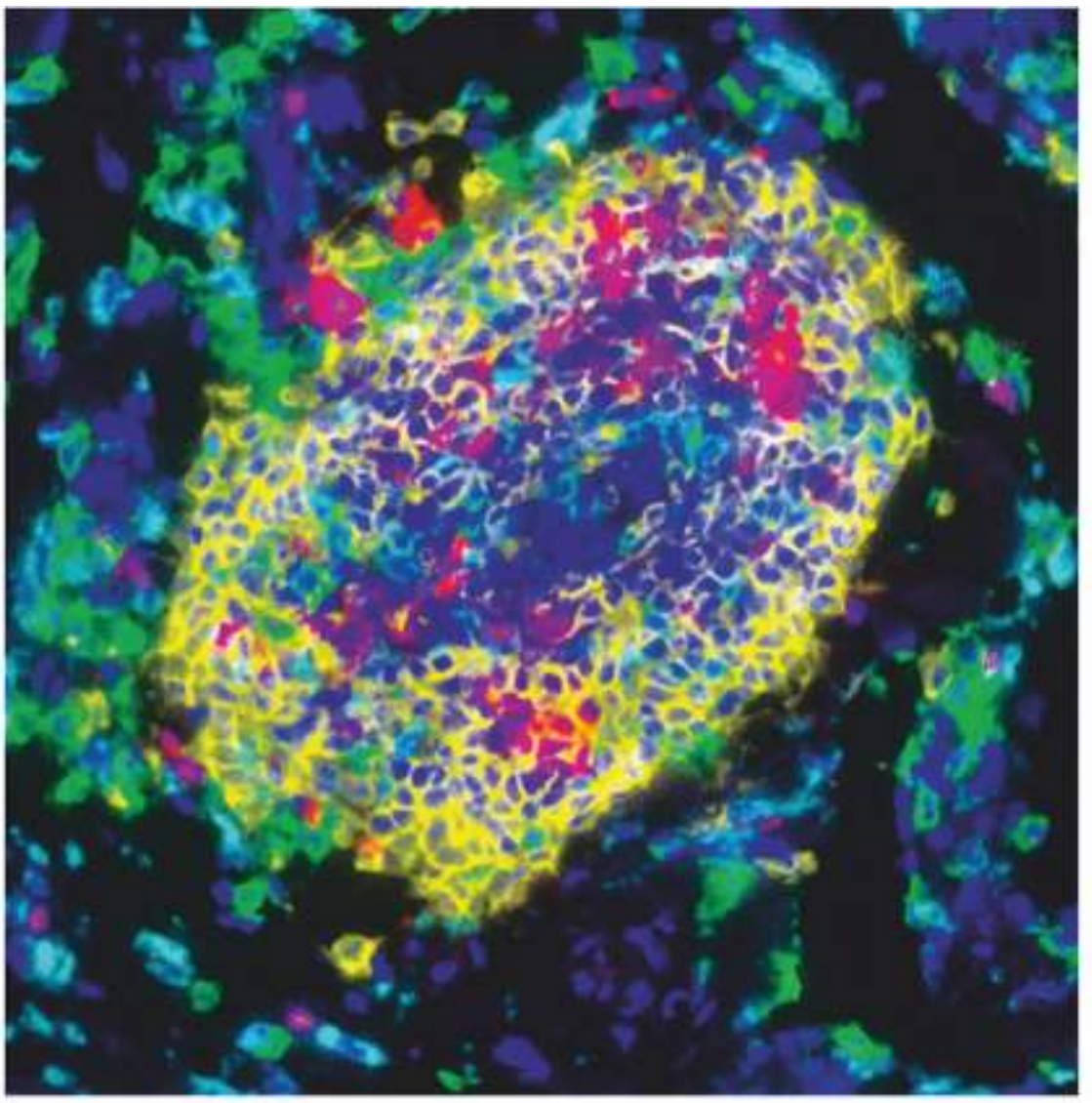
NEWSCIENTIST.COM/ESSENTIALGUIDE

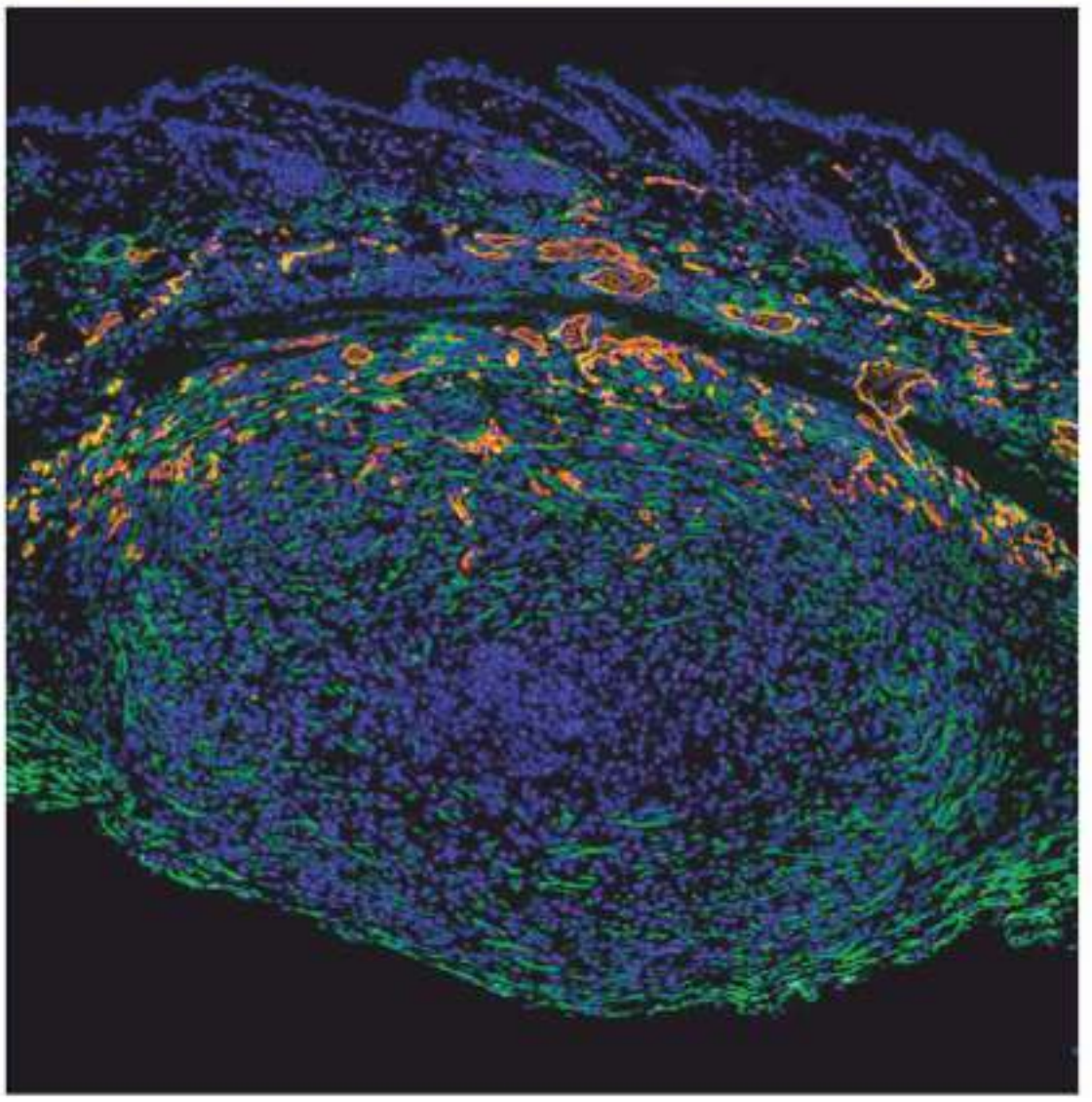






L-R CLOCKWISE: DR MARTA FORES MARESMA; DR STELLA MAN; DAVID MANSFIELD; SARAH ASH; SUMANA SHRESTHA





Strange beauty

Institute of Cancer Research's Science and Medical Imaging Competition: shortlisted images

THESE striking images show the intricate and unexpected beauty of cancer research. All were taken by people working at the Institute of Cancer Research (ICR), London, and the Royal Marsden Hospital, London. They are shortlisted for the ICR's annual Science and Medical Imaging Competition.

Far left, top, is Marta Forés Maresma's image of larval-stage tissue of a fruit fly, an organism used to study cancer and tumours. Fluorescent confocal microscopy was used to detect proteins in cells that glow red or green, a method that can help in studying cell interaction in cancer.

Top centre is Stella Man's image of a soft tissue sarcoma tumour spheroid – a ball of cancer cells.

David Mansfield's entry, top right, shows a protein-detecting technique to highlight cells – here, in a lymphoid structure that can occur in cancer. The method uses antibodies attached to molecules that either fluoresce or catalyse reactions that make colours.

Below right is an image by Sarah Ash of a breast cancer tumour in a mouse, using nearby connective tissue cells to help it spread.

Next are flower-like structures (bottom centre) captured by Sumana Shrestha. These are stem cells involved in brain formation, and they can be used to explore the origins of brain cancers. Her other submission (far left, bottom) uses images of stem cells shaded in to create the shape of a head with a cancer surgical scar.

You can vote for your favourite entry on the ICR website. Winners will be named in early March.

Gege Li

Game of Thrones meets Brexit

Just as we are totally reliant on technology to survive lockdowns, *Tribes of Europa* shows us a violent, divided world without it, says **Anne Marie Conlon**

TV

Tribes of Europa

Written by Philip Koch

Netflix, from 19 February

WHAT would it take to completely destroy our society, and how quickly would things decline? In Netflix's series *Tribes of Europa*, the world as we know it has collapsed in a mere 45 years, following a catastrophe in 2029.

Writer Philip Koch was inspired to write about the dissolution of Europe following the Brexit vote, and today's viewers don't have to look very far to see how much the world can change in a short space of time.

Set in 2074, *Tribes of Europa* doesn't give us a full explanation for just how its post-apocalyptic world came to be, but alludes to a mysterious collapse of technology known as "Black December" that led what one of the characters describes as "lights off and darkness. And that was it. Middle Ages."

The series was produced by the German team behind the Oscar-winning *The Lives of Others*, and Netflix's first original German series, *Dark*. In this latest dystopian future, the world is divided into a number of distinct factions, or tribes, as referenced in the title.

We follow three young siblings – Kiano, Liv and Elja – from the forest-dwelling Origine tribe, whose peaceful existence is disrupted when an advanced aircraft is shot from the sky above their village.

Visiting the crash site, they quickly realise that this isn't technology from "the old world", but something more modern. The ship's ailing pilot reveals himself to be from the Atlantian tribe (the only one apparently unaffected by the technology blackout) and he hands a mysterious cube to the young Elja.

The cube holds an important message about coming danger, and Elja is entrusted to bring it to the pilot's homeland to help them make sense of it. Lured by the promise of answers to his questions about what happened with Black December, Elja agrees, but it puts him in danger because the violent Crows tribe is also seeking the cube as a key to power, and they will kill anyone who gets in their way.

As the lives of the Origines are threatened, Elja's elder siblings are caught in the crossfire, setting them off on separate paths. Kiano and his father are captured by the Crows, while Liv escapes and tries to find her family by bargaining with another tribe, the militaristic Crimsons, who also turn out. to be seeking the cube's power

The idea of people vying for control of a mysterious powerful object isn't hugely original, and we aren't given many unexpected plot twists in the first three episodes, but some fantastic world-building and hints of bigger, more exciting puzzles to solve make this a big-budget production that seems well worth sticking with.

"Fantastic world-building and hints of bigger puzzles make this seem well worth sticking with"

Halfway through the series, plenty of questions remain. How extensive was the historic technology blackout, and why are the otherwise villainous Crows somehow unable to lie?

Having a group of siblings pursuing separate quests in a hyper-violent world evokes *Game of Thrones*, and the show matches it in cinematic scope, with production designer Julian R. Wagner referencing *Blade Runner* and *Children of Men*, and creating an epic, gritty feel, especially when it comes to the cut-throat world of the Crows.

It might be a very apt time to release a Brexit-inspired show about the collapse of society. Not only are the effects of the UK's exit from the European Union starting to become clear, but we are now also living in the shadow of a world-changing pandemic and leaning on technology more than we could ever have imagined.

As social distancing means a constant reliance on video calls, streaming and instant messaging to maintain even a fragile sense of normality, *Tribes of Europa* brings us the prospect of a truly nightmarish future – a world without technology.

Elja, one of three siblings, is caught up in a world of danger in *Tribes of Europa*

NETFLIX

Polluted discourse

Fake news and conspiracy theories create a kind of pollution – and we should treat it as such, finds **Simon Ings**

Book

You Are Here
Whitney Phillips and Ryan M. Milner
MIT Press

PACIFIC PRESS/LIGHTROCKET VIA GETTY IMAGES

The symbol of the QAnon far-right conspiracy theory

THIS is a book about pollution, not of the physical environment, but of our civic discourse. It concerns disinformation (false, misleading information deliberately spread), misinformation (false, misleading information inadvertently spread) and malinformation (information with a basis in reality spread specifically to cause harm).

Communications experts Whitney Phillips and Ryan Milner finished their book just before the election that replaced Donald Trump with Joe Biden. That election and the seditious activities that prompted Trump's second impeachment have clarified many of the issues the authors were at pains to explore. *You Are Here: A field guide for navigating polarized speech, conspiracy theories, and our polluted media landscape* is an invaluable guide to our problems around news, truth and fact.

The authors' US-centric – but globally applicable – account of "fake news" begins with the rise of the Ku Klux Klan. Its deliberately silly name, cartoonish robes and the routines that accompanied all its activities, from rallies to lynchings, prefigured the "only joking" subcultures of Pepe the Frog and the like that dominate social media.

Next, their examination of the 1980s Satanic panics reveals much about conspiracy theories. They also unpick QAnon, a far-right conspiracy theory alleging that a secret cabal of cannibalistic, Satan-worshipping paedophiles plotted against Trump. This pulls together their points in a way that is more troubling for being so closely argued.

Polluted information is, they say, a public health emergency. By treating the information sphere as a threatened ecology, the authors push past factionalism to reveal how, when we use media, "the everyday actions of everyone else feed into and are reinforced by the worst actions of the worst actors".

This is their most striking takeaway: the media landscape that enabled QAnon isn't a machine out of alignment, or out of control, or somehow infected, but "a system that damages so much because it works so well".

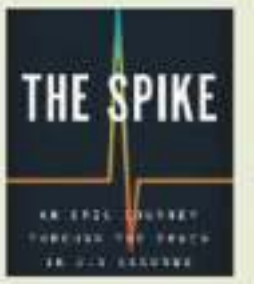
It is founded on principles that seem only laudable. Top of the list is the idea that to counter harms, we must call attention to them: "in other words, that light disinfects". This is fine as long as light is hard to generate. But what happens when that light – the confluence of competing information sets, depicting competing realities – becomes blinding?

Take Google. The authors characterise it as an advertising platform that makes more money the more people use it. The deeper down the rabbit holes our searches go, the more Google and others earn, incentivising promulgators of conspiracy theories to produce content, creating "alternative media echo-systems". When facts run out, create more. Media algorithms don't care: they are designed to serve up as much as possible of what Phillips and Milner call pollution.

The authors bemoan the way memes, rumours and conspiracy theories have swallowed political discourse. They teeter on the edge of a more important truth: that our moral discourse has been swallowed too. *You Are Here* comes dangerously close to saying that social media has made whining cowards of us all.

So what is to be done? The authors' call for "foundational, systematic, top-to-bottom change" is mere floundering. It has taken the environmental movement decades to work out mechanisms to address the climate emergency. Nothing in *You Are Here* suggests the media emergency will be less intractable.

Don't miss



Read

The Spike is computational neuroscientist Mark Humphries's vivid tale of the epic 2.1-second journey taken by a single electrical impulse as it propagates through the billions of neurons of a human brain.

Watch

Boss Level, a new film streaming on Hulu from 5 March, stars Frank Grillo, Naomi Watts and Mel Gibson in a not entirely serious sci-fi shoot-em-up involving a dastardly government project, time loops and a race to save tomorrow.

Read

Under the Blue, by debut novelist Oana Aristide, sees speculation about artificial intelligence collide with the story of an artist fleeing a global plague: a startling, intellectual, post-covid adventure.

MIDDLE: HULU

The TV column

Once more, with feeling

For All Mankind, an alternative space race story, returns with the cold war raging. NASA is under pressure to militarise the moon, politicking is everywhere and small acts of defiance are as good as it gets, says **Bethan Ackerley**

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

APPLE TV

Molly Cobb (played by Sonya Walger) faces some tough choices

EARLY in the second season of *For All Mankind*, Ronald D. Moore's counterfactual take on the space race, astronaut Molly Cobb is faced with an impossible decision: let a friend die on the lunar surface as a massive solar storm hits, or rescue him and risk getting a fatal dose of radiation. Viewers know Cobb has beaten tougher odds before, but as she is forced to choose, you fear that she is living in a world that no longer rewards heroics.

The show's alternative history began with one key change: in this universe, the US was beaten to the moon by the Soviet Union in 1969. The rivalry between the nations grew and accelerated progress in space, with NASA sending women to the moon in the early 1970s and establishing a base, Jamestown, there in 1973.

After a slow start, the first season did a terrific job of conveying the importance of space travel, while killing off astronauts left and right to show what a grim endeavour it can be. All the same, despite the thrills, it felt a little soulless at times.

When the second series begins, after a jump to 1983, life on Earth doesn't look too rosy. In its version of world events, Ronald Reagan became president earlier than he really did and superpower relations curdled, prompting yet more resources to be poured into space exploration. History fans should comb through the opening montage to catch all the ways this drama diverges from the real timeline: the Camp David Accords that brought peace between Israel and Egypt, the Three Mile Island nuclear accident and the Iran hostage crisis among them.

> **"Politicking threatens to scupper plans for an astronaut and a cosmonaut to shake hands while in orbit"**

In this version of the 1980s, the moon is just another front of the cold war. Up to 30 astronauts at a time now live at Jamestown while looking for lithium at Shackleton crater, but the Russians edge ever closer to US mining operations. On Earth, the Johnson Space Center's director Margo Madison and other NASA officials are under pressure to militarise the moon. Politicking even threatens to scupper plans for an astronaut and a cosmonaut to shake hands while in orbit, the lone gesture of peace in a world on the brink of annihilation.

For All Mankind is hardly the most nuanced take on the US-Soviet relationship – aside from a few scenes between Madison, astronaut Danielle Poole and their Russian counterparts, almost no common ground is acknowledged between the nations. Yet the cold war setting has made the show a leaner, darker beast.

Underdeveloped characters like Ed Baldwin, the sour-faced, square-jawed lead, have fewer but better things to do this time around. Ed, for instance, is now unhappily settled in his role as head of the astronaut office, sartorially muzzled by milquetoast sweaters and clearly longing for adventure.

And despite the streamlining, key plot threads from last season aren't left dangling. Take Poole's decision to break her own arm to hide a fellow astronaut's declining mental health. Though she was the first African-American person in space, Poole's "accident" gave NASA an excuse to sideline her – like the few other black astronauts.

As the season progresses, it is clear the astronauts and the NASA team are at the mercy of natural and geopolitical forces almost entirely outside their control – almost. It is in the small moments of defiance and sacrifice, whether that is staring down a solar storm or shaking an enemy's hand, that *For All Mankind* proves it has figured out what kind of show it wants to be. ▮

TV

For All Mankind
Created by Ronald D. Moore, Matt Wolpert and Ben Nedivi
Apple TV+

Bethan also recommends...

TV

Battlestar Galactica (2004-9) Ronald D. Moore
When human civilisation is decimated, survivors must travel the galaxy in search of a home. Moore's thoughtful series doesn't shy away from the grim practicalities of space exploration.

Film

The Martian
Ridley Scott
Stranded on Mars, astronaut Mark Watney goes to ingenious lengths to survive. A rare space blockbuster in terms of its homage to realism – or something close.

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 57 out Friday 5 March

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 56
How to spend a trillion dollars, landing on Mars, exercise and metabolism myths

Episode 55
Rescuing nature, Mars missions and new covid mutation

Episode 54
Next-gen vaccines, alien space probes and ethics of fish

Episode 53
Pandemic burnout, vaccines for the world and sustainable fuel

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

Listen on Apple Podcasts · Listen on Spotify · Google Podcasts · Stitcher

Friendship-ology

Why do some friendships last and others fade? Evolutionary psychologist **Robin Dunbar** reveals the hidden rules of our relationships and what your social style says about you

FACEBOOK users used to have a lot more friends. The social networking site pursues a commercial strategy of trying to persuade people to "friend" as many others as possible. However, sometime around 2007, users began to question who all these people they had befriended were. Then, someone pointed out that we can only manage around 150 relationships at any time. A flurry of "friend" culling followed and, since then, the number 150 has been known as "Dunbar's number". Thank you Facebook!

Modern technology may have brought me notoriety, but Dunbar's number is rooted in evolutionary biology. Although humans are a highly social species, juggling relationships isn't easy and, like other primates, the size of our social network is constrained by brain size. Two decades ago, my research revealed that this means we cannot meaningfully engage with more than about 150 others. No matter how gregarious you are, that is your limit. In this, we are all alike. However, more recent research on friendship has uncovered some fascinating individual differences.

My colleagues and I have made eye-opening discoveries about how much time people spend cultivating various members of their social networks, how friendships form and dissolve and what we are looking for in our friends. What has really surprised us is that each person has a unique "social fingerprint" – an idiosyncratic way in which they allocate their social effort. This pattern is quite impervious to who is in your friendship circle at any given time. It does, however, reveal quite a lot about your own identity – and could even be influencing how well you are coping with social restrictions during the covid-19 pandemic.

Layers of intimacy

The typical social circle of 150 people is made up of a series of layers, each containing a well-defined number of people and associated with specific frequencies of contact, levels of emotional closeness and willingness to provide help (see "The structure of friendship", page 38). In fact, our social world consists of two quite distinct sets of people: friends and family. What's more, we tend to give preference to the latter. With our social networks limited to around 150 relationships, we first slot in family members and then set about filling any spare places with unrelated friends. As a result, people who come from large families tend to have fewer friends.

Some years ago, I examined evidence from various cultures and economies to try to find out how much time we actually spend on social interactions with our friends and family. I found around half a dozen studies where researchers had recorded the amount of time in the day that people devoted to different activities, including things like sleeping, cooking, relaxing and interacting socially. This gave me a diverse selection of societies: Maasai pastoralists in East Africa, Nepalese hill farmers, New Guinea horticulturalists, agricultural tribes in sub-Saharan Africa, !Kung San hunter–gatherers from southern Africa and housewives in Dundee, UK. My analysis revealed that people spent around 20 per cent of their time, on average, on ›

ANĐELA JANKOVIĆ

social interactions. That's about 3.5 hours a day talking, eating and sitting with people in a social context.

This may seem like a lot, but distributed evenly among your 150 friends and family, it works out at just 1 minute and 45 seconds per person per day. Of course, that isn't what we do. Around 40 per cent of this social time is devoted to the five people in our innermost social circle, the support clique, with another 20 per cent given to the 10 additional people in the next layer, the sympathy group. That's about 17.5 minutes and 4.5 minutes per person, respectively. The remaining 135 people in the two outer rings of our social circles get an average of just 37 seconds a day each.

These interactions are often not face to face, of course. Throughout most of human evolution, people lived in the same village as their friends and family, but today our social circles are far more geographically dispersed. In social networks, there is a very strong effect called the 30-minute rule that dictates how long you are willing to travel to go to see someone. It doesn't matter much whether this is on foot, by bicycle or by car: it's the psychological significance of the time it takes you that counts. Surprisingly, though, research reveals that we are also more likely to phone or text friends if they live nearby. For example, one study found that the frequency of phone contact between friends declined gradually the further apart they lived, with a sharp drop-off at about 160 kilometres.

Subconsciously, we seem to be aware that failure to contact someone will weaken a relationship, so we make up for it. Analysing mobile phone records, Kunal Bhattacharya and Asim Ghosh at Aalto University, Finland, found a correlation between the length of the gap since the last call and the duration of the next call – for special friends, but not for weaker friendships. Indeed, humans aren't alone in making such subconscious calculations. I saw something similar in gelada baboons I was studying in Ethiopia. As their infants grew, mothers were forced to spend more time feeding, leaving less time to groom their main social partners – their best friends forever (BFFs). Instead, they relied on the friends to do all the work to keep the relationship going. However, once the infant had started to wean, they paid back the debt, devoting much more time to grooming the BFFs than the BFFs groomed them.

"We all spend about 20 per cent of our time, on average, on social interactions"

Oiling your contacts

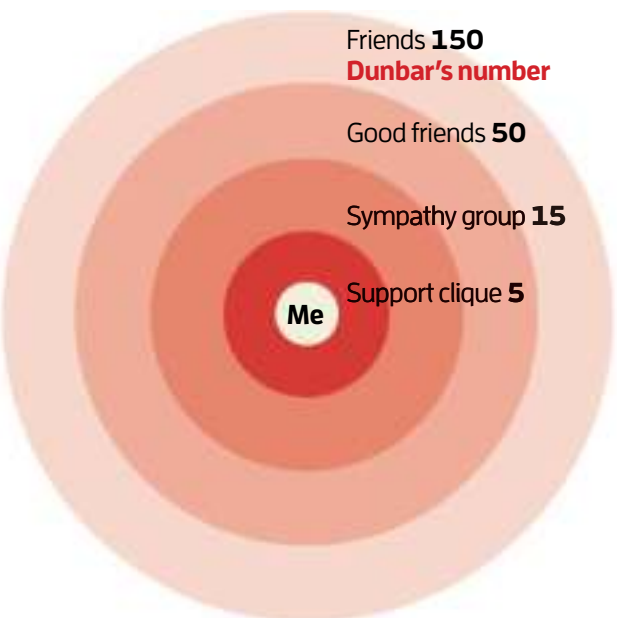
Such behaviours matter because friendships are fragile. Unlike family bonds, they depend on you investing enough time and effort in each other to keep the relationship well oiled and functional (see "Six rules for keeping your pals", page 40). If you see someone less often, whether deliberately or by force of circumstance, that relationship will weaken. Bob Kraut at Carnegie Mellon University in Pennsylvania calculated that a friendship of high strength will decline to no more than a mere acquaintanceship in just three years. To be fair, there are a few friendships that stand the test of time and absence: usually no more than three or four, and they tend to be people we were particularly close to in early adult life. However, until the internet, social media and mobile phones became widely available a mere decade ago, friendships would have died naturally if someone moved away.

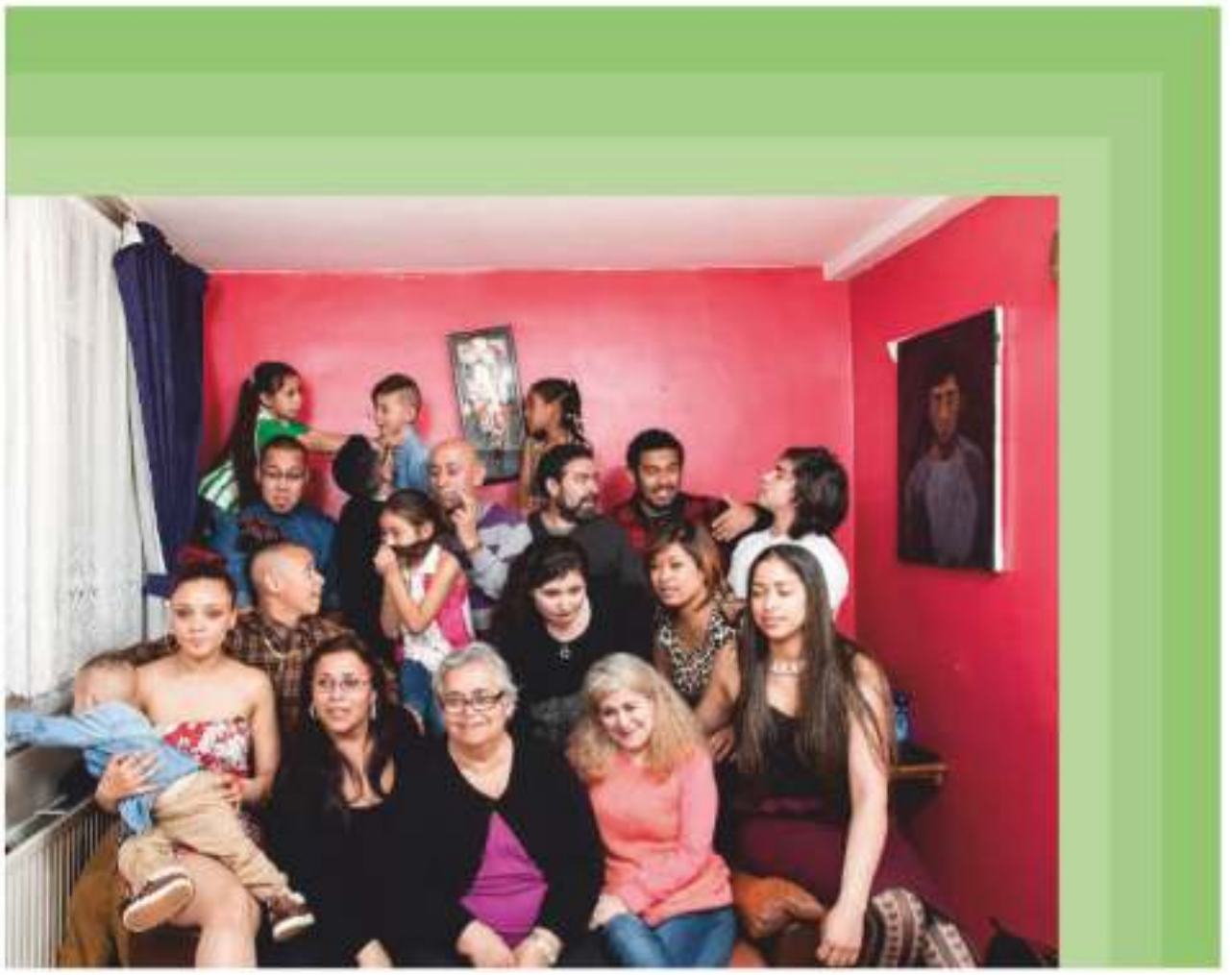
Is that changing? To take a closer look, Sam Roberts at the University of Chester, UK, and I studied a group of 30 students – half of them female, half male – to find out how moving away from home affected their social networks. We picked them up in their final term at school and monitored them through the following 18 months to the end of their first year at university. The deal was that we gave them a free mobile phone subscription in return for being able to download their monthly bills so we could see who they phoned and texted. They also had to fill in a questionnaire at the beginning, middle and end of the study telling us who everyone in their network was, how emotionally close they felt to each person, when they had last contacted them and how, and what they had done with them when they met face to face.

We collected huge quantities of information. (We were particularly impressed by three of the

The structure of friendship

We can only manage a maximum of 150 people in our social circle, and they fall into layers depending on their emotional closeness (all figures are cumulative)





CHRIS STEELE-PERKINS/MAGNUM PHOTOS

Our social circle includes family, so people with larger families tend to have fewer friends

students who sent an average of 100 texts a day – and kept this up for the entire duration of the study.) Luckily, I was collaborating at the time with some physicists on a project about online networks and persuaded a couple of them to help with the complicated task of analysing the data. We were amazed by what we found.

We could see the layers of the students' social circles very nicely. What we hadn't expected, however, was the fine detail in how individuals allocated their social effort. Each showed a distinct pattern in the frequency with which they called friends. One might call their best friend 30 times a month and their second best friend 10 times, while another would call their two top friends 20 times each, for example. But that wasn't the most surprising thing. There was an average of around 40 per cent turnover in network membership over the 18 months – which is fairly normal for young adults – yet, when we looked at the patterns of contact before and after a change in friendship, they were almost identical. It seems that when we replace someone in our social network, we slot the new friend into exactly the same position the old one previously occupied in terms of the frequency with which we contact them. Our study had revealed that people have a characteristic social fingerprint.

"Our study had revealed that people have a unique social fingerprint"

How often you contact each of your friends probably reflects aspects of your personality, such as extraversion, neuroticism and conscientiousness. Our analysis revealed another factor influencing your social fingerprint: whether you are male or female. Over the course of the study, some friendships held up better than others, and we wondered why. The answer tended to differ between the sexes. For the girls as a whole, the activity most effective in preserving a pre-university friendship was talking together, whether in person or by phone. For the boys, talking had absolutely no effect on how likely a friendship was to survive. What made the difference was doing stuff together more often than they had before – going to the pub, playing sports, climbing mountains or whatever. Such activities also had a positive effect on the girls' friendships, but it was nowhere near as great.

Calling patterns

This could have implications for how well our friendships are bearing up during the pandemic, while face-to-face meetings are restricted. It might also help explain a difference we found in the amount of time girls and boys spent on the phone. Of course, there were big individual variations, but for girls, calls averaged 150 seconds in the morning, rising to 500 seconds by the end of the day. Boys' calls, by contrast, averaged just 100 seconds throughout the day.

Further analysis, led by Talayeh Aledavood at Aalto University, revealed another aspect of our identity with an influence on our social fingerprint. When we looked at the times at which our students were calling and texting, they found clear differences. Some were most active on their phones during the day and others used them mostly at night. We also ›

Six rules for keeping your pals

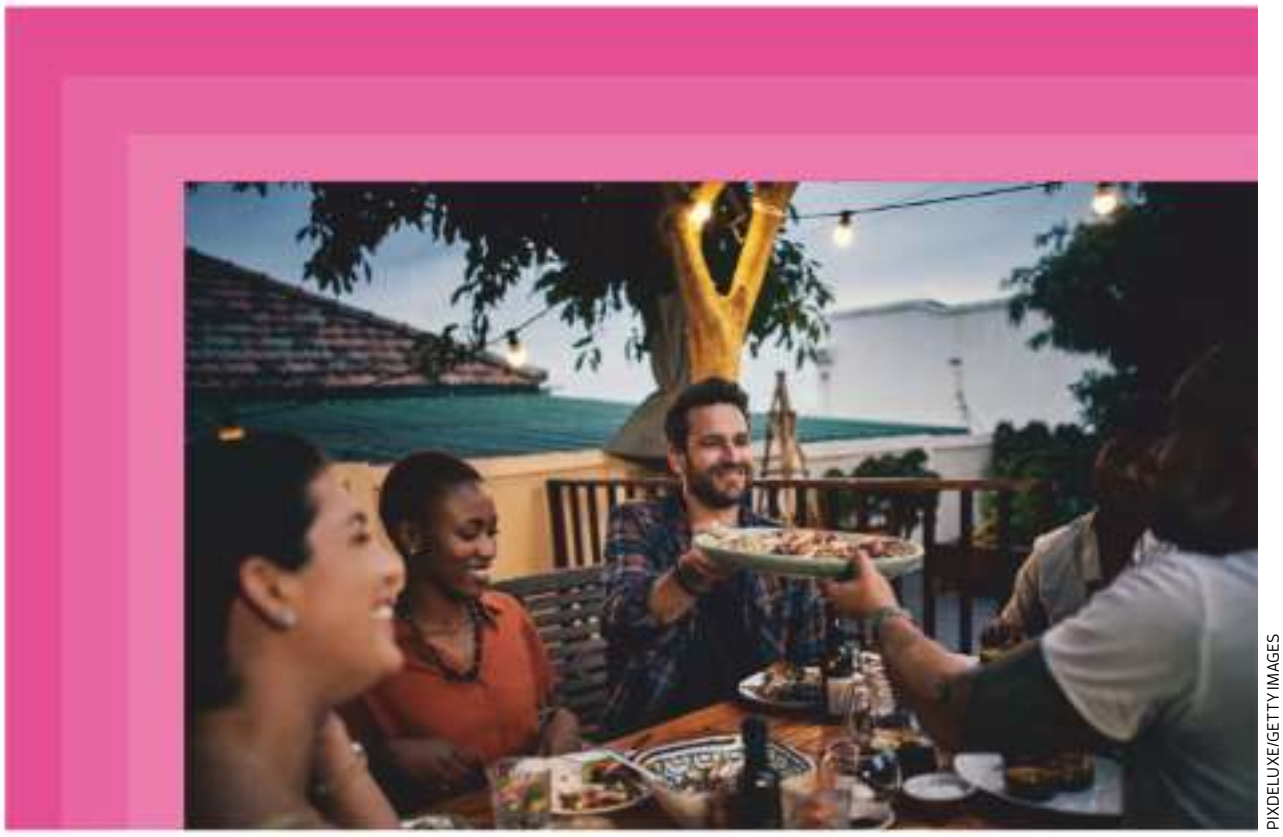
Friends come and go for all sorts of reasons, but if you want to keep a friendship alive, you must obey these six rules:

1. Stand up for friends in their absence
2. Share important news
3. Provide emotional support when it is needed
4. Trust and confide in one another
5. Volunteer to help when a friend needs you
6. Try to make your friends happy

Seven pillars of friendship

Our friends tend to be surprisingly like us, and there are certain personal characteristics that predict how close a friendship is likely to be:

1. You speak the same language or, better still, dialect
2. You grew up in the same area
3. You have the same educational and career experiences
4. You pursue the same hobbies and interests
5. You see eye to eye on moral, religious and political matters
6. You share a sense of humour
7. You have the same taste in music



PIXDELUXE/GETTY IMAGES

The 30-minute rule dictates how long we are prepared to travel to see friends

found that those who were early birds, or larks, at the start of the study were still larks 18 months later, and the night owls at the start were still owls at the end – despite the turnover in their friends. That may not be so surprising, but being a lark or an owl turns out to have big implications for your social network.

Aledavood discovered this when she and her colleagues analysed a similar data set of 1000 Danish university students. Being a much larger group, it allowed them to look at the relative frequencies of communication of larks and owls in more detail. Some 20 per cent of the students were committed larks, the same proportion were committed owls and the rest were neither one nor the other. Larks showed no particular preference for having larks as friends, but owls favoured associating with owls, strongly reinforcing research showing that what we most want in a friend is someone just like us (see "Seven pillars of friendship", left). Owls also had larger social networks than larks, at least in terms of the number of people they phoned frequently – 35 rather than 28. However, they spent less time on the phone to each friend – 94 seconds compared with 112 seconds, on average, for larks – so their networks weren't as well integrated and reinforced. Again, restrictions to our social lives caused by covid-19 may be proving more disruptive to some friendships than others.

I hadn't anticipated quite how much we would learn from scrutinising the mobile phone bills of students. I was surprised to find that everyone appears to have their own unique social fingerprint, and intrigued to discover that aspects of an individual's social style influence their friendship choices. What was most unexpected, however, is the durability of a person's social fingerprint in the face of change. It is as though exactly who our friends are doesn't really matter, as long as we have friends. Of course, we opt for people who are as congenial as possible, but, provided these boxes are ticked, more or less anyone will do. That may sound opportunistic or even callous, but it makes sense. Friendship isn't just for fun; it has huge benefits for our mental and physical well-being. In a changing world, our approach to making and maintaining friends needs to be both flexible and stable so that we can optimise those benefits. ▮

Robin Dunbar is at the University of Oxford. This is an edited extract from his new book *Friends*, published by Little, Brown on 4 March 2021

Spillover

The covid-19 pandemic was precipitated by our disruption of natural ecosystems. But how exactly, asks **Adam Vaughan**

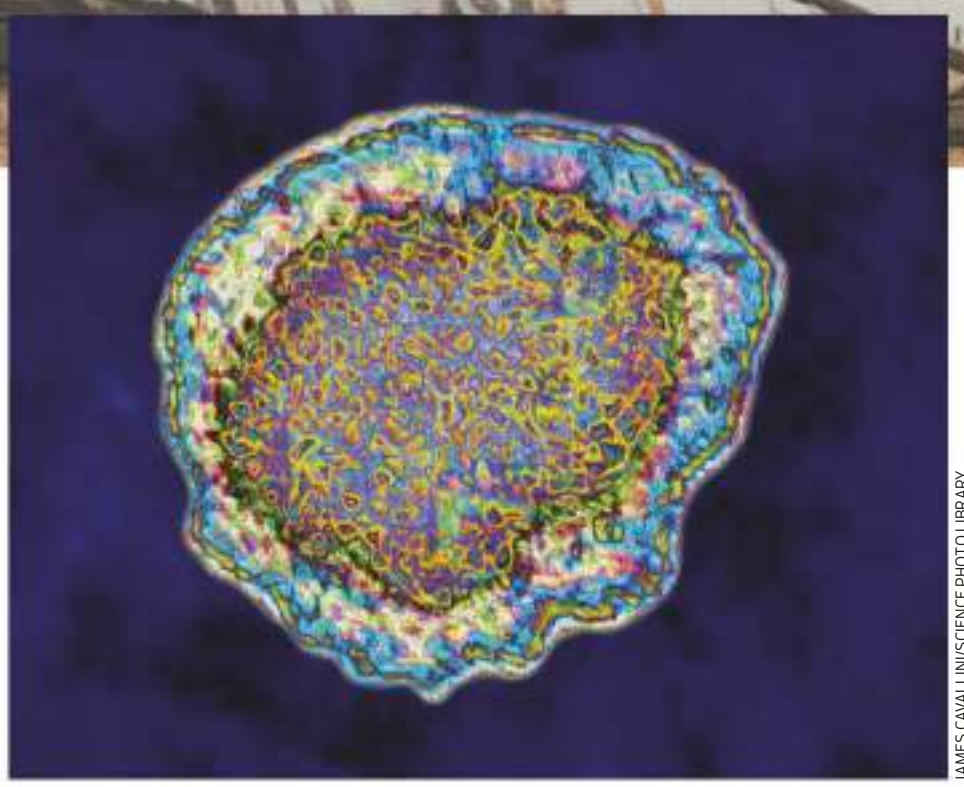
RELEASED from quarantine in a hotel in Wuhan, China, this January, Peter Daszak made for the wildlife market linked to the first cases of a mystery pneumonia in the closing days of 2019. Back then, the Huanan seafood market was a jostling scrum of stalls selling not just seafood, but all manner of domestic and exotic wild animals, the living cheek by jowl with the dead.

It is now an empty shell, closed since the first cluster of cases of what morphed into the covid-19 pandemic. Daszak, a zoologist, visited earlier this year as a member of the World Health Organization-backed team sent to investigate the origins of the virus causing that illness, SARS-CoV-2, and assess what role the now-infamous market might have played.

No one yet knows, and hypotheses will take years to test. But it is clear that the Huanan outbreak was just a symptom of a sickness, not a cause of it. For two decades, evidence has been building of the link between how we encroach on, degrade and exploit the natural world and the risk of "zoonoses" – animal diseases that spill over into humans.

Some of those links are still fuzzy, and there are competing views on how important each is. "It's big and complex, and there are quite a lot of unknowns," says Christian Walzer at the Wildlife Conservation Society in New York. But we know enough to say one thing: if we don't act on what we have already learned, the costs to human health and wealth of pandemics ›

SELMAN HOŞGÖR



JAMES CAVALLINI/SCIENCE PHOTO LIBRARY

The deadly Nipah virus jumped from bats to pigs to humans in 1998

such as covid-19 will just keep on recurring.

That certainty comes not least because we do now know that a lot of candidate diseases are out there. "The last 15 years has seen a real explosion in the understanding of how many potential pathogens there are," says Walzer. A UN biodiversity panel report last year estimated that there are 1.7 million undiscovered viruses in animals. Not all will acquire the traits they need to infect us (see "How diseases jump to humans", right). But about five new infectious diseases in people are identified every year, and 70 per cent of emerging diseases are caused by microbes of animal origin.

One major factor driving these developments is the growing human population and rising living standards. Both of these fuel our need for land, and so our encroachments into nature's habitats. Every new road or mine, or area of forest cleared for agriculture, increases the chance that people come into contact with species carrying potential spillover diseases. "We have these edges of destruction, the disturbed areas, often only several hundred metres in. You trap for food, hunt, you collect firewood, you may be driving livestock in," says Walzer. "You're creating this interface, and that does increase the contact rate." In that sense, the increasing risk of zoonoses is essentially just a numbers game.

According to research by Daszak, who works at the EcoHealth Alliance in New York, and his colleagues, highly biodiverse tropical regions, where land use is often changing rapidly, are hotspots for emerging zoonotic diseases.

About this feature

This feature is the second in a series of five produced in association with the United Nations Environment Programme and UNEP partner agency GRID-Arendal. *New Scientist* retains full editorial control over, and responsibility for, the content. Part three of the series next week will look at how developing a rescue plan for nature post-covid-19 means developing a rescue plan for the people who depend on it

The most frequent spillover occurs around people's homes and fields. For some diseases, we know in some detail how our activities helped it occur. One of the best described instances is the Nipah virus. Its jump from bats to pigs to people in 1998 followed years of the intensification of pig farming and deforestation in Malaysia that increased the interface between the species. There is still no vaccine for Nipah, which kills up to 75 per cent of people it infects. Another example is the Hendra virus in Australia, where deforestation is linked to bats carrying the virus reaching people and horses. SARS-CoV-2, originally also thought to have arisen in a bat, may one day be added to the list.

The growing interface with other animals created by our expanding cities, farms and extractive industries is just one aspect of the story, however. Another, perhaps even more important one, is how human encroachment is changing the composition of ecosystems. "It's this idea of how habitat degradation is leading to sick landscapes," says David Redding at the Zoological Society of London.

Disturbed habitats

Case studies suggest that as we disturb habitats, we alter the community of animals in ways that increase disease risk. Take Lyme disease, which is carried by ticks found across the northern hemisphere. As forests become degraded, they support fewer larger-bodied species that are better at removing ticks, while smaller tick-friendly species such as rodents thrive. More hosts means more ticks to bite us, and more risk of the disease spreading.

Despite such compelling evidence, Redding was initially sceptical that the sick-landscape hypothesis was generally applicable. But last year, he and his colleagues examined data on disturbed and undisturbed ecosystems across the world, gathered as part of a project looking at emerging diseases called PREDICT. What they found dispelled his doubts: disturbed landscapes such as cities and plantations that have replaced natural forest have both a higher proportion of disease-carrying species and greater

GERRY ELLIS/NATUREPL

How diseases jump to humans

The pathogens other animals host include bacteria, viruses, fungi and other assorted parasites. They can spread to humans by direct contact, for example by eating the animal.

Often, though, another host plays the role of an intermediary. Genetic analysis has suggested – although it remains far from certain – that SARS-CoV-2, the virus behind the covid-19 pandemic, may have spread to humans from an original bat host via anteater-like animals called pangolins.

These intermediate hosts can provide an opportunity for a potential pathogen to acquire the genetic traits it needs to infect people. The closest known relative to SARS-CoV-2, a coronavirus designated RaTG13 that infects the *Rhinolophus affinis* horseshoe bat, doesn't appear to have a spike protein suited to bind to human receptors.

If a virus does spread to a human, the danger comes when it successfully replicates in them. Fortunately, most animal viruses can't do this. To have the potential to unleash an epidemic, a pathogen must acquire the ability to transmit from human to human, which is what SARS-CoV-2 did.

Finally, once it has the ability to replicate in humans, a pathogen can evolve, as SARS-CoV-2 has with its new variants – or as HIV (human immunodeficiency virus) did, eventually becoming, as its name suggests, a human-only virus.

numbers of them too.

Redding hasn't yet been able to quantify what that means for the risk of people becoming infected. Kimberly Fornace at the London School of Hygiene & Tropical Medicine is involved in one effort to find out, using GPS collars on macaques and GPS tracking on human volunteers to map the emergence of a zoonotic malaria in Malaysian Borneo.

"We've found exposure to infected mosquitoes is often higher at forest edges, where mosquito, macaque and human habitats overlap," she says.

But we should be wary of a simplistic idea that biodiverse habitats are a hotbed of pathogens all waiting to jump to us. "The problem is that story doesn't wash, it's wrong," says Felicia Keesing at Bard College in Annandale, New York. "It assumes all the elements of biodiversity are equally dangerous to us. They are not."

Five groups of animals are the most likely to carry zoonotic diseases that spill over into humans, says Keesing. They are rats, bats, primates, carnivores such as cats and dogs, and cloven-hoofed animals such as sheep, goats, cows and camels. Camels were the source of infection for the coronavirus behind Middle East respiratory syndrome, or MERS, which has seen sporadic outbreaks since its first appearance in 2012.

Why it is these five groups is still being explored. With primates, it is probably because they are close relatives to us and the same pathogens can more easily infect us. For carnivores and hoofed animals, it may be due to our proximity to them. With rats and bats, it could partly be because of their large number.

Blaming any one animal or group of animals for a zoonosis can be difficult. Take bats, often mentioned as the ultimate source of SARS-CoV-2. "You've been told a story about bats being the most dangerous group," says Keesing. Although another virus in horseshoe bats is 96 per cent identical to SARS-CoV-2's genome, the missing 4 per cent is a reminder that the "vast majority of pathogens come from lots of hosts". More often than not, a pathogen has passed through, and mutated in, more than one animal before it arrives in ›

"More often than not, a pathogen has passed through more than one animal"

XIAO SHIBAI/WILD WONDERS OF CHINA/NATUREPL

STR/EPA/SHUTTERSTOCK

Left: the Chinese pangolin (*Manis pentadactyla*) may have helped transfer the SARS-CoV-2 virus to humans. Right: a Middle East respiratory syndrome (MERS) clinic in Malaysia in 2014

Market sources

It would be hard to create a better breeding ground for diseases to jump from animals to humans than live animal markets. Coronaviruses in particular are good at recombination, in which two viruses infect the same living cell and obtain new genetic material from each other. This helps them leap from species to species. Keeping live animals close together in cages, some ill, stressed and shedding more pathogens as a result, and excreting and sneezing on each other, increases the likelihood of this.

"Wild animal markets, with wildlife brought in from across the region and often globally, are just an inherent risk," says Christian Walzer at the Wildlife Conservation Society. "It's just silly to do that nowadays. What we've created with these markets is super interfaces."

The trade routes to the markets also contribute. The wildlife trade in China readily mixes legally and illegally captured and traded animals, both farmed and wild-caught. "Viruses exploit this pathway very well, as they did with SARS, and probably with covid," says Peter Daszak at the EcoHealth Alliance.

Slow, long, cramped transport of live animals along trade routes seems to be high risk. Daszak and his colleagues found no coronaviruses in wild pangolins in Malaysia over a decade. But the identification of viruses in trafficked pangolins that are similar to the SARS-CoV-2 virus that causes covid-19 suggests that recombination of bat and other mammal viruses could have happened over months of transport, says Daszak. Similarly, a higher prevalence of coronaviruses has been found among bamboo rats in Vietnamese markets – at the end of trade routes – than in the farms where they are raised.

The exact route of SARS-CoV-2 to Wuhan in China isn't yet known. "The most likely scenario for the emergence of covid-19 is a person involved in the wildlife trade got infected by bats in rural China and spread the disease through their social network in the wildlife trade, into the Huanan seafood market in Wuhan," Daszak said before the World Health Organization's recent mission to China. "Or perhaps it got into one of these farmed wildlife species and moved through the trade network in animals." In an update on 9 February, the WHO team said it was likely that the virus spread from a bat via an intermediary animal to people. But that intermediary is unknown and, so far, no wildlife in China has tested positive for SARS-CoV-2.

Regardless of the details of this virus's origins, addressing wildlife markets and trade routes, and the way animals are farmed or captured, is an effective way of reducing the likelihood of future pandemics. China and Vietnam have committed to a permanent ban of the wildlife trade and markets, but conservationists fear the problem may just get displaced to other countries.

Millions of people worldwide also rely on bushmeat for sustenance, including Indigenous peoples, and their rights and needs must be protected, says Walzer. One solution might be a ban on commercial trade focused in large cities where eating wildlife is a luxury and doesn't constitute a nutritional necessity.

AMILIA ROSO/THE SYDNEY MORNING HERALD VIA GETTY IMAGES

The Satria bird market in Denpasar on Bali, Indonesia, pictured in May 2020

ARTUR DEBAT/GETTY IMAGES

humans. Different species coming together, sometimes because of humans, is where disease risk often shoots up.

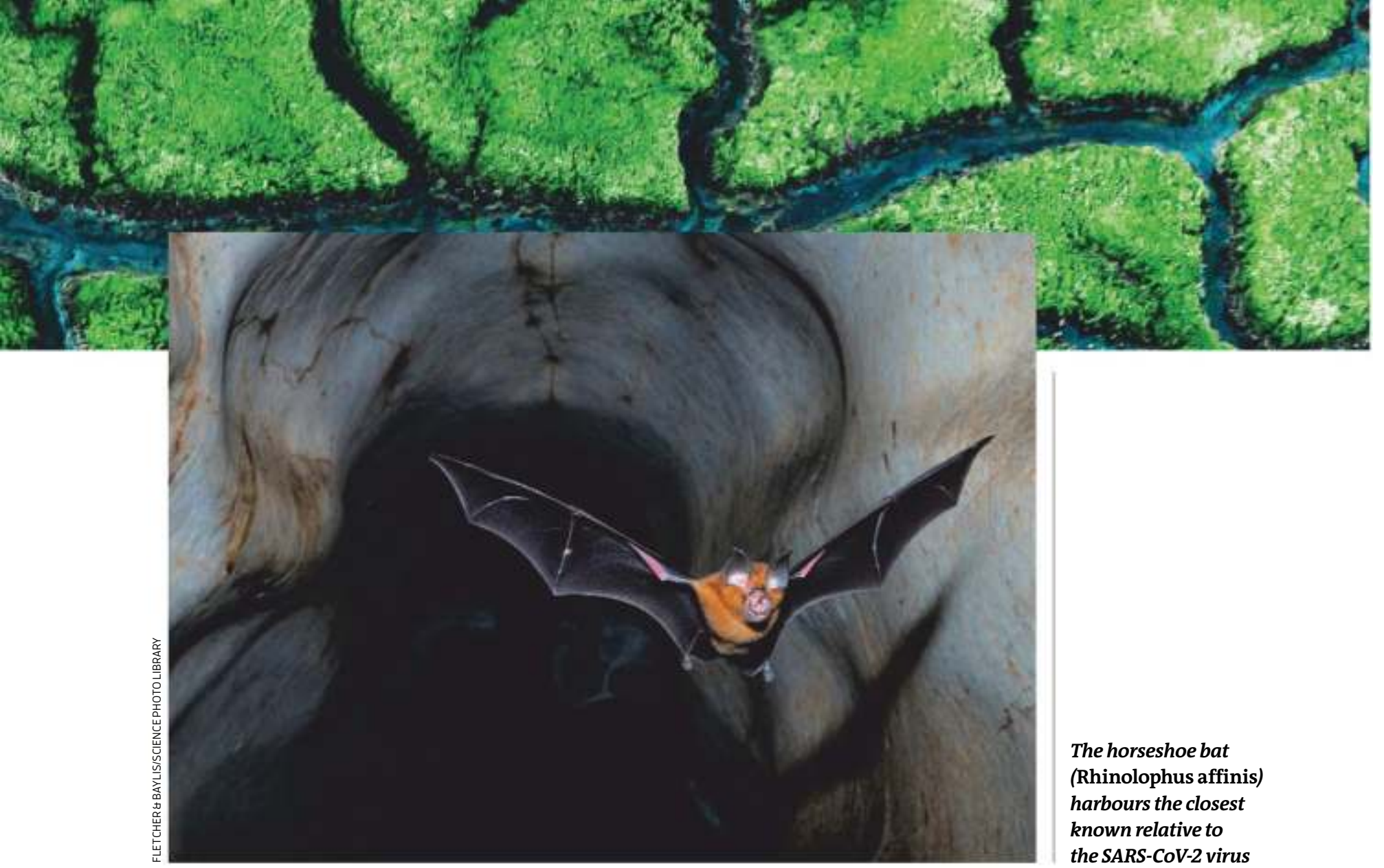
The coronavirus SARS-CoV-1, which caused the 2002-04 severe acute respiratory syndrome (SARS) outbreak, illustrates her point. The virus has been traced back to cave-dwelling horseshoe bats, but there is no direct evidence of transmission from bats to humans. One possibility, uncovered by a team of researchers including Daszak in 2017, is that masked palm civets at a wildlife market in Guangdong, China, provided an intermediary.

Sick business

The stories of SARS-CoV-1 and SARS-CoV-2 suggest that it isn't just our encroachment into nature's space that increases the risk of zoonosis, but how we increasingly trade in and transport wildlife over large distances (see "Market sources", left). Better regulation of the legal international trade in animals would help stem the risk of pandemics, says John Scanlon, the former head of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Secretariat, which oversees that trade. He is calling for amendments to the CITES treaty, which came into force in 1975, that build animal health into its decision-making, as well as a new global agreement to tackle the illegal trade. "Spillover can happen in any country, and to succeed we need to take a global approach," says Scanlon, now at the End Wildlife Crime initiative.

It isn't as if any of these things are new. In the wake of the SARS outbreak, conservationists and health experts drew up the "Manhattan Principles", a list of 12 recommendations for preventing future zoonotic epidemics, based on the realisation that the health of humans, other animals and ecosystems are interrelated. Walzer was part of a team that in 2019 began updating those principles, in an effort that just predated covid-19. "Although the wording of the principles might seem prescient, this pandemic was predicted and largely inevitable, and will happen again if decisive actions are not taken," they write in the resulting paper, which has just been published.

If there is any silver lining to the covid-19



FLETCHER & BAYLIS/SCIENCE PHOTO LIBRARY

*The horseshoe bat (*Rhinolophus affinis*) harbours the closest known relative to the SARS-CoV-2 virus*

pandemic, it might be that we learn to take seriously the idea that humans aren't apart from the natural environment, but a part of it, says Steve Unwin at the University of Birmingham, UK. He is a veterinarian who works with wildlife regularly infected by pathogens from humans. "We often put humans at the end of a chain, but we are part of a web of spillover. Pathogens don't know directions," he says. That is well understood in scientific circles, but we will only get better at reducing the risk of pandemics if this realisation spreads to governments, too, he says.

Beyond that, we need to fundamentally rethink our interactions with animals and how we are changing their habitats.

"The covid-19 pandemic was inevitable and will happen again if decisive actions aren't taken to protect nature"

"Nature is unpredictable. We tend to get very narrow – you know, we've got to stop SARS-CoV-3," says Redding. "But actually, we've got to think broadly about how we interact with animals and how we disturb landscapes." His research suggests that misplaced responses to the covid-19 pandemic – such as a backlash against bats that led to their culling – would simply disturb environments and make matters worse. A simple positive step, however, would be to stop our removal of predators that check the numbers of disease-carrying species such as rodents.

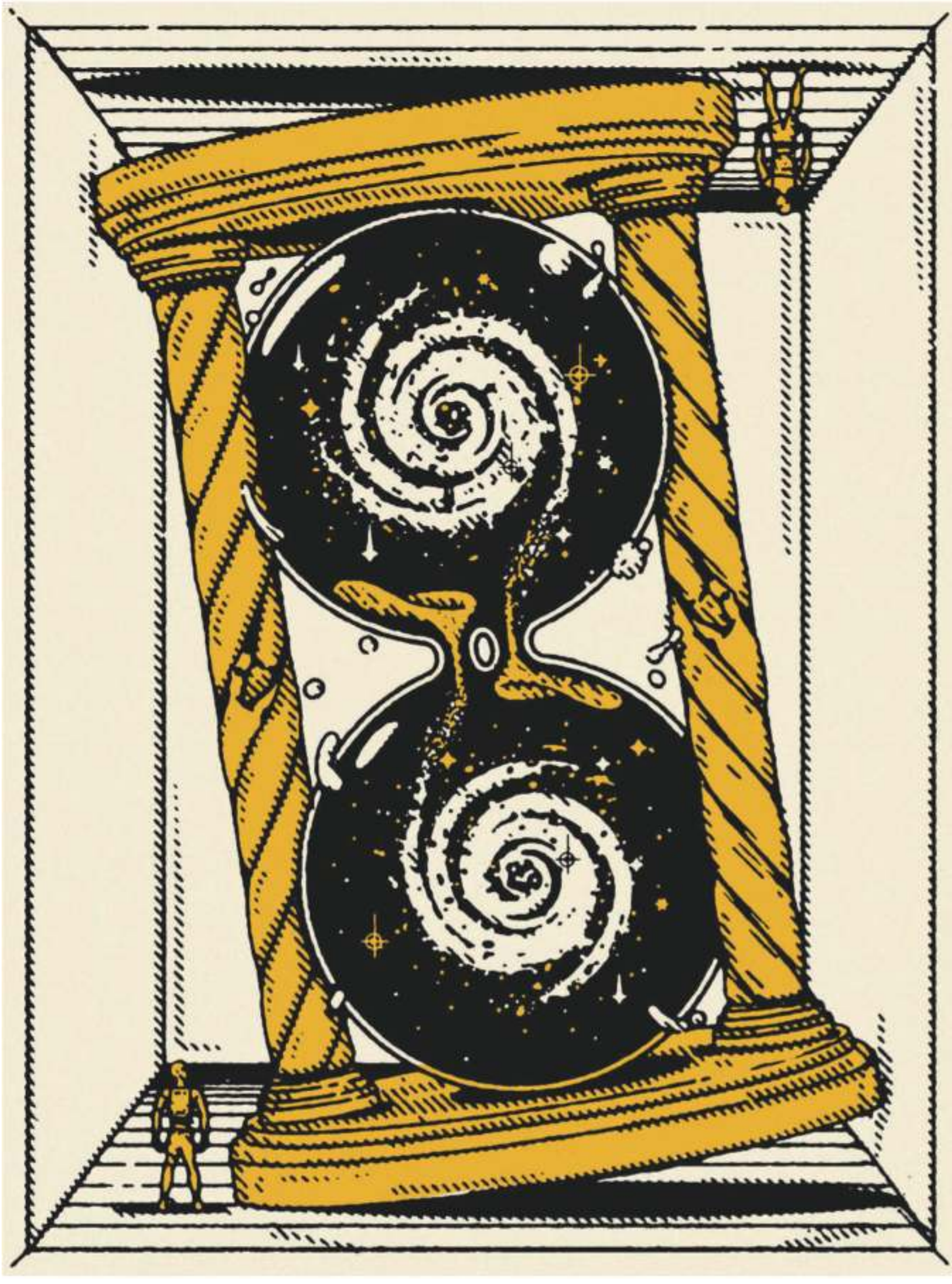
Ecological restoration – creating more protected areas, allowing forests to regrow – is also key. The UN has designated this the Decade on Ecosystem Restoration. Now we need governments to step up and take action to make that happen. "One of the big frontiers is to what degree we can restore habitats," says Keesing.

Decisions that individuals make in all parts of the world can play their part, too. As Daszak points out, encroachment of people into biodiverse areas is largely to supply demand for goods in richer countries, be it palm oil from Malaysia and Indonesia or meat from cattle ranches in South America. "We are sleepwalking into these disasters. We just need to open our eyes about the decisions that we make," says Redding. "People consuming make decisions that impact the likelihood of future spillovers."

He suggests shifting to more plant-based diets as one step people can take. "It's all the choices that we make: what we eat, what we wear," says David Quammen, author of the 2012 book *Spillover*. There are signs some governments in richer countries are stepping in the right direction, putting checks or bans on the import of goods that disrupt ecosystems. In November, the UK passed a law to that effect. Pressure is on the European Union to do similar.

For now, research on the links between our destruction of nature and emerging diseases is growing fast. It is also nascent and sometimes woolly: Redding likens the science to where we were in the 1970s on climate change. But we don't need to wait: there are a multitude of other reasons to protect habitats and biodiversity, from the fresh water they provide to the carbon they store. It is rather like the point made by a famous 2009 cartoon, where a delegate at a climate summit asks: "What if it's a big hoax and we create a better world for nothing?". As Redding puts it: "What's the downside of trying to better protect ecosystems and keep them more intact?" ▮

Adam Vaughan is chief reporter for *New Scientist*



MICHAEL HADDAD

Double time

Why does time only move forwards? Perhaps it doesn't, says physicist **Julian Barbour** – perhaps it goes in two directions from the big bang

TIME moves forward. This is so obvious that we take it for granted, and the rule seems to apply everywhere we look. Observable phenomena only ever unfold in one temporal direction. We get older, not younger. We remember the past, not the future. Stars clump in galaxies rather than dispersing, and radioactive nuclei decay rather than assemble.

The big question is, where does this forward-facing arrow of time come from? The most popular explanation relates to entropy. In this picture, the flow of time is essentially a manifestation of the universe's inescapable inclination towards disorder.

I have a different idea, or rather two. The first is that time goes both ways – that the big bang isn't an origin for time, but a midpoint from which two parts of one universe play out, running in opposite directions. We can never see the one unfolding in the other temporal direction, yet it is there, I suggest, as a consequence of a fundamental law of nature.

My second idea is even more radical. It could transform our understanding of the very nature of time. The consequences might even reach beyond the realm of classical physics, the world we can easily see, and offer fresh clues to the quantum nature of gravity – the elusive theory that marries general relativity with quantum mechanics.

Physicists' current ideas about time owe much to Albert Einstein. His general theory of relativity merged the three dimensions of space with one of time into space-time, the all-encompassing backdrop against which events play out. In principle, if not always in practice, we can move in space as we wish. Not so in time. Time insists on a direction of travel: we have no choice but to be swept along from past to future.

This flow of time isn't dictated by the fundamental laws of nature. All but one of these are time-symmetric: they work equally well towards the past or future. Take the collision of two billiard balls, governed by one of these laws: a film of what happens doesn't look odd when played backwards or forwards. The one time-asymmetric law we know of is one that dictates the decay of certain elementary particles, an oddity that prevented the complete mutual annihilation of matter and antimatter in the early universe and ensured that we, being made of matter, are here today. But there is no way it can explain the onward flow of time.

To explain this, physicists have instead turned to a law that isn't considered fundamental, but which emerges from more basic laws. The second law of thermodynamics says that in a closed system, overall disorder, characterised by a statistically defined quantity called entropy, always increases. It does so because there are many more possible states of disorder than of order. Thus, a small ice cube in the corner of a large box will melt and become liquid water, spreading the molecules out and increasing disorder. Entropy has increased. Note the "statistically defined" bit: the laws of physics don't rule out this process being reversed, but just say that event is statistically hugely unlikely.

In this picture, the direction of time is created by the increase in disorder. If snapshots showing the position of the molecules in that box were shuffled out of order, my 4-year-old granddaughter could put them back in order. For many scientists, this is enough: entropy puts direction into time.

For my part, I don't doubt the robustness of thermodynamics. Einstein described it as "the only physical theory of universal content which I am convinced that, within the framework of applicability, its basic concepts will never be overthrown". I wouldn't be so bold as to disagree.

But Einstein's caveat is important, and leads to a question: does the "framework of applicability" of thermodynamics include our universe? It doesn't appear to be a closed system. It might be infinite in size and is certainly expanding, possibly without impediment. If so, it isn't in a box. But a box, physical or conceptual, is crucial for the interpretation of entropy.

That alone is reason to question the application of thermodynamics more or less unchanged to cosmology. But there is another reason. With the entropic arrow of time, physicists assume that the universe began at the big bang with very low entropy, ›

a special state of extraordinarily high order. That is arbitrarily imposed. One of the most profound aspects of existence is attributed to a special condition put in by hand. This has been called the "past hypothesis" and in my view it isn't a resolution to the issue of time, but an admission of defeat.

In fact, an alternative to the past hypothesis may have been staring us in the face for more than two centuries. In 1772, mathematician Joseph-Louis Lagrange proved something about the behaviour of a system of three particles that interact according to Isaac Newton's law of gravitation. This says that every particle attracts every other with a force proportional to their masses and inversely proportional to the square of the distances between them.

Past forwards

Lagrange's result, which extends to any number of particles, showed that if a system's total energy (potential plus kinetic) is either zero or positive then its size, essentially its diameter, passes through a unique minimum at just one point on the timeline of its evolution. This process runs just as well backwards as forwards, Newton's gravity being time-symmetric. And with one fascinating exception to which I will return, the size of the system grows to infinity both to the past and future.

Interestingly, the uniformity with which the particles are distributed is greatest around the point of minimum size. It has long been known that a uniform distribution of particles is gravitationally unstable and breaks up into clusters. What nobody seems to have realised, however, is that when you run the evolution of the particles' motion backwards from the clustered state to the minimum, most uniform state and then take it beyond this point, it goes on to become clustered again.

In a paper I published in 2014, together with Tim Koslowski at the National Autonomous University of Mexico and Flavio Mercati at the University of Naples, Italy, we showed that this is the case in a simple proxy of the universe. A computer simulation of a thousand particles interacting under Newtonian gravity showed that pretty much every configuration of particles would evolve into this minimum state and then expand outwards, becoming gradually more structured in both directions. I call the minimal state the Janus point, after the Roman god who looks simultaneously in opposite directions of time.

LEE ROBINSON PHOTOGRAPHY

A hiker on Japan's Mount Fuji wouldn't be able to see its mirror image in Lake Kawaguchi. A similarly limited view might explain why we think time flows only one way

What would this mean for us? If we lived in the model universe I have just described, we must be on one side or the other of the Janus point. We find Newton's time-symmetric law governs what happens around us, but also a pervasive arrow of time that defines our future. In our past direction, we can just make out fog – what we call the big bang – and nothing beyond it. Not realising the fog is a Janus point, we invoke a past hypothesis to explain the inexplicable. But Newton's laws say the special point must be there, so there is no need to invoke the past hypothesis. Instead, we can mathematically define a quantity that reflects the evolution of our system of particles into something that looks like structure. Let's call it "complexity".

Complexity is calculated using all the masses of the particles and all the ratios of the distances between any two of them. It has nothing to do with the statistical likelihood of possible states and differs from entropy in that its growth reflects an increase in structure, or variety, rather than disorder. I argue that it should take the place of entropy as the basis of time's arrow.

In my recent book *The Janus Point*, I take things further. I propose that, ultimately, our model suggests that the history of the universe isn't a story of order steadily degrading into disorder, but rather one of the growth of structure or complexity, as we define it.

The suggestion for this comes in the first place from Newton's theory of gravity. It isn't yet clear it can be extended to a general relativistic description of gravity. But in many cases, Newtonian gravity predicts behaviour almost identical to relativity, so there is a hint to look for a similar effect in Einstein's theory.

This brings me to the fascinating exception to Lagrange's result I mentioned earlier. In everything discussed so far, the minimum size of the "universe", at the Janus point, isn't zero but finite. But general relativity at the big bang leads to a zero size of the universe, known as a singularity, where the equations break down.

It has been known since a remarkable paper by Frenchman Jean Chazy in 1918 that singular events called total collisions can also occur in Newton's theory. In them, all the particles come together and collide simultaneously at their common centre of mass. At this point, Newton's equations break down; they can't be employed to continue any solution past a total collision. Instead of two-sided solutions, we have one-sided solutions.

If we take this exception seriously, we cannot say time has two opposite directions but, significantly, it doesn't rule out complexity giving time a direction.

The equations for Newton's gravity are still time symmetrical, so the solutions that terminate at a total collision can run the other way. They become Newtonian "big bangs" in which all the particles suddenly fly apart from each other. Right at the start, the particles are arranged in a remarkably uniform way, but they soon begin to look like the motions on either side of the Janus point we saw in our calculations.

As they emerge from zero size, their configuration, characterised by the complexity, satisfies a very special condition. There are plenty of configurations, or shapes, that satisfy the condition but just one has the absolutely smallest possible value of the complexity. It is more uniform than any other shape the universe could have.

This is where a radical twist in the tale was all but forced on me, during the final stages of writing my book. The fact that the universe had an extremely uniform shape immediately after the big bang set me thinking. Could the special shape I've identified, which I call Alpha, serve as a guide to a new theory of time – and also point the way to arguably the biggest prize in physics, a quantum theory of gravity?

Quantum theory describes the often counter-intuitive behaviour of subatomic particles. For all its successes, it has always relied on an essentially classical conception of a time that exists independently of and outside the system. But surely any attempt to create a quantum theory of the universe, and with it gravity, should start without the notion of a pre-existing external time. Time has to originate somewhere, and where else but the quantum realm.

"Complexity doesn't just give time its direction – it literally is time"

My ideas about complexity can help. What I'm proposing might be called Newtonian quantum gravity because it unifies aspects of Newton's theory of gravity, above all this value of complexity, and the two key novel features of quantum mechanics: probabilities for the state a system finds itself in, and an entity known as a wave function that determines how these probabilities evolve.

The idea is that a wave function of the universe determines the probabilities of all the possible shapes it can have. This is relatively conventional. What I'm suggesting, however, is how that happens: I put the birth of time at Alpha, this uniquely uniform configuration of particles, and make complexity time itself.

Heaps of time

I said my granddaughter could sort the shuffled snapshots into the correct order. Now suppose I give her snapshots of all possible shapes of the universe to sort into heaps, one for each value of their complexity. In the first heap there will be just that one most uniform shape: Alpha. After that, there will be infinitely many for each value of complexity. The wave function determines relative probabilities for each of the shapes within each heap.

This is what standard quantum mechanics does for the probabilities of a system's possible states at different external times. My proposal includes something similar but with invisible, external time replaced by complexity, which is visible in the sense that it is directly determined by the shape of the universe. Hence, complexity doesn't just give time its direction – it literally is time.

The picture I have sketched matches the known history of the universe, but is only a start. The good news for next steps is that there is, at least in principle, an observational test.

Scrutiny of the first light in the universe, known as the cosmic microwave background (CMB), indicates that very soon after the big bang the distribution of matter in the universe was extremely uniform, while also revealing tiny fluctuations of a very specific structure. Inflation, a theory that suggests the universe underwent a huge expansion in its first split second, can explain the form of those fluctuations rather well. But it doesn't tell us how inflation began and key parameters must be fitted to match observations.

According to my idea, the universe must begin as uniform as it possibly can and then develop small nonuniformities. This might sound like an arbitrary assumption, but it is a direct consequence of the simplest quantum law one can propose for the universe, which forces the wave function to evolve from a necessarily unique condition at its most uniform shape. It is possible we could use first principles to directly predict the form of the fluctuations, which we could at some point verify or rule out by further scrutinising CMB.

This idea could go either way. I am hopeful, and not only because Newtonian complexity has a counterpart in Einstein's theory. I also find encouragement in the thoughts of Niels Bohr, a founder of quantum mechanics, who said any new quantum idea needs to be crazy. The idea that complexity is time is certainly that – and it could be transformative. If time really is complexity, and it is a big if, it will kill two birds with one stone: provide a new starting point from which to formulate a quantum theory of gravity and show, on the basis of simple first principles, how time gets its direction. ▮

Julian Barbour is an independent physicist, formerly a visiting professor at the University of Oxford, UK, and author of *The Janus Point: A new theory of time* (The Bodley Head, 2020)

The back pages

Citizen science

Become a disease hunter

With Etch A Cell, we can help biologists understand killer diseases hidden in mountains of images, says **Layal Liverpool**

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

What you need

Internet access
A web browser open to zooniverse.org

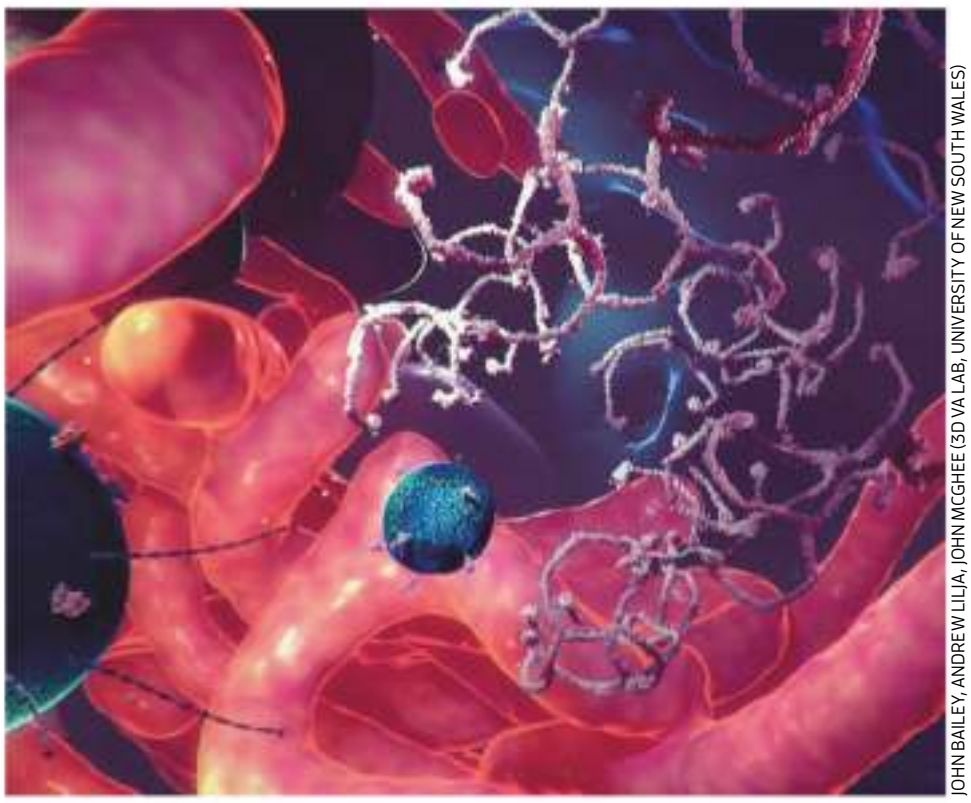
EVER since I was a child, I have been fascinated by the vast world within our bodies and have long dreamed about what it would be like to shrink myself down and explore the inside of a human cell at the microscopic level. It turns out I'm not alone: biologists are trying to do exactly that – and you and I can help them.

Just as the human body contains organs that perform different functions, our cells have various structures and pieces of molecular machinery called organelles. Examples of organelles are the nucleus, where DNA is stored, and the mitochondria, which are sites of energy production.

Advances in microscope technology allow researchers to peer inside human cells in unprecedented detail, fuelling key insights. Electron microscopes use beams of electrons to illuminate objects, and provide much higher magnification than standard light microscopes.

The rate at which electron microscopy images of cells can be generated has accelerated in recent years, says Helen Spiers at the University of Oxford. "We are now producing data at a rate faster than we can analyse it," she says.

"The gold-standard approach for analysing this visual data to make sense of it is segmentation," she says. This involves marking out the organelles by tracing lines around their edges in a two-dimensional microscope image. To speed up the process, Spiers and her colleagues regularly enlist the help of citizen scientist volunteers, through the Etch A Cell project.



JOHN BAILEY, ANDREW LILJA, JOHN MCGHEE (3D VA LAB, UNIVERSITY OF NEW SOUTH WALES)

I like the occasional colouring book and found etching cells in microscope images online similarly comforting. But it is also hugely helpful to the researchers: data gathered through Etch A Cell has helped artificial intelligence software learn to identify some organelles automatically, further accelerating the analysis process.

One of the latest iterations of the project, Etch A Cell – VR, aims to take the process to another level by using segmentation data from citizen scientists to reconstruct three-dimensional cells with labelled organelles that biologists can explore using virtual reality.

"It's about changing your perspective and allowing you to interact with your data differently," says Spiers. "Being able to rotate things while you've got a VR headset on and just seeing things in three dimensions, you might notice something that you wouldn't otherwise."

Researchers could use this technology to compare cancerous and non-cancerous cells, for instance. "That can help you understand what's gone wrong and how you can potentially fix it," says Spiers.

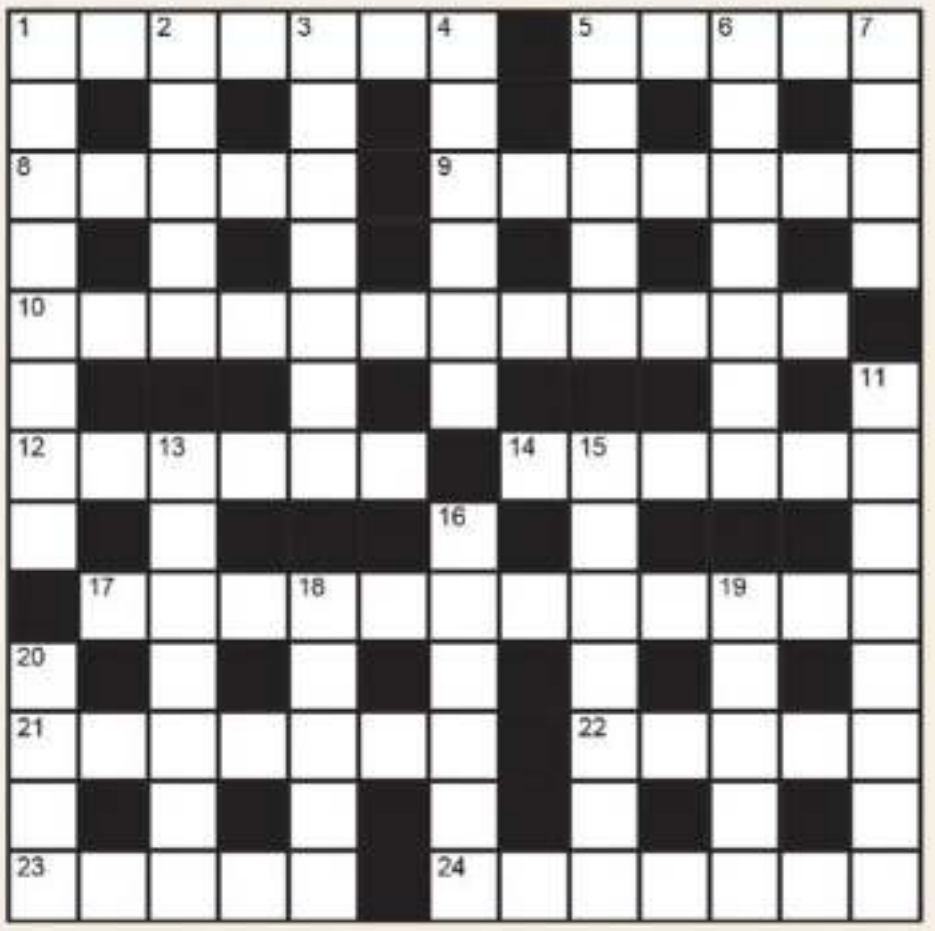
You can find all the Etch A Cell projects, and take part in Etch A Cell – VR, by heading to the zooniverse.org web portal for citizen science. ▮

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

Citizen science appears every four weeks

Next week
Science of cooking

Cryptic crossword #52 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Once again take in Cambridge university in wake of study (7)
5 Electronic part from *Candle in the Wind 1997*? (5)
8 Spy nods off at current location for proposed megastructure (with 14 Across) (5,6)
9 Made fun of coddled misses beginning to nap (7)
10 Mark almost feeling a little thrill wearing rude look (8,4)
12 Make certain error coming after disorganised nurse (6)
14 See 8 Across
17 Sterno used to produce hormone (12)
21 Salt (very small quantity) coats article (4,3)
22 Ungulate blood factor in human blood type (5)
23 Meat pie from previous year (5)
24 Type of battery used for cars and trucks and so on found in water source (3,4)

DOWN

1 Entrées topped with practically raw vegetables (8)
2 Lost a certain amount of fat seasonally (2,3)
3 Lizard egg laid in heath (7)
4 Titanium added to balanced concoction (6)
5 Witty doctor let loose "lol" (5)
6 Indignation displayed by Newton amid spilt coffee (7)
7 Swirl in topless nightwear (4)
11 Backward facilities enclose, say, source of inheritance (4,4)
13 Call for assistance around returning abysmal swimsuits (7)
15 I report deranged clown (7)
16 Avoid south-eastern hiking champ (6)
18 Sycophant's promotion interrupting play (5)
19 Am after round Martini garnish (5)
20 Stat: leaders in anaesthesia sometimes abuse paracetamol (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #91

1 Akira Yoshino is credited with creating the first commercially viable what?

2 What are the three forms of plague?

3 The Exocoetidae family of fish is better known by what name?

4 How old was US astronaut John Glenn when he became the oldest person to fly in space?

5 Nordic Gold, a gold-coloured alloy often used in coins, is made of copper, aluminium, tin and which other metal?

Answers on page 55

Puzzle
set by Holly Biming
#103 Trouble brewing

Our office vending machine normally allows me to get any combination of tea, coffee, chocolate, milk and sugar, each with its own button. Unfortunately it has developed a glitch.

What happens now is that instead of delivering its own ingredient, each button delivers two other ingredients instead. Each button delivers a different pair, and each of the ingredients is delivered by two of the buttons.

However, if two buttons demand the same ingredient, such as tea, they cancel each other out and I don't get tea at all.

The result? If I ask for chocolate with milk, I get tea with sugar. If I ask for tea with milk and sugar, I get those three ingredients plus coffee!

What do I get if I press the coffee and milk buttons?

Answer next week

Now is the time

Buddhists recommend living in the present moment. How long is this gap between the past and the future? (continued)

Andrew Fenn, Venerable Sampasadana (a Buddhist monk)
Perth, Western Australia
The whole "present moment" idea is probably a little inaccurate. There is no sense of the Buddha using it in that form in the earliest texts, except as being mindful. It seems that it may well be a modern inspiration that became pop culture.

A little-known fact about mindfulness is that the ancient Pali word *sati* (or *smrti* in sanskrit), from which mindfulness is translated, means memory or recollection. It is about being mindful of what we have been trained in, in order to avoid unnecessary harm, delusion and conflict to oneself and others.

Buddhist practitioners are likewise taught to recollect why we are doing things, to realise there is

"The 'present moment' concept might be a modern idea. There is no sense of the Buddha using it in that form in early texts"

a clear cause-and-effect going on. This is just a small part of what is called dependent origination in Buddhist lingo, which is the idea that the existence of any given phenomenon is dependent on the existence of other phenomena.

Education is very important. We say *samma sati*, meaning "right mindfulness", fully understanding that there is a "wrong" type of mindfulness. It was always meant to be used in an informed context with other factors, such as "right view" and "right intention", and never on its own where it may easily be harmful.

The practitioner gains a clear realisation that while there is no absolute free will, we do have responsibility for and some agency over our choices, and positive change only starts from the here and now.

The whole "living in the moment" thing can be a trap since, as any good meditator knows, by the time you have experienced something and it has entered your brain, it has already gone into the past.

Bob McCrossin
Cooroy, Queensland, Australia
In a previous response to this question, Hillary Shaw discussed quantum Buddhists and black hole Buddhists who experience a very small gap between past and future, which is the present moment.

Yet consider the relativistic Buddhist. The laws of relativity state that an object travelling at the speed of light – a photon, for example – doesn't see time passing at all.

From the time when a photon is created until it hits something, no time at all passes. If created in the big bang, a photon has no past, no present and no future.

From our perspective, however, photons of the cosmic microwave background have existed for the entire age of our universe, more than 13 billion years. How can something that is measurable and therefore exist have experienced no time at all? Since time doesn't exist in photon nirvana, does it actually exist at all?

Jim Bailey
Southampton, UK
No one, as far as I know, has shown that time moves in a series of quanta in the way that electromagnetic radiation does, so it follows that there can be no "now", and everything is either in the future or in the past.

Time doesn't stand still; it is a continuum. From this, it follows that nothing can be anywhere either, since to be somewhere requires time to stand still while the "being" is going on.

Everything is moving and time is merely a way of describing the amount of that movement taking place.

Peter Holness
Hertford, UK
This intriguing question delicately balances perception, physics, psychology and perhaps even religion.

A possible answer is that we sail through space-time on a perceptual "spike" of space-time, which is a pulse with zero or infinitesimal width. The caveat is whether we accept the existence or convenient fiction of time. All we are reasonably sure of is the existence of change.

John Stevens
Bad Münstereifel, Germany
It isn't just Buddhists who live in the present moment. We all do.

When I am out walking, my eyes will perhaps focus on a patch of sunlight, which I recognise as such after a few milliseconds. The next moment, the squelching of my wellies may trigger a memory that lasts for a second or two. This perception is then, perhaps, replaced by a pang of hunger, which sets me planning a future meal.

All the while, I am in my perceived present, never in the past or the future. My memory of the past is my momentary present, and the future meal is also my momentary present. In that sense, I am only ever in the present.

REGGIE CASAGRANDE/GETTY IMAGES

Does crashing onto the sofa create gravitational waves?

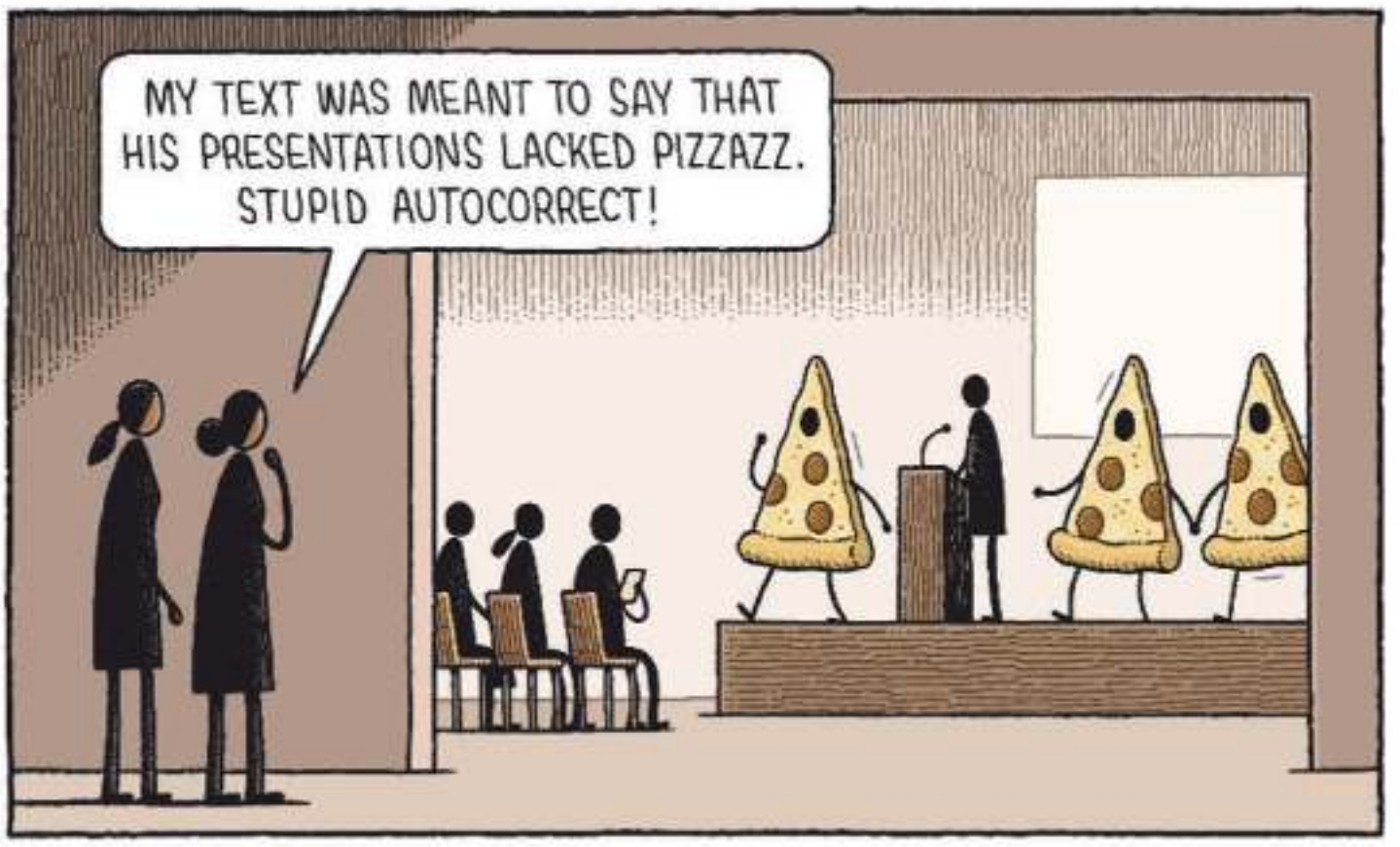
This week's new questions

Weighty waves **Gravitational waves arise when very heavy objects spiral into each other, but is there a lower limit to this? Do I create one when I crash into the sofa after a day of work?** ***Bruno Billiaert****, Duffel, Belgium*

Limb renewal **Why can't humans regrow limbs like an axolotl or a lizard?** ***Fabiola Bartolomei****, Moscow, Russia*

Want to send us a question or answer?
Email us at lastword@newscientist.com
Questions should be about everyday science phenomena
Full terms and conditions at newscientist.com/lw-terms

Tom Gauld
for New Scientist



Bird banter

Many birds are able to remember and mimic sequences of sounds they hear, including human speech. What evolutionary advantage does this skill give them?

Mike Follows
Sutton Coldfield, West Midlands, UK
The evolution of the advanced ability to mimic the birdsong of other species, and even sounds heard in the environment, is usually driven by sexual selection.

Female superb lyrebirds, for instance, are more attracted to male lyrebirds that have a more sophisticated repertoire of songs and sounds. This is probably because this ability signals greater biological fitness, which increases the likelihood that their offspring will survive.

New research also shows that male superb lyrebirds imitate alarm calls of a "mobbing flock" while mating. And captive lyrebirds have been observed mimicking the camera shutters of picture-taking visitors and the sound of chainsaws on a nearby construction site.

"Greater racket-tailed drongos imitate raptor calls, inducing other birds to take flight and abandon their food to them"

Perhaps learning to mimic a more diverse range of sounds requires more intelligence and this might translate into an ability to find scarce food or evade predation.

Flocks of greater racket-tailed drongo often share the same trees as other bird species. By imitating raptor calls, the drongos can induce the other birds to take flight and abandon their food to them. They then hop over and steal it. So being described as a drongo isn't quite as insulting as intended.

Some species of bird, such as the grey parrot, only exhibit obvious sound mimicry when in captivity. Grey parrots are social birds that communicate important information with their flock-mates. In the absence of a flock, they vocalise with other species or their human companions. Perhaps they derive intellectual satisfaction from parroting their owners?

Seeing small

What is the smallest animal with eyes and could it see a molecule? (continued)?

Eric Kvaalen
Les Essarts-le-Roi, France
I think it is possible for us humans to see a single molecule.

There is a technique in which single molecules are tagged with fluorescent labels, then a microscope is used to see whether different molecules occur in the same place.

If the illuminating light is strong enough, I suppose it would be possible to see a dot of fluorescence at the location of one of the labelled molecules, even without a microscope. ▮

Answers

Quick quiz #91
Answers

1 Lithium-ion battery
2 Bubonic, pneumonic, septicemic
3 Flying fish
4 Glenn was 77 when he flew on space shuttle Discovery's STS-95 mission in 1998
5 Zinc

Quick Crossword #77 *Answers*

ACROSS 1 Shipbuilding, **10** Neptune, **11** Chiasma, **12** Y-axis, **13** Gene chip, **15** Tear glands, **16** Plan, **18** Toes, **20** If you ask me, **22** Ontogeny, **24** Alula, **26** Ehrlich, **27** Tool kit, **28** Chess problem

DOWN 2 Hypoxia, **3** Plus sign, **4** Uvea, **5** Locked door, **6** Imide, **7** Gasohol, **8** And yet it moves, **9** Carpenter ants, **14** Half-inches, **17** Catacomb, **19** Enteric, **21** Knuckle, **23** Glide, **25** Star

#102 Passport to success
Solution

The passport number is 381654729. Since AB is divisible by 2, B must be even, and by similar reasoning so must D, F and H.

Since ABCDE is divisible by 5, E must be 5, meaning A, C, G and I must be 1, 3, 7and 9 in some order. ABCD is divisible by 4, so CD is also divisible by 4, meaning CD must be one of 12, 16, 32, 36, 72, 76, 92 or 96. This means that D can only be 2 or 6.

Similar reasoning narrows down which digit can go where, ending with the unique answer. 381654729 is the only pandigital (i.e. uses all the digits once) polydivisible number.

Fresh mint

The UK's Royal Mint has revealed the new 50-pence coins it has struck to celebrate Victorian fossil hunter Mary Anning. But eagle-eyed pedants (of whom we know a few) have spotted a slight error.

One coin marks the discovery of the first ichthyosaur, an extinct marine reptile that looked rather like a modern dolphin. It says "Temnodontosaurus, Mary Anning 1811" and includes a picture of a fossilised skull. But, a colleague points out that, according to the Natural History Museum in London, she didn't actually discover this bit of the ichthyosaur. Instead it was her brother Joseph who found it in 1810. Mary dug up parts of the neck in 1811, the museum's website says.

Who are we to split hairs, though? Mary Anning was constantly overlooked for her work during her life. Her name was often omitted from scientific papers that mentioned her fossils, including the ichthyosaur, and the Geological Society of London refused to admit her because she was a woman. If we get hold of one of these 50p coins, we will be sure to treasure it.

Not so for a recently minted £2 coin that was made for the 75th anniversary of the death of author H. G. Wells, however. The coin shows the invading Martian tripods from *War of the Worlds* with four legs. "The clue is in the name," irate sci-fi fans complained.

You have to pity the Royal Mint, it just can't please everyone. Another recent controversy came from a 50p coin struck to commemorate Brexit. The coin reads "Peace, prosperity and friendship with all nations", a laudable enough statement, you might think, but it failed to include an Oxford comma after "prosperity", provoking fury among enthusiasts for the controversial punctuation mark. Author Philip Pullman said the coin should be "boycotted by all literate people". Well, at least it distracted people from arguing about Brexit.

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

Superpowders

Hollywood star and purveyor of peculiarly scented candles Gwyneth Paltrow has graced the pages of this magazine before, when she went from flogging pricey "lifestyle" accoutrements (£41 for a water bottle, anyone?) to offering alternative advice that medical experts said could carry risks to health through her TV show *The Goop Lab* .

Now, as the world battles a deadly pandemic, Paltrow has popped up again to share how she is defeating long-lasting covid-19 symptoms with herbal cocktails, kombucha tea and detoxifying superpowders.

Spoilsport and national medical director for NHS England, Stephen Powis, wasn't impressed with Paltrow's most recent pearls of wisdom. "Some of the solutions she's recommending are really not the solutions we'd recommend in the NHS," he said. "We need to take long covid seriously and apply serious science."

Let them eat cake

Continuing the unconventional advice theme, functional medicine expert Will Cole has a new diet book that sounds appealing. Although, according to Wikipedia, functional medicine has previously been described as quackery, Feedback wonders if Cole's book on "intuitive fasting" may be a turning point.

His suggestion is that we should be more willing to listen to our body and intuition. This sounds like a very clever idea to which we have only one question: what if it feels right to eat large quantities of cake? We can't help but intuit that such a diet may have some flaws.

Perhaps, instead, we need to experiment with a few other approaches, to which we turn to one of the UK's most prolific TV health presenters, Michael Mosley. He has, at various points in the past few years, advocated low-carbing, a Mediterranean diet, the 5-2 method, where you fast two days a week, and a "clever guts" diet designed to boost your microbiome. We can't help wondering whether the earlier advice was wrong or if we are supposed to follow all the different regimes simultaneously.

After all of that you would need a decent palate cleanser and what better than a goat's milk cleanse, where you have nothing but goat's milk and herbs for eight days? As Paltrow told *Marie Claire*: "We all have parasites, and they love the milk protein. So if you eat nothing else, they all come out of the intestinal wall and then you kill them with the herbs." Got it.

Party pooper

Speaking of intestinal matters, a reader's attention was caught by a rather graphic advert on the side of a south London bus stop asking: "How do you poo?".

The ad urges people to match the appearance of their stool to different categories – smashed avocado, "poo-doh", the smooth criminal and so on – with a handy pictorial guide. It reminds Feedback of our favourite nugget of health-related trivia, the existence of the Bristol stool chart.

This is an entirely serious medical faeces classification system, ranging from type 1 (severe constipation) to type 7 (severe diarrhoea), although it is unclear how Bristol residents feel about being associated with this endeavour.

Digging deeper, the bus-stop ads seem to be in aid of a campaign to raise awareness of bowel health, or to help a food company sell its high-fibre snack bars, or possibly both. All very worthy, but our bus-stop correspondent wishes he hadn't been eating his breakfast at the time of his encounter.

MANCHESTER 1824
The University of Manchester

BREAK THROUGH

We're helping to build a more sustainable future through applied discovery and innovation

Mitigating climate change. Making renewable energy generation more efficient. Improving batteries and storage technologies with graphene.

Get in touch for knowledge, evidence and expertise:

manchester.ac.uk/beacons

Research beacons

GLOBAL CHALLENGES
MANCHESTER SOLUTIONS