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This week's issue

On the cover

38 Electric you
How the electricity inside you shapes your body and your health

Vol 257 No 3427
Cover image: Spooky Pooka

12 Will chatbot search engines transform the internet?

46 Animal divorce and why it's on the rise

42 The next generation of particle accelerators

16 Neanderthal body clocks
16 Taxidermy bird drones
54 How scones get their shape
34 Hunt for the oldest trees

20 News

"It's becoming apparent that the chemical state of rivers is really, really poor"

News

8 Ageing faces
Bacteria on our skin may make us look older

11 Net-zero homes
Energy-saving devices put to the test in a giant climate-controlled chamber

20 Something in the water?
How to tell if your local river is healthy

Views

27 Comment
Ray Nayler on what governments can learn from speculative fiction authors

28 The columnist
Was farming really a big mistake, asks Michael Marshall

30 Aperture
Capturing the Polar Silk Road

32 Letters
The 2000-watt challenge sparks a lot of interest

36 Culture columnist
Simon Ings on the disturbing afterlife of *Next Exit*

TAYFUN COSKUN/ANADOLU AGENCY VIA GETTY IMAGES

34 Ancient history Tracing the epic story of the world's oldest trees

Features

38 You are electric
Every cell in your body generates electricity with the power to shape, heal and harm you

42 New wave physics
Meet a new type of particle accelerator that sends electrons surging on a wave of plasma

46 The break-up
Climate change may encourage some animals to "divorce"

The back pages

51 Science of cooking
How to make confit parsnips

53 Puzzles
Try our crossword, quick quiz and logic puzzle

54 *Almost* the last word
Why do we have nerve endings in our teeth?

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

56 Feedback
Dive into the many non-gustatory uses for coffee

Elsewhere on New Scientist

Virtual event

Fermilab: Solving the mysteries of matter and energy, space and time

Join Fermilab senior scientist Don Lincoln as he explains what the particle physics facility in Illinois has taught us about our universe. Major discoveries made at Fermilab include the top and bottom quarks – and future work there might be critical for a "theory of everything". Online on 4 April at 6pm BST/1pm EDT. Early booking tickets are £14.

newscientist.com/events

Tour

Astronomy and Radio Telescopes in New South Wales: Australia

Discover why Australia has played an important role in radio astronomy by visiting its famous observatories. Accompanied by *New Scientist* features editor Abigail Beall, you will also explore the outback, where the dark skies are ideal for stargazing. The eight-day tour begins on 9 April and costs £4189.

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Podcast

Weekly

With reports of objects being shot down over North America, the podcast team explore where the "spy balloon" story began. They also discuss a study of love in different countries. Plus, in a bonus episode, podcast editor Rowan Hooper visits Venice to learn about a barrier designed to defend the coastal city against rising seas.

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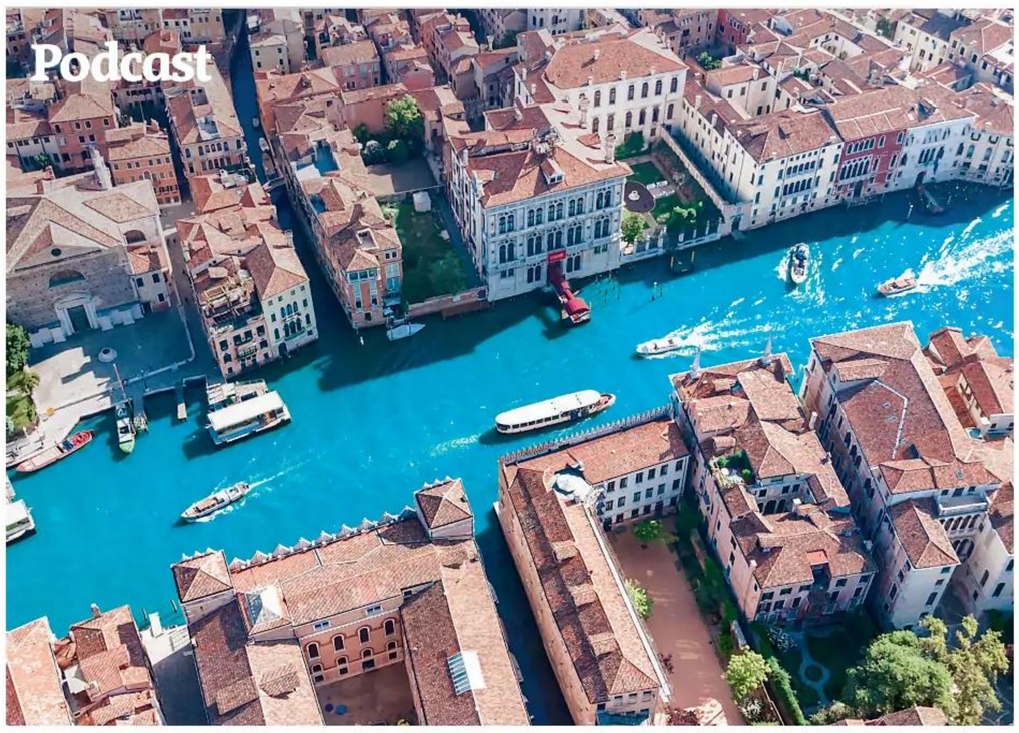

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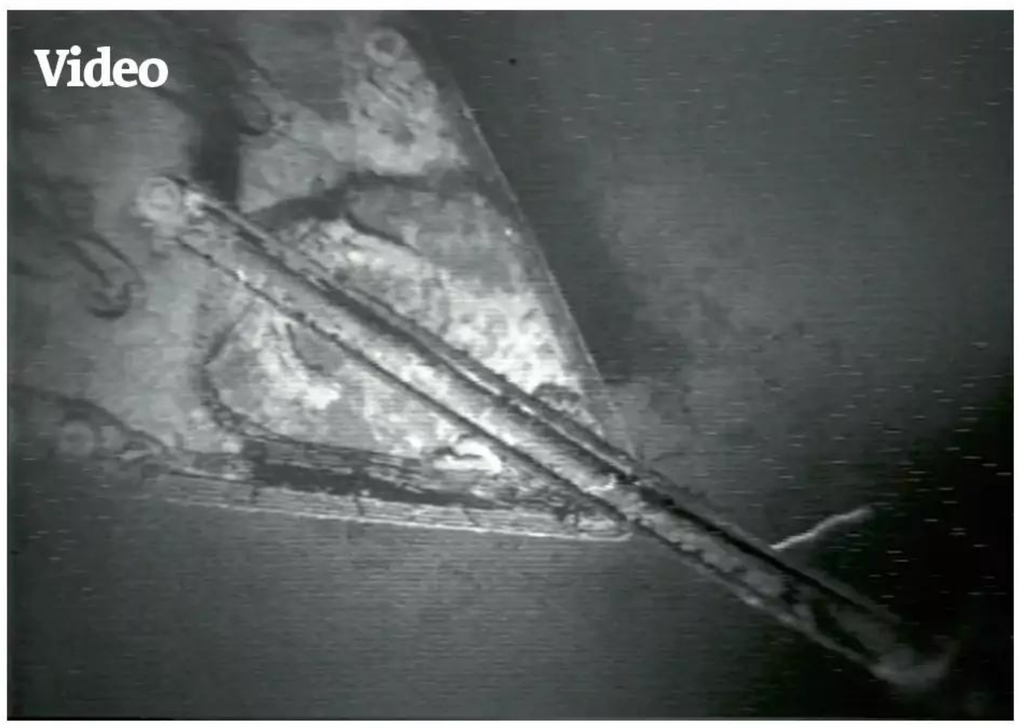
Hold back the water Can we protect Venice from rising seas?



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Historic dive Footage from the first exploration of the Titanic's wreck

Video

Unseen Titanic footage

The wreck of the Titanic was discovered in 1985 and explored by submersibles for the first time in 1986. On our YouTube channel this week, there is previously unreleased footage from those first dives. It was captured using two craft: the crewed Alvin as well as a smaller, uncrewed submersible called Jason Jr. that was able to explore the Titanic's interior.

youtube.com/newscientist

Newsletter

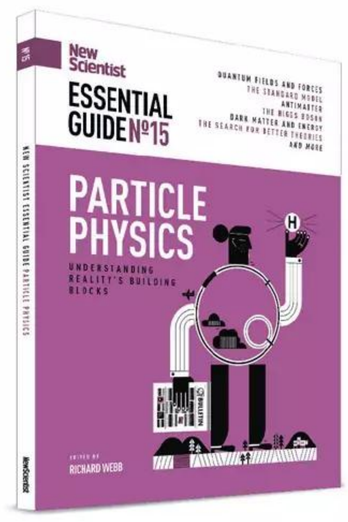
Our Human Story

It is sometimes claimed that the invention of farming worsened human health because it was thought that early farmers were shorter than their ancestors. But, writes Michael Marshall, a new study shows that humans across Eurasia and North Africa began shrinking long before farming, complicating the narrative.

newscientist.com/our-human-story

Newsletter

"Farming has been described as the worst mistake in the history of the human race"



Essential guide

The past century saw a revolution in our understanding of the building blocks of reality and led to the "standard model" of particle physics. Learn about the model in this *New Scientist Essential Guide*. Available to download in the *New Scientist* app or to purchase in print from our shop.

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Cut the chat

Rushing the release of chatbots for search is a risky experiment

IMAGINE living in a city that, overnight, changed all its road signs. Some of them are still familiar, directing you to the city centre, while others offer more whimsical destinations such as the moon or Narnia. Some changes streamline the driving experience, while a few are outright dangerous, such as a speed limit of 300 miles per hour. "Oh, we know it doesn't quite work," say the city planners. "But the neighbouring city is going to do it and we wanted to get there first. Will you test it for us so we can win?"

We would rightly question the competence of anyone wanting to alter vital city infrastructure in this way and yet search engines, a key part of our internet infrastructure, are being subjected to a similar experiment. As we report on page 12, Google, Microsoft and Baidu are racing to add artificial intelligence chatbots to their search offerings, with the last two attempting to wrest a 90 per cent market share away from Google. But the large language models behind these bots simply aren't ready for mainstream use.

"Large language model chatbots have been allowed to escape from the lab far too early"

Releasing half-finished software, known as the "minimum viable product" in Silicon Valley circles, allows upstart tech firms to quickly release a new app and iterate based on user feedback, and it has its place. But these chatbots are being created by some of the largest companies in the world, on which billions of people rely, and they have a duty of care. Already, Microsoft has had to rein in the AI version of its Bing search engine, after finding that lengthy questioning can lead to it offering results that appear increasingly bizarre.

Large language models certainly could be transformative in the way their proponents hope, but they have been allowed to escape from the lab far too early. This is partly due to raw economics – the scale of these models makes them too costly for individuals to run, limiting researchers' abilities to create and study their own – but also to the particular brand of hypercapitalism practised by tech firms, racing to exploit the next big thing. If our chatbot future is indeed coming, there is no need to rush. ▮

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Nestled in the richly biodiverse water of the Atlantic Ocean, the Azores archipelago is a hidden paradise. This is a rare opportunity to experience the islands and their lush vegetation, volcanic craters, lagoons ana picturesque towns, accompanied by a team of marine experts including marine biologist Russell Arnott.

During this eight-day tour, you will spend time both at sea and on land surrounded by a host of different species. You will hopefully spot blue whales – the world's largest mammals – and sperm whales, which boast the world's largest brain. Species such as baleen, pilot and fin whales, as well as bottlenose, risso, spotted and striped dolphins, may be seen too.

You will spend your days exploring and learning about marine life, intelligence and ecosystems through a series of talks. You will also actively take part in whale research and have the opportunity to watch the social interactions of whales at the surface and listen for their "click" sounds as they descend into the water.

On land, you will visit a seabird colony and discover the charming towns and villages of these islands, which is like stepping back in time. You will also have the opportunity to inspect the islands' fascinating volcanic geology and learn how this supports unique viniculture.

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News

Fish out of water
New insights from "evolutionary link" fossil *Tiktaalik* p9

Gene-edited food
Modified wheat cuts levels of cancer-risk chemical p11

Pneumonia threat
Lockdowns linked to rise in antibiotic resistance p14

Toxic train crash
Leak of hazardous chemicals prompts concern in Ohio p15

Dark energy
Is the mysterious force hiding in black holes? p19

GARY M. HART

Environment

Spectacular 'firefall'

For a few weeks in February, when weather conditions are just right, the Horsetail Fall in Yosemite National Park, California, appears to be transformed by the setting sun into a glowing stream of lava. This "firefall", as it is sometimes called, has been diminished in recent years due to drought, but devastating floods this year have bolstered its flow.

Ageing

Can bacteria make you look older?

The presence of certain bacterial species on our faces has been linked with a decline in collagen, the protein that gives youthful skin a plump appearance, finds **David Cox**

FROM our mid-20s onwards, our skin progressively loses its elasticity and plumpness, leading to wrinkles and sagging. Why this occurs isn't entirely understood. However, new research suggests that the microorganisms that reside on our faces may be involved.

A protein called collagen acts as a scaffold for our skin, giving youthful skin a smooth appearance, but the quantity and quality of our collagen production declines with age.

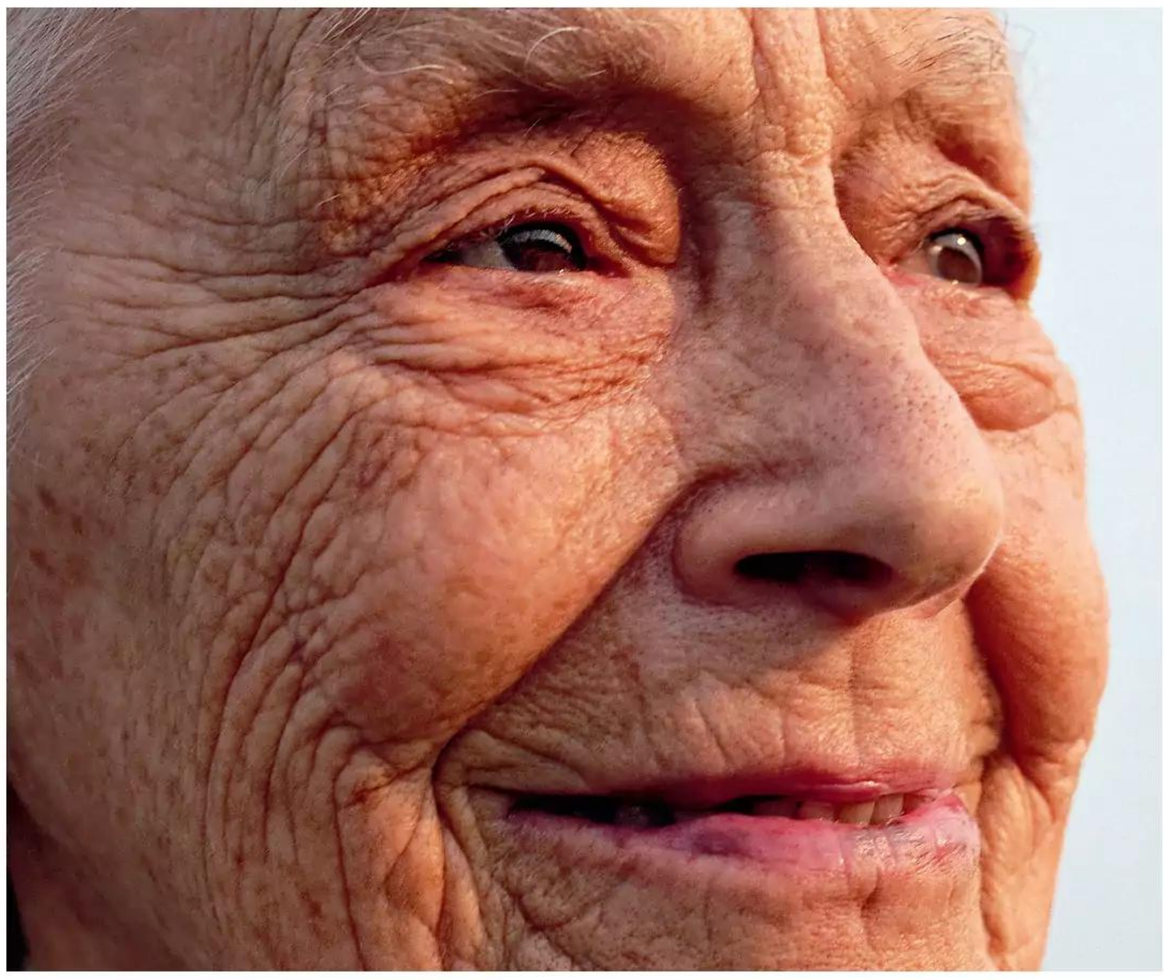
Julia Oh at the Jackson Laboratory in Connecticut and her colleagues wondered whether the skin microbiome – a variety of organisms including bacteria, fungi and viruses that live and interact with each other – could be involved in the loss of collagen.

"We were interested in examining to what degree the skin microbiome differed in ageing skin, because we've found previously that it is the manifestation of genetic and environmental factors, including lifestyle, ethnicity, geographic residence, sun exposure, skin characteristics, hygiene habits, overall health and age," says Oh.

"Targeting these bacterial species could one day lead to new anti-ageing skin treatments"

To learn more, the researchers took swabs from the external cheeks of 51 white women living in Paris, France. Of these volunteers, 26 were aged between 20 and 26, with the remainder aged between 54 and 60.

The team analysed the swabs using a technique known as shotgun metagenomics. This involves identifying nucleotide sequences – the building blocks of DNA – in the swabs and mapping them against a general database of microbes and their corresponding nucleotides to gauge the bacterial species present on the volunteers' cheeks.



ANDREAS KUEHN/GETTY IMAGES

Our skin microbiome may be involved in the physical signs of ageing. Below: Collagen fibres

Oh and her colleagues found that strains of the bacterial species *Cutibacterium acnes* and *Staphylococcus epidermidis* were associated with a decline in collagen levels, measured via infrared light, among the volunteers aged 54 to 60 (bioRxiv, doi.org/jxfn).

Previous research suggests that certain strains of these two species can drive inflammation in the skin, which may also be involved in the physical signs of ageing, says Oh. For example, *C. acnes* is found in sebum, the natural oil that keeps skin moisturised. Excess sebum levels are associated with inflammation.

Julie Thornton at the University of Bradford, UK, says that if further evidence supports the role of certain bacterial strains in driving physical skin changes, these species could one day be targeted in anti-ageing treatments. However, it is currently unclear whether these bacteria cause a loss of collagen or if a loss of collagen is what changes the skin microbiome.

"Is it chicken or egg?" says Thornton. "To answer that, we need more molecular studies where you put cells from different layers of the skin and different microbiomes together in controlled experiments to see what is happening."

The researchers also found that the skin microbiomes of the older participants were made up of a greater proportion of bacteria with antimicrobial-resistant genes, compared with the microbiomes of the younger volunteers.

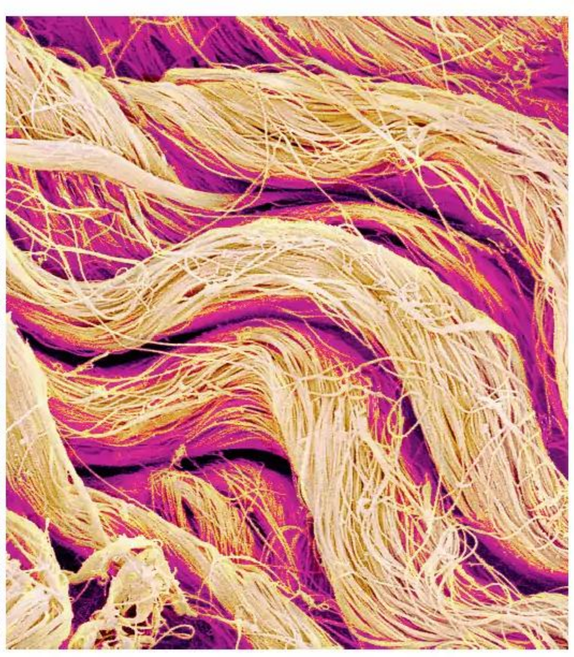
According to Oh, we don't know whether the presence of certain antibiotic-resistant bacteria on our skin affects the physical signs of ageing. However, she believes it is plausible that they could play some role.

"As we age, we've cumulatively been exposed to many antibiotics, and microbes can acquire antibiotic resistance genes from the environment and each other, and these can be maintained in the cumulative gene pool of our skin microbes," she says. "For sure, antibiotic use can change microbiome characteristics, which in turn can have immune and skin barrier effects."

Oh adds that the latest study should serve as a starting point for further research, rather than imminently influencing the development of new anti-ageing treatments.

"These association studies try to pinpoint weak links in our skin microbiome-skin interactions that can then be tested mechanistically," she says. "The next step would be to examine how the skin microbiome might directly influence collagen production."

Future studies should also examine the skin microbiomes of individuals of a range of ages, within a larger group of people of different ethnicities, says Oh. They should also sample the skin microbiome on more areas of the face, not just the cheeks, she says. ▮



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Palaeontology

Early crawling fish was evolving a spine more like that of a land animal

Michael Le Page

X-RAYS of a fossil of one of the first fish to crawl on land have revealed new signs that it was an intermediate step between fish and land-dwelling animals. The work shows that *Tiktaalik*'s fins were becoming connected to its spine, a feature of limbs in land vertebrates, but not of fins in fish.

"That's an unexpected result given the way we've reconstructed this animal in the past," says Thomas Stewart at Pennsylvania State University.

Neil Shubin at the University of Chicago and his colleagues found the first fossil of *Tiktaalik* on Ellesmere Island in Canada in 2004. It was clear from the start that this extinct animal had many features intermediate between those of fish and land vertebrates. In particular, its fins, while still clearly fins, have primitive wrist and elbow joints.

However, parts of the fossil remain embedded in rock. To see these, in 2016, a CT scan was done to reveal hidden features, but at the time, studies of these X-ray-derived images focused on the head region. Last year, Stewart looked at the images of *Tiktaalik*'s spine and ribs and spotted features previously overlooked.

"There was a lot more in there than we realised," he says. Stewart, Shubin and others have now created a more detailed reconstruction of *Tiktaalik* (bioRxiv, doi.org/jxfr).

In land vertebrates, the hind legs are connected to the spine via the pelvis. In fish, the equivalent of the pelvis is positioned away from the spine with no direct connection to it. In *Tiktaalik*, the shape of the vertebrae and ribs suggest that the pelvis was closer to the spine and that there was a soft tissue connection between the pelvis and spine, says Stewart. Other features, such as the shape of the ribs, are also intermediate, he says.

"It is a very nice looking piece of research," says Martin Brazeau at Imperial College London. "A connection between the vertebral column and the pelvis is one of those things that's neither explicitly expected or excluded based on where *Tiktaalik* sits in the evolutionary tree."

But Per Ahlberg at Uppsala University in Sweden thinks that the reconstruction is wrong in the way it connects the spine to the head, shoulder and pelvis. "This has big consequences for the interpretation," he says. "I hope to engage in a constructive debate."

Shubin rejects this claim. The reconstruction draws on evidence from other specimens of *Tiktaalik* and closely related species as well as this one fossil, he says.

There is also debate about this animal's place in the evolutionary tree. No one is claiming that it is the direct ancestor of land vertebrates, but while Shubin and others think *Tiktaalik* is a close cousin of that ancestor, Ahlberg calls it a distant cousin.

"It's rather like looking at a chimpanzee as a model for a human ancestor – not completely out-to-lunch, but not nearly as informative as you might imagine," says Ahlberg.

DOTTED ZEBRA/ALAMY

Illustration of *Tiktaalik*, a fish that was alive 375 million years ago

Technology

AI spots possible archaeological sites in satellite images

ARTIFICIAL intelligence could help archaeologists identify sites to investigate based on satellite or aerial images, and even find ones we might otherwise have missed.

Archaeology can be painstaking and is often slow because it isn't always obvious where remains may be hidden. Researchers use satellite photos to decide where to dig, a technique called remote sensing.

To speed things up, Luca Casini at the University of Bologna, Italy, and his colleagues have trained an AI on labelled satellite images of some 66,000 square kilometres of the historical region of Mesopotamia, in what is now the Middle East. This involved locations where archaeological surveys had taken place, mostly in Iraq, with a few in Iran.

Once the system was trained, the researchers tested it with other satellite images of areas where there have been archaeological surveys and asked the AI to identify those worth digging.

The test areas covered parts of Mesopotamia and what seemed to be topologically similar sites in Uzbekistan. In Mesopotamia, the AI identified dig-worthy sites with 80 per cent accuracy (arxiv.org/abs/2302.05286). This would allow an archaeologist to assess a much smaller selection of areas to decide where to dig, says Casini.

However, with the Uzbekistan images, accuracy was less than 30 per cent. Casini thinks this is because the more urban and vegetation-rich images from Uzbekistan flummoxed the AI.

"AI can help identify patterns in the data that might be difficult for humans to detect"

Overall, Casini believes the AI will speed up the process of finding promising dig sites. "You can do it in minutes with the system," he says.

Despite the limitations, Filippo Brandolini at Newcastle University, UK, sees a place for this approach in archaeology. "AI can help identify patterns in the data that might be difficult for humans to detect, leading to the discovery of sites that might have otherwise been overlooked," he says.

Chris Stokel-Walker

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Biotechnology

Gene-edited wheat cuts level of cancer-risk chemical

Clare Wilson

THE first field trials of a gene-edited form of wheat show it produces less of a potentially cancerous compound called acrylamide when baked.

While acrylamide in food isn't a large concern for most people, many countries have set limits on how much is allowed to be present in processed foods, so some manufacturers are interested in lowering levels of it in products such as bread, biscuits and pastries. Studies in rodents have found that acrylamide causes cancer, although it is unclear what levels would be dangerous in people.

Acrylamide is formed when the amino acid asparagine – found particularly in starchy foods – is cooked at high temperatures. Many food products already breach acrylamide guidelines, but food agencies are likely to get stricter about this in future, says Nigel Halford at Rothamsted Research in Harpenden, UK, who has been developing the gene-edited wheat.

In 2021, Halford's team used CRISPR gene editing to remove one of two genes necessary for making asparagine from common wheat plants (*Triticum aestivum*). When grown in the lab, this wheat produces flour with about half the level of asparagine.

Now, the group has reported similar results when the wheat was grown in outdoor fields. As expected, when the flour was heated to cooking temperature, its acrylamide content was about 45 per cent lower (*Plant Biotechnology Journal*, doi.org/grsgd4).

In the UK, legislation currently going through Parliament would allow gene-edited foods to be sold without having to be labelled as such. "We have got support from a number of plant breeders, but they are nervous about the thought of using gene editing," says Halford. ▮

Field notes Energy House 2.0

Homes for the net-zero age

Energy-saving ideas are being put to the test in a unique facility, reports **Madeleine Cuff**

ON A late winter's day in Manchester, UK, the sky is a steely grey and the air temperature hovers shy of 10°C (50°F). But as I step inside the University of Salford's latest state-of-the-art research building, the chilly 3°C (37°F) air bites immediately.

No, the heating system in this brand-new block hasn't malfunctioned. In fact, this sleek hangar is a giant climate-controlled chamber, designed to test how homes built today will cope with the wilder weather climate change could bring.

The £16-million chamber is an "engineering masterclass", says Richard Fitton, who leads the Energy House 2.0 project for the university. Inside, researchers can create any weather they want with the touch of a button, from –20°C (–4°F) chills to 40°C (104°F) heatwaves, alongside gale force winds, rain, snow and ice.

"We can cover 95 per cent of the globally populated landmass – anywhere generally where people live, we can recreate those conditions," says Fitton.

Nestled rather incongruously inside this industrial hangar are two new-build homes, complete with neat brickwork and pot plants flanking their front doors. Both are kitted out with cutting-edge green tech, such as heat pumps, batteries and electric vehicle charging points, and will act as test beds for housebuilders facing new regulations to build greener homes in the UK nations.

In 2025, the Future Homes Standard (FHS) will come into force in England, requiring all new homes to be built without gas central heating and with other green measures such as extra insulation. Homes built to the FHS must deliver a 75 to 80 per cent reduction in carbon emissions, compared with homes built today.

UNIVERSITY OF SALFORD

The Future Home built inside the climate-controlled chamber

That is why Bellway, one of three developers partnering with the project, has built a three-bedroom detached house from its Coppersmith range of homes inside the Energy House 2.0. The Future Home is a near-perfect replica of a Coppersmith in the real world, complete with a modern kitchen-diner and a living room decked out with throw pillows and mood lighting.

£11

Predicted annual energy cost of Bellway's Future Home

Yet it is clear that this is no ordinary new-build. For one thing, packed inside are three different heating systems: two air source heat pumps, including the UK's first roof-mounted pump, plus infrared panel heaters dotted around the walls and ceilings. There is also a solar power input, a battery in the loft and a smart hot water tank that heats water using excess solar generation.

Over the coming months, Bellway will test different combinations of these technologies – both virtually and with the help of overnight house guests – to find the most cost-effective, scalable way of meeting the FHS regulations. Financially, at least, things are looking promising: based on energy-performance calculations, Bellway says its Future Home could have energy bills of just £11 a year.

A home built today could well be standing in 100 years. That means we must build properties that are not only fit for net zero, but can also cope with a wetter and warmer future climate.

Energy House 2.0 will let researchers see how houses perform in the UK's future climate. "We can take those houses and we can see if they work in 2023," says Fitton. "But we can then cycle through the climate change predictions that we have got for 2030, 2050, 2080... We get to cycle those buildings 50 years into the future and see if we are getting any problems." ▮

Technology

Searching for answers

The move by Google, Microsoft and Baidu to add AI chatbots into search engines may bring advantages, but at what cost, asks **Matthew Sparkes**

THE progress of artificial intelligence models over the past few years has been faster than almost anyone expected. Some advances have left society scrabbling to adapt. Teachers are struggling to stop students using chatbots to write their essays, artists claim they are losing paid work to image-creating AIs and efforts are under way in some places to replace journalists with large language models. But bigger changes are afoot.

Google, Microsoft and Baidu, which run the three most-used search engines in the world, have all announced that their services will be upgraded, or at least augmented, with AI chatbots. Rather than entering a simple query and being presented with a list of potentially relevant websites, users will be able to ask niche and detailed questions and get a bespoke answer.

It sounds like a simple change, but the ramifications could be wide reaching, including damaging online shops, making more services subscription based, threatening endeavours like art and journalism and shaking up the online advertising industry.

The potential benefits to having an AI chatbot answering your search queries could be large. Want instructions on fixing a flat bicycle tyre? Check. Want them written as a Shakespearean sonnet? No problem. You can ask it to plan a holiday that considers the tastes of every member of your family, or even to write an application letter for a new job. The answer doesn't have to appear on the internet, but the AI will still craft an appropriate response.

Ritam Gandhi at digital media agency Studio Graphene says AI-linked search engines could be transformational for users, increasing efficiency and productivity – if the problems AIs have with accuracy can be solved.

Quick visits that start and end at a search engine could be good news to many, but this set-up is conceivably even better for the tech firms running these services. The Google and Baidu search engines, and Microsoft's Bing, will

"If punk was a spontaneous cultural happening, then it's not likely to be repeated with AI"

be able to reduce how often they send people to other websites and instead keep them on their own one, where they can be shown advertisements and monetised.

More echo chambers

This lack of movement across the internet is where one big issue emerges. The sea of varied answers and opposing viewpoints we see as we go through a list of search results would be replaced by output from a single entity.

Carissa Véliz at the University of Oxford says such centralisation risks creating an internet where "echo chambers might become smaller and more solidified". This could mean people mainly coming across opinion and information that reinforces their own viewpoints, rather than being exposed to voices from other communities.

As this single AI would be controlled by a company reliant on profit, there is also a danger its responses may be tailored to serve up certain content, says Véliz.

"It worries me that they might get income from ad publishers influencing the output of the AI," says Véliz. "The AI could end up recommending the brands that are paying their bills."

Such outcomes aren't unprecedented. Google has previously been fined billions of euros by European Union regulators for giving advantages to its own shopping comparison service. And although the workings of AI models are mysterious, the firms behind them can still steer or influence output or the language used.

An AI model would also be able to deliver instantly created content, such as a short story about your pet dog to entertain your toddler. Doing this rather than diving into the diverse wealth of human-generated writing, images, video and art online risks homogenising culture itself, says

JASON REDMOND/AFP VIA GETTY IMAGES

Mark Lee at the University of Birmingham, UK.

He imagines a time when blog posts for prominent people and organisations are written automatically by the same AI, bands are fronted by neural network-generated images and artwork for a range of private and commercial settings is quickly and cheaply produced based on a text prompt. This ersatz art will be good enough to look convincing at first glance, but will be bereft of real creativity, he says.

"If you believe punk was a spontaneous cultural happening, then it's not likely to be repeated with AI," says Lee. "I think one thing AI can't do is explain either the meaning or story behind its art, so perhaps it could generate

LEON NEAL/GETTY IMAGES

Microsoft is integrating OpenAI's ChatGPT into its Bing search engine

Microsoft introduced its AI-powered search engine on 7 February

a *Guernica* but wouldn't be able to contextualise it in terms of [its painter] Picasso and his reaction to the Spanish civil war."

We are at a point at which AI chatbots are technically impressive, but not yet totally reliable factually. This lack of accuracy presents another potential problem. Language models like OpenAI's ChatGPT, which Microsoft is integrating into Bing, essentially output a string of words based on the statistical likelihood that they would appear together in the real world. However, this isn't the same as assessing accuracy or objectivity.

BuzzFeed, *Sports Illustrated* and CNET have all recently dabbled with using AI to write articles for them, although the last of these quickly rolled back the idea after finding the output riddled with errors.

AI-powered search engines have also got off to a rocky start. Google ran an ad for its Bard AI model in which it erroneously claimed that the James Webb Space Telescope took the first images of an exoplanet. A Bing demonstration by Microsoft revealed similar mistakes. Google, Microsoft and Baidu didn't respond to a request for comment for this article.

"The AI could end up recommending the brands that are paying the bills"

Incorrect results may just be an inconvenience if you are looking for a recipe, but they could be life-threatening if you want medical advice in an emergency.

Errors aside, a change to the way search operates could alter the internet fundamentally. Search engines like Google crawl the web, following links from page to page, building up a vast database of information about them: what they contain, how many other websites link to them and how influential and trustworthy they are. With this knowledge, search engines tailor results and bring the most relevant information to the person searching.

Drying income stream

When people leave the search engine to visit one of those suggested sites, that site receives readers and often gets advertising revenue based on the number of visitors. Once search engines serve up more AI results, then this stream of traffic will dry up because people won't need to leave the search engine. If Google, say, then adds AI recommendations for goods or services, then the number of customers on unrecommended shopping sites will probably plummet overnight.

Online journalism, too, is likely to struggle. How will newspapers or magazines fund themselves if internet traffic, like print sales before it, plunges?

Charlie Beckett at the London School of Economics says AI will allow some publishers to automate a lot of journalism, potentially putting people out of work. "People need journalism, they don't need journalists," he says.

There will remain a market for insightful analysis online that AI can't provide, says Beckett, even if basic news journalism might be written by AI. But a reduction in people arriving from search engines is likely to push more firms towards subscription models, rather than seeking the advertising revenue that comes with clicks, he says.

"There's an optimist in me says that, in this new world, there's going to be an added premium on the human, the creative, the critical, the independent, the partisan," says Beckett.

A reduction in internet traffic won't just affect sites that are visited less. Search engines will also lose advertising revenue if they no longer send traffic to third-party websites, says Gandhi. "The whole advertising model is going to be really shaken up," he says, making subscription models for search engines probable, too, and altering how websites of all types make money.

Shops and other companies will need to innovate to survive, says Gandhi, with email and social media becoming even more important in driving sales.

Legislation may also be needed to help with readjustments, to change the way that the owners of content – be it art, text or sound – and personal data can retain rights to it, and adjust the ability to profit from it in a world where AI uses it to train and learn, he says.

"There's a huge, huge trademark and intellectual property set of questions that have to be answered and played out. I think we're very behind on AI regulation and law, and I think it's going to be our biggest challenge and blocker to progress," says Gandhi.

The recent public mistakes by AIs show that most people are unlikely to be using AI chatbots in their searches in the short term, says Gary Marcus at New York University. But we should prepare for their widespread arrival.

"The risks to truth and trust are enormous. Few people are paying enough serious attention to them," he says. "Chat-style search, if it worked, could hurt or kill organisations if it doesn't link out to them." ▮

Medicine

Covid-19 pandemic linked to antibiotic resistance in pneumonia bacterium

Carissa Wong

THE covid-19 pandemic may have led to a rise in antibiotic-resistant bacteria. While a modelling study suggests that Europe's various lockdowns resulted in a decline in cases of a pneumonia-causing bacterium between 2019 and 2020, the proportion of those that were resistant to antibiotics increased.

People with covid-19 may be at a greater risk of bacterial infections because fighting off viruses limits the immune system's ability to tackle invading bacteria. Confirmed or suspected bacterial co-infections may be treated with antibiotics, which can contribute to the bacteria becoming resistant to the drugs.

Aleksandra Kovacevic at the Pasteur Institute in France and her colleagues modelled how people interacted in and out of Europe's covid-19 lockdowns, alongside changes to the prescription of antibiotics between 2019 and 2020, and how these affected the bacterium *Streptococcus pneumoniae*'s ability to evolve antibiotic resistance and its transmission in non-hospital settings.

KIYOSHI TAKAHASE SEGUNDO/ALAMY

***Streptococcus pneumoniae* bacteria can cause pneumonia**

The team also used data on the transmission of the original SARS-CoV-2 coronavirus and the extent to which it affects *S. pneumoniae*'s ability to go from being carried asymptomatically to resulting in illness – the bacterium lives harmlessly in many people's throats, but can cause pneumonia and serious blood infections.

Within the model, the team simulated the planting of two coronavirus cases in a population of 100,000 people. On day 120 of the simulated outbreak, a 90-day wave of infections began. The model, which tracked changing levels of antibiotic-resistant and antibiotic-sensitive *S. pneumoniae* cases, spanned one year.

The team ran six scenarios through the model. Three included population-wide lockdowns, which reduced the spread of *S. pneumoniae*.

But in all six scenarios, the coronavirus wave was associated with a rise in the proportion of *S. pneumoniae* that was antibiotic-resistant (bioRxiv, doi.org/jw4k).

This could lead to more medical complications and hospitalisations, says team member Lulla Opatowski. But we don't know if higher-than-expected morbidities linked with antibiotic-resistant *S. pneumoniae* have occurred in the pandemic, says Scott Olesen at the US Centers for Disease Control and Prevention.

The situation could even be worse than the modelling suggests, as it only simulated *S. pneumoniae* in non-hospital settings, says Olesen.

It is also unclear whether similar results apply to bacteria other than *S. pneumoniae*.

"We don't know if higher morbidities have occurred during the pandemic due to antibiotic resistance"

This model indicates there were changing levels of antibiotic resistance among a bacterium that causes respiratory infections, but you would need different models to gauge resistance in a bacterium such as *Escherichia coli*, which mainly spreads via contaminated food, says Kovacevic. ▮

Ecology

Urban beekeeping boom may be bad for native bee species

EFFORTS to "save the bees" by encouraging urban beekeeping over the past decade may have been good for honeybees, but wild, native bees appear to be paying the price.

Researchers in Montreal, Canada, surveyed wild bee populations across the city in 2020 and found that the diversity of species of wild bees was lower in areas with higher concentrations of honeybee hives.

The overall bee diversity in the city also dropped since the survey was last done in 2013, before an influx of around 3000 new honeybee hives. A survey of the same sites found 177 different wild bee species in 2013, but just 120 species were spotted in 2020 (*PeerJ*, doi.org/grqqm6).

"The sites that saw the largest increase in honeybees over the years had the fewest wild species," says Gail MacInnis, now at the National Bee Diagnostic Centre at Northwestern Polytechnic in Beaverlodge, Canada.

The honeybees seem to be crowding out wild bees by competing with them for food. MacInnis and her colleagues also sampled white clover at every study site and found that the amount of available clover pollen declined as honeybee numbers went up.

While the study doesn't prove that the honeybees are directly causing the drop in wild bee diversity, research in other cities has pointed to a similar trend.

Phil Stevenson at the Royal Botanic Gardens, Kew, in London says the drop in wild bee diversity is concerning. Although honeybees are vital for pollination in many agricultural settings, wild bees are better pollinators for native plants, and even some crops, such as apples. "Many wild bees actually provide the services that we attribute to honeybees," he says. ▮

Brian Owens

WESTEND61/VASILY PINDYURIN/GETTY IMAGES

Colonies of domesticated honeybees may crowd out wild bee species

Health

Why chocolate cravings strike before a period

Sara Novak

SOME people crave particular foods before a menstrual period, but why this occurs isn't entirely understood. Now, a study has found that women who have high levels of inflammatory markers in their blood a week or two before they start their period are more likely to crave food like chocolate.

Khushbu Agarwal at the National Institutes of Health in Maryland and her colleagues assessed 259 women aged 18 to 44 over two menstrual cycles. No transgender men or non-binary people were included in the study.

The women were asked about any cravings they had for food like chocolate, as well as other sweet and salty foods, during their menstrual cycles. They also provided eight blood samples over the two cycles to test for the presence of inflammatory markers.

Overall, 57 per cent of the women reported having moderate to severe cravings for sugary or salty food at some point in their menstrual cycle. This was most pronounced in the week or two before their period began.

The women who craved chocolate and other sweet foods had higher levels of inflammatory markers called hsCRP, GCSF, GMCSF, IL-4, IL-6, RANTES and MIP1B during their premenstrual stage, compared with at other times in their cycle. Elevated levels of inflammatory markers called CRP, IFNA and MIP were associated with salty cravings (medRxiv, doi.org/jw4r).

But Jennifer L. Payne at the University of Virginia says we can't be sure that the inflammation itself is behind premenstrual food cravings. "Just because inflammation and cravings are correlated doesn't mean that inflammation is causing cravings." Other unknown factors may cause them both, she says. ▮

Environment

Toxic train spill fears

Locals are concerned about chemicals released by a train crash in Ohio

James Dinneen and Jeremy Hsu

GENE J PUSKAR/AP/SHUTTERSTOCK

A portion of the train cars that derailed caught fire

A FREIGHT train carrying hazardous chemicals partially derailed and set fire near East Palestine, Ohio, on 3 February. It contaminated the surrounding area and raised concerns about health effects for residents.

Around 50 of the train's 150 cars derailed. Approximately 20 contained hazardous materials, including vinyl chloride, a carcinogen. Over 1000 people in the area were evacuated.

Due to concerns over the risks of a large explosion, a team from the US Environmental Protection Agency (EPA) conducted a controlled burn of vinyl chloride on 6 February, diverting the chemical into a trench and burning it off. When burned, it creates phosgene and hydrogen chloride, which are toxic to people at high concentrations.

On 8 February, state and local officials announced that air quality monitoring had not detected contaminants at levels considered unsafe for humans, and people could return home. Some residents remained concerned following reports of fish and chickens dying in the area. The Ohio Department of Natural Resources said the spill had killed thousands of fish, but the chicken incident hasn't officially been linked to the spill.

The EPA set up air-quality monitoring instruments around the burning train, and took soil and water samples from streams. It found that

150

Number of cars on the derailed train, about double the average

hazardous chemicals from the train – including vinyl chloride, butyl acrylate and ethylhexyl acrylate – were released into the air, soil and water following the derailment. On 10 February, Norfolk Southern Railway, the company that operated the train, released a plan to clean up the site.

The incident has left people wondering how a 3-kilometre-long freight train can come off the rails like this. "You're basically dealing with a big mile-long or more Slinky," says Russell Quimby, a retired investigator for the US National Transportation Safety Board.

"The first thing they teach you in engineering school is the biggest problem in controlling a train... is getting the train to stop and not getting that mile-long Slinky to kill you."

The 50 derailed cars ended up lying alongside each other almost perpendicular to the track. That suggests a "catastrophic derailment" where a broken component causes a train to derail "real quick and real sudden", he says.

Security cameras in Salem, Ohio – about 32 kilometres from the site – showed one of the cars glowing bright on its underside, likely due to a malfunctioning, overheating axle. Railroad tracks typically have wayside detectors every 16 kilometres, on average, to check the temperature of axles on passing trains. The train crew told investigators that they received a detector alert shortly before derailment.

The crew then initiated an emergency braking action. But it can take a distance longer than the length of a train to come to a complete halt, says Quimby. The 150-car train is more than double the length of an average freight train. In December 2022, the US Government Accountability Office found that the largest freight railroads have all started running longer trains to improve efficiency.

On 16 February, another train operated by Norfolk Southern derailed outside Detroit, Michigan. Officials say only one car carried hazardous materials, but there were no signs of leakage. ▮

Genetics

Early risers may have inherited faster body clocks from Neanderthals

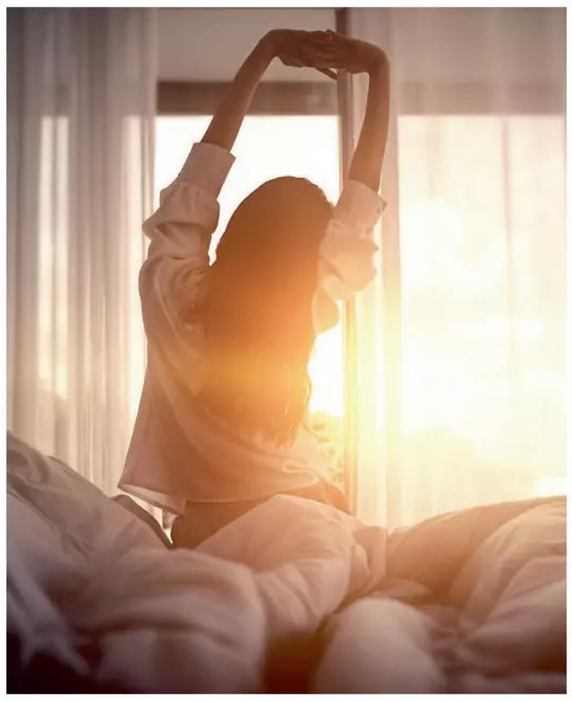
Carissa Wong

GENETIC variants inherited from Neanderthal and Denisovan ancestors may increase the odds that some individuals are morning rather than evening people.

"This was really exciting to us, and not expected," says Tony Capra at the University of California, San Fransisco.

Following a split from our common ancestor with archaic humans such as Neanderthals and Denisovans around 700,000 years ago, our species spent hundreds of thousands of years evolving in Africa, while other archaic humans adapted to higher-latitude regions in Europe and Asia.

Around 50,000 years ago – and perhaps much earlier – some members of our species migrated and interbred with other species of humans. As a result, Neanderthal DNA makes up roughly 2 per cent of the genome in people of European or Asian descent and Denisovan DNA comprises up to 5 per cent



OATAWA/ISTOCKPHOTO/GETTY IMAGES

A person's propensity to get up early is partly down to their genes

of the genome in people from Papua New Guinea.

Previous studies have revealed that genetic variants from Neanderthals and Denisovans give some modern humans higher fertility or a better tolerance for low oxygen levels at high altitudes.

Capra and his colleagues wondered if archaic DNA may have affected the evolution of our circadian clocks, which set the rhythm of our sleep-wake cycles and are driven by dozens of genes.

The researchers compared the genomes of three Neanderthals and one Denisovan with those of thousands of modern humans, 80 per cent of whom were of European descent. They found that, of the genetic variants that the modern humans had inherited from archaic humans, more were linked to regulating the circadian clock than would be expected by chance. This suggests there was a survival benefit to inheriting them. People with these variants from archaic humans were more likely to describe themselves as being a morning person (bioRxiv, doi.org/jwz6).

This doesn't mean that being a morning person is itself advantageous, says Capra. People with these variants might have a biological clock that responds more quickly to changes in light-dark cycles, which may be beneficial for living at high latitudes.

"Faster clocks help other species like fruit flies adapt to higher latitudes where there is higher seasonal variation in light-dark cycles and ultraviolet exposure," says Capra. "We think it was the same case for *Homo sapiens*."

One limitation of the study is that it only included four archaic genomes, but this is what was available, says Capra. The study also focused on modern humans of European ancestry, so further work should look at more diverse populations, he adds.

"Faster biological clocks help other species adapt to higher latitudes. We think it was the same for us"

"This is an interesting and well-done study, but the relationship between our DNA and traits can be complex," says Joshua Akey at Princeton University. "I think the authors have made a compelling case that it should be studied in more detail." ▮

Technology

Stuffed dead birds make for unusual spy drones

ADDING taxidermy bird parts to drones might enable stealthy snooping on wildlife – and possibly spying for military purposes.

Mostafa Hassanalian at New Mexico Tech and his colleagues flight-tested two of these look-alike bird drones – one combining artificial bird body parts with a real pheasant head and feathers, and the other having real pigeon wings attached to an artificial bird body.

The researchers used computer software to simulate wing motions and to improve the mechanical control of the wings after each test.

"This removes the need to design and manufacture a wing, [which] is notably difficult," says Raphael Zufferey at the Swiss Federal Institute of Technology in Lausanne. "The remarkable resemblance of the robot to a real bird could be a large advantage when flying amongst birds."

The drones can glide with wings motionless, flap quickly to hover in place and soar if they catch thermal columns of rising hot air. But they lack the flexibility to perform avian motions such as folding their wings to dive quickly.

"We can certainly place the entire taxidermy wing on some sort of 'flapparatus' and move it as a whole, but in a living bird there are also various smaller muscles and ligaments to adjust its shape or fold it up," says Matěj Karásek at Czech company Flapper Drones. Such drones could eventually help study how living birds conserve energy by flying in a "V" formation, or how feather colour patterns change heat absorption and airflow in flight.

NEW MEXICO TECH

A flapping-wing drone with feathers from a dead bird attached

If the motors inside the drone body are sound-proofed, the bird-like drones could be useful for both sneakily studying birds and for acting as "spy drones for military use", according to the research paper the team presented at the American Institute of Aeronautics and Astronautics SciTech Forum in Maryland last month. ▮

Jeremy Hsu

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Astrophysics

Dark energy may have been hiding in the cores of black holes all along

Alex Wilkins

MASSIVE black holes could be the source of dark energy and the accelerating expansion of the universe, according to observations of ancient, dormant galaxies with black holes at their centre.

The laws of physics suggest that gravity should cause the universe to contract, but a mysterious force, which physicists call dark energy, seems to be counteracting this and making the universe expand at an accelerating rate.

One possible explanation is that the source of this dark energy is black holes, but there hasn't been good experimental evidence to support this idea.

Chris Pearson at the Rutherford Appleton Laboratory in Harwell, UK, and his colleagues compared groups of galaxies with black holes at their centre: a young, distant group and a closer, older group that have stopped growing. They calculated that the black holes grew in mass by seven to 20 times, which can't be fully explained by the absorption of stellar material or mergers with other galaxies.

Instead, Pearson and his team tried to account for the growth by proposing that it is related to the universe's accelerating expansion. "When we model that into what we see, we can actually explain the observations," says Pearson. "We can see that, in addition to these astrophysical processes for black hole growth, we can explain away this discrepancy in the mass growth by adding in the fact that they may contain dark energy and they're coupled to the expansion of the universe."

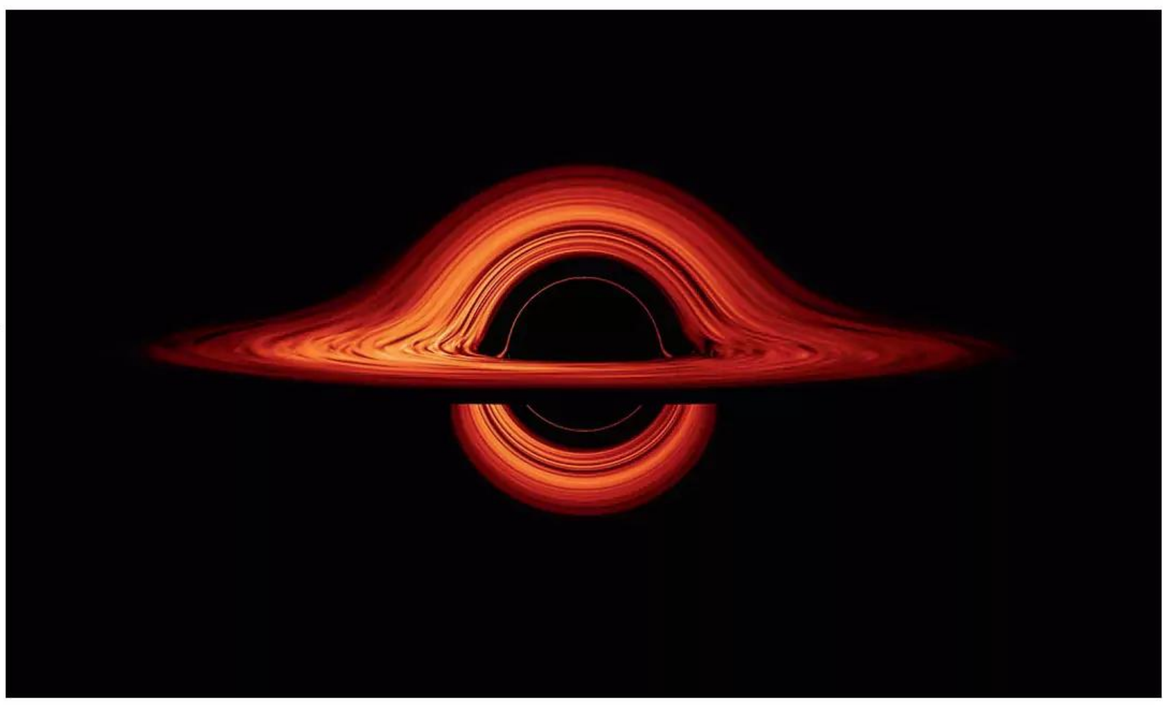
The model they used involved an interpretation of Albert Einstein's general theory of relativity that says that black holes contain vacuum energy, a kind of energy that exists in space everywhere due to quantum particles popping in and out of existence (*The Astrophysical Journal*, doi.org/grsgnk).

"When we did the sums, we found that these black holes might actually be able to explain the entirety of what's required to balance the universe with this dark energy," says Pearson.

If black holes really are the source of dark energy, it would also solve another outstanding cosmic conundrum: what happens at the centre of black holes – so-called singularities – where the laws of physics break down. Black holes with cores of dark energy avoid the need for singularities, but there weren't any easy ways to test this. "These have just been theories until now. Now, you've got the observational evidence that supports black holes having dark energy cores," says Pearson.

It is a solid and reasonable explanation of the observations, says Andy Taylor at the University of Edinburgh, UK, but the interpretation of Einstein's general theory of relativity it uses to explain the black hole growth hasn't been widely studied. "There's some nice discussion there, but we have to be cautious [because] it's not built on well-established theoretical principles, it's built on more speculative models." ▮

Simulation of a black hole, showing light distorted by its gravity



NASA'S GODDARD SPACE FLIGHT CENTER/JEREMY SCHNITTMAN

Technology

Fully autonomous F-16 fighter jet takes part in dogfights

AN ARTIFICIAL intelligence has controlled a US F-16 fighter jet in fights against other aircraft in tests.

The series of AI-powered flights took place in December 2022, but have only just been revealed by the Defense Advanced Research Projects Agency (DARPA), the research and development branch of the US Department of Defense.

DARPA had already tested AI control of jets on a simulator as part of its Air Combat Evolution programme. That research has now progressed to using a modified F-16 fighter jet. This jet, known as the X-62A, flew from the Air Force Test Pilot School at Edwards Air Force Base, California, several times during a single week.

A few AI algorithms were tested, attempting take-offs, landings and using simulated weapons in aerial battles. A human pilot was on board in case of emergency.

Autonomous military aircraft are being researched by countries around the world because they can be used in dangerous situations without risk to human life – at least on the aggressor's side – and can operate at g-forces that would incapacitate or kill a human pilot.

Notable as the achievement might be, Kenneth Payne at King's College London says the tests aren't that important in the overall progress of autonomous vehicles.

"There's relatively not a lot of complexity. In some respects, dare one say, it's easier as a challenge than autonomous cars," says Payne. With cars, you are in a complex environment, especially in a city with narrow streets and lots of humans around, he says. "A lot of these problems are stripped back in aerial combat."

> "In some respects, dare one say, it's easier as a challenge than autonomous cars"

Having AIs control combat also raises ethical issues about whether an algorithm can make the right decisions in complex, high-stakes scenarios, says Payne. But given that many countries are working on such technology, AI warplanes are likely to be developed and used anyway, he says. ▮

Matthew Sparkes

Environment

How healthy is your river?

Pollution isn't always easy to spot, but there are visible indicators that can reveal whether rivers are in a good ecological state, finds **Graham Lawton**

LOOKS can be deceiving when it comes to the state of UK rivers. I recently spent some time by the Fal river in south-west England, which looks beautiful and pristine, but is far from it. Much of it is in the Cornwall Area of Outstanding Natural Beauty and the river is the source of the Fal oyster, a protected designation of origin food. Yet it has been dubbed "the most polluted river in England".

Last year, the *Independent* newspaper analysed Environment Agency (EA) data on sewage spills in England and found that the Fal is the most fouled river in the country. In 2021, raw sewage flowed into the river for nearly 7500 hours, or more than 10 solid months, from one or more of the 103 storm overflows that discharge into it.

That seems shocking, but such events are an inbuilt feature of the wastewater treatment system in the area. They happen after heavy rain – not uncommon in these parts – meets Cornwall's 100-year-old drains. This is a combined system that mixes sewage (brown water) and household drainage (grey water) with rainwater and sends all of it to treatment plants.

"It's archaic," says Tessa Wardley at The Rivers Trust, a conservation charity based in Callington, Cornwall. "It hasn't been updated and upgraded. Sewage leaves your house in a pipe and it then goes into a pipe that the road drains go into as well."

After a storm, this deluge of rainwater and sewage overwhelms the treatment plants, threatening backflow of dirty water into homes and businesses. The local water company, South West Water, is permitted to open the emergency overflow pipes and discharge the excess straight into the Fal. "It's a massive problem," says Wardley.

One way, then, to gauge the likely health of a local river is to find out whether your sewage system is combined with rainwater run-off or is separate. In general, urban areas combine their sewage and rainwater while rural ones keep them separate. But this is only a rule of thumb, as Cornwall's system shows.

Alternatively, the EA publishes a detailed annual data set of storm overflows in England. Similar

"It's really becoming apparent that, actually, the chemical state of rivers is really, really poor"

resources exist for the other nations of the UK. It takes a bit of digging, but the information is there in granular detail. I was able to find that an overflow pipe near my accommodation in Cornwall, which drains into the Fal from a wastewater treatment plant in Mylor Bridge, made 179 discharges in 2021, adding up to 145.8 hours.

But bear in mind that this is far from comprehensive data, as not all of the overflow sites are monitored. Only 67 of the 103 discharging into the Fal collect data.

There are other gaps in the record too. The data only records the number of discharges and their duration, not the quantity of sewage-infused water going in. To the naked eye, the Fal clearly isn't awash with sewage, and the *Independent*'s story provoked fury in nearby communities. The claim that the Fal is the most polluted in England is "absolute rubbish", oyster fishery owner Martin Laity at Sailors Creek Shellfish, in the village of Flushing, told local newspaper *The Packet*.

Laurence Couldrick at the Westcountry Rivers Trust said the story was "dismaying". "This isn't

EDUCATION IMAGES/UNIVERSAL IMAGES GROUP VIA GETTY IMAGES

The river Fal has been called the most polluted in England

about the River Fal being the most polluted in the UK but rather the river suffering from the longest duration of a Combined Sewage Overflow (storm drains) spilling," he told *The Packet*. The monitoring that water companies do "only shows frequency and length of spills but crucially not volume," he said. In other words, the Fal is the river most frequently polluted with sewage in England, but not necessarily the most polluted.

16%
Proportion of rivers in England in good ecological health

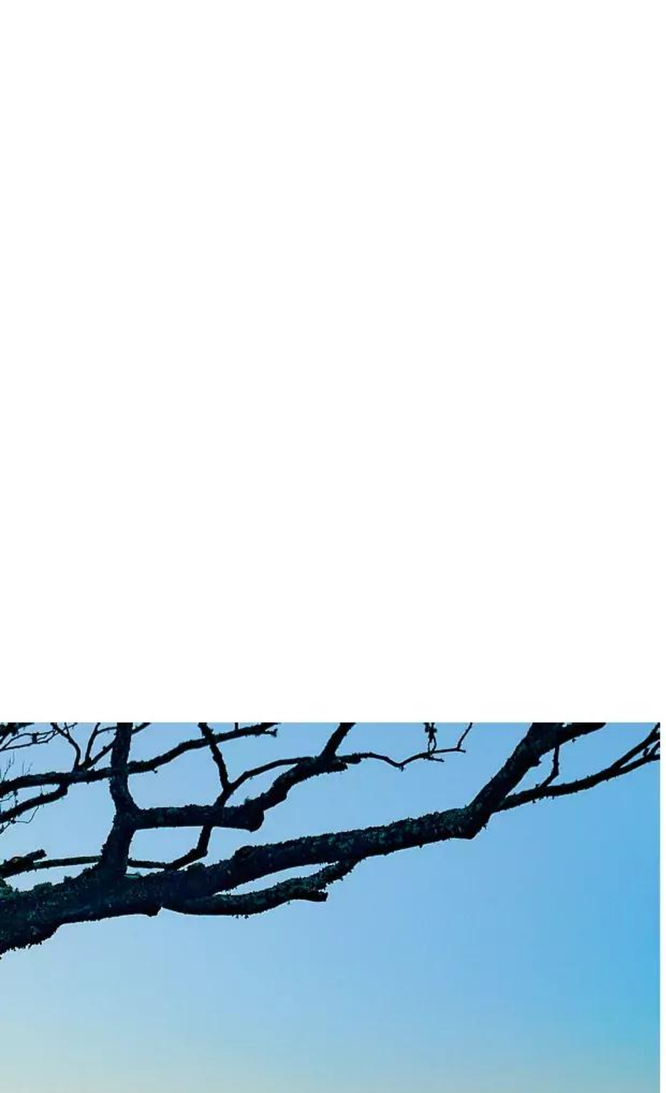
55%
Proportion of rivers in Scotland in good or high ecological health

44%
Proportion of rivers in Wales in good ecological health

33%
Proportion of rivers in Northern Ireland in good ecological health

Status updates

To get a better idea of the state of a river in the UK, you can check its ecological and chemical status. All surface water bodies in the country are assessed according to criteria laid down in the European Union's Water Framework Directive, and the classifications are published by the EA in England



and its counterparts in Scotland, Wales and Northern Ireland.

These ratings indicate that you can pretty much guarantee that any river in the UK isn't in the best ecological health and is polluted with chemicals.

On ecological health, there are five categories ranging from high to bad. Figures released by the Joint Nature Conservation Committee, which advises the UK government and devolved administrations, show that none of England, Wales and Northern Ireland's rivers is in the highest category, and only 8 per cent of Scotland's rivers reach this standard.

On chemical pollution, rivers are either classed as good or failing, based on allowable concentrations of 52 priority substances. According to these assessments, every single one of England's rivers is failing.

"It's really becoming apparent that, actually, the chemical state of rivers is really, really poor," says Wardley. The list of pollutants and their sources is long: pesticides, fertilisers, "forever chemicals" such as per- and polyfluoroalkyl substances (PFASs), factory effluent, microplastics, microfibres, medications that have been flushed down the toilet, paint thinners and cooking oil chucked down the drain, detergents, car wax and so on.

Without a chemical testing kit, however, there aren't many obvious signs of these pollutants. But there are visual clues that are decent indicators of the state of a river, in a more general sense, wherever you are in the world.

"You can look at the appearance of the river in terms of its physical nature," says Stephen Addy at CREW, Scotland's Centre of Expertise for Waters at the James Hutton Institute in Aberdeen. "Is it straight? Is it canalised? Is it deep? Is it not connected to its floodplain? These are all unnatural attributes."

Natural attributes are easy to spot, says Michael Acreman at the UK Centre for Ecology & Hydrology in Wallingford. "Natural rivers have complicated forms, meanders and so on, and habitat diversity. There'll be one bit that'll be deep and the next bit is quite shallow, and you can see some rocks and you can see the water being turbulent and sparkling a bit, and you can often hear it. All those things you note from a healthy river that you don't get if you go to an unhealthy river."

JANE TREGELLES/ALAMY

Pollution can cause blooms of blue-green algae that stifle plants

As for water quality, it is difficult to judge from simply looking at the water itself. "Rivers are often quite murky and people will think, 'I wouldn't jump in there', but very often that's just sediment," says Wardley. "They collect colour from their geology, so they're not necessarily polluted, but really you can only tell if you start to look at the plants and animals."

Smaller species are a good starting point. "In terms of water quality, there could be issues such as very high algae cover, or even, in extreme cases, blue-green algae, which is dangerous," says Addy.

Flagship species

Wardley says a total giveaway is the presence of so-called sewage fungus, a gross-looking mass of slimy, brown filamentous bacteria that thrive in nutrient-polluted water. "If you see that coating the stones and in the water on the river, you can be pretty sure you've got water quality issues."

Larger flora and fauna are good indicators of river health. The presence of fish is a positive sign, as is lush, green vegetation in the channel and along the banks. There are also a few "flagship species" of good health, including otters, freshwater pearl mussels and birds called dippers. "They rely on a good supply of macroinvertebrates in the river and they're an indicator of good water quality," says Addy. As for raw sewage, we all know it when we see it.

"It can be quite hard to tell just by looking at the river," says Wardley. "But there are signs that anyone can see. And smell." ▮

MATT CARDY/GETTY IMAGES

Fishers gathering Fal oysters near Falmouth in Cornwall, UK

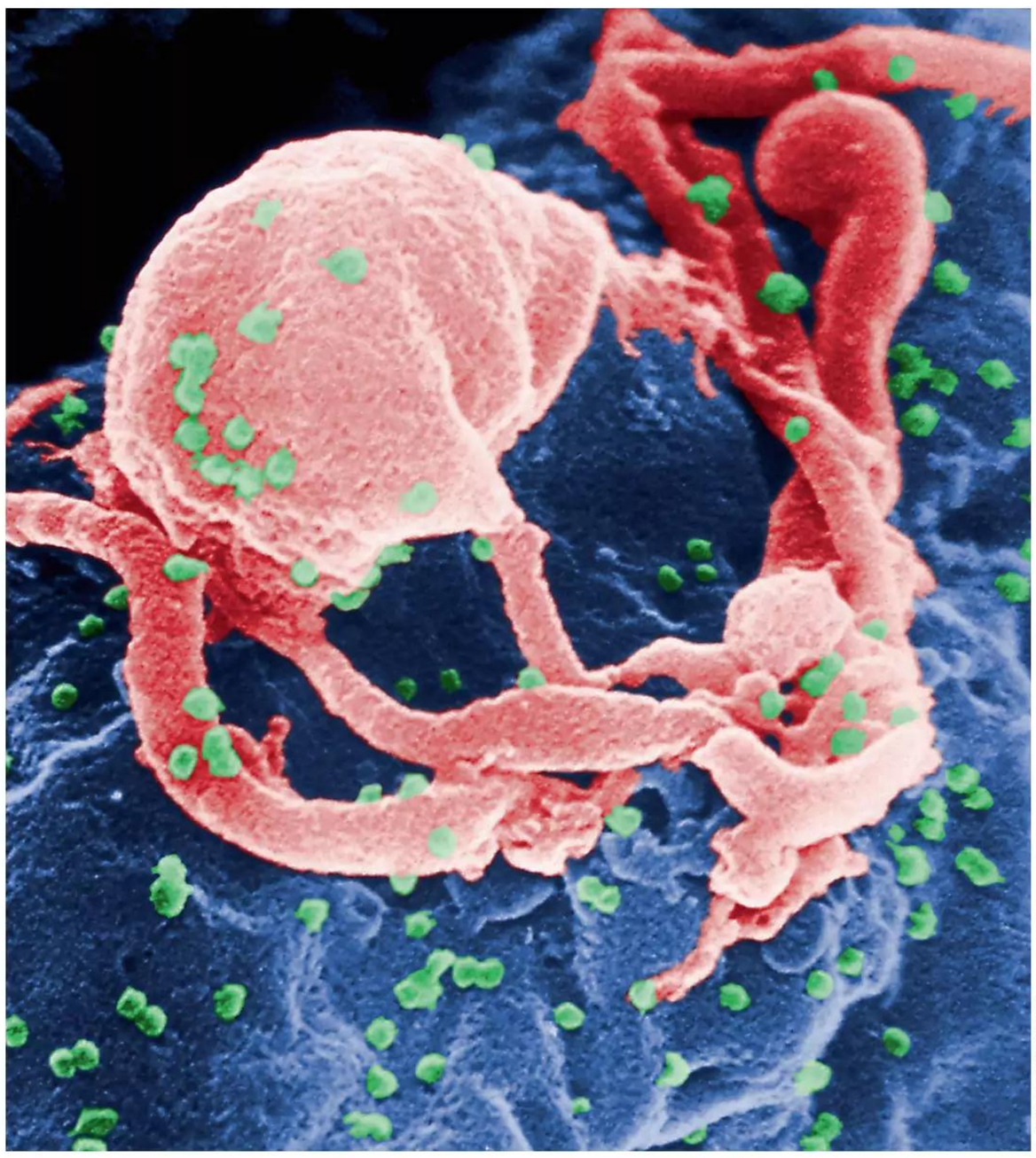
Zoology

Young prawns make their eyes invisible

PRAWN larvae camouflage their eyes with a light-manipulating material that reflects the colour of the surrounding water.

Some sea creatures have transparent bodies to avoid being seen by predators. However, their eyes contain dark pigments essential for vision. Benjamin Palmer at Ben-Gurion University of the Negev in Israel and his team investigated how transparent-bodied larvae of the giant freshwater prawn (*Macrobrachium rosenbergii*) conceal their eyes.

They found they are overlaid by photonic glass – a material that has unusual optical properties. In the case of the prawns, this reflects yellow-green light, matching the colour of the murky estuaries in which they live, suggesting it helps to camouflage them (*Science*, doi.org/jw4m). **Alice Klein**



C. GOLDSMITH/CDC

Physics

Water drops bounce on weird waves

AN UNUSUAL water wave can repeatedly toss a water droplet into the air thousands of times without breaking it.

For the past decade, Nicolas Mujica at the University of Chile and his collaborators have studied how wave patterns emerge on the surface of water when it is shaken or disturbed. Recently, they made the accidental discovery that, under the right conditions, a wave can bounce a droplet of water up and down thousands of times.

The finding came while Mujica and his team were making a type of wave called a soliton – instead of having ripples at the surface, each of these is formed of a single undulating bump. They used high-speed cameras and found water droplets could bounce on the surface for up to 90 minutes (*Physical Review Fluids*, doi.org/jw4q). **Karmela Padavic-Callaghan**

Medicine

Third person is 'cured' of HIV by cancer treatment

A 53-YEAR-OLD man in Düsseldorf, Germany, has been declared cured of HIV by doctors after a blood stem cell transplant to treat leukaemia – the third case of this kind.

The man has no signs of active infection four years after he stopped taking antiretroviral drugs. "We don't think there's a functional virus present," says Björn Jensen at Düsseldorf University Hospital

The "Düsseldorf patient" tested positive for HIV in 2008. In 2011, he developed leukaemia that was treated with chemotherapy, but it came back the following year. So, in 2013, the blood stem cells in the man's bone marrow that give rise to immune cells – including the cancerous ones – were killed off by chemotherapy and then replaced with donor blood stem cells.

Crucially, doctors found a donor with a mutation that disables the CCR5 receptor that HIV uses to infect immune cells (pictured above is HIV, in green, infecting an immune cell). This transplant made the man's immune system HIV-resistant.

In 2017, the team was able to stop giving him immunosuppressing drugs to prevent rejection of the donor cells and, in November 2018, antiretroviral treatment was halted (*Nature Medicine*, DOI: 10.1038/s41591-023-02213-x).

Two other people treated for cancer have previously been reported to have been cured of HIV in the same way. However, because bone marrow transplantation is risky, and given that drug treatment can keep the virus in check, this will never be used to treat HIV alone.

One alternative approach that is being explored is to use gene editing to mutate the *CCR5* gene in the immune system of people who are HIV-positive. Michael Le Page

Really brief

RICCARDO ALBA (UNIVERSITÀ DI TORINO, TURIN, ITALY)

Avalanches boost diversity of birds

Periodic avalanches in the Alps clear sections of dense forest populated mainly by tits, thrushes and woodpeckers, making way for shrubs and smaller trees that appeal to whinchats (pictured above), pipits and buntings. Overall, the landscapes host a wider variety of bird species (*Journal of Ornithology*, doi.org/jw4g).

Making your voice sound less weird

It is easier to recognise your own voice if you listen to recordings of it via bone conduction headphones, as they mimic the vibrations from your skull that the brain detects as you speak. The discovery could help some people with schizophrenia who hear voices (*Royal Society Open Science*, doi.org/jw4j).

Wood shield blocks electromagnetism

Ultra-thin sheets of wood modified with nanocrystals can work as a shield against electromagnetic waves. They could be a way of protecting electrical devices against potential disruption caused by electromagnetic radiation (*Advanced Functional Materials*, doi.org/jw4p).

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Views

The columnist
Was farming really a big mistake, asks **Michael Marshall** p28

Aperture
Chilling photos capture the Polar Silk Road p30

Letters
The 2000-watt challenge sparks a lot of interest p32

Culture
Tracing the epic history of the world's oldest trees p34

Culture columnist
Simon Ings on the disturbing afterlife of *Next Exit* p36

Comment

Parliaments of the future

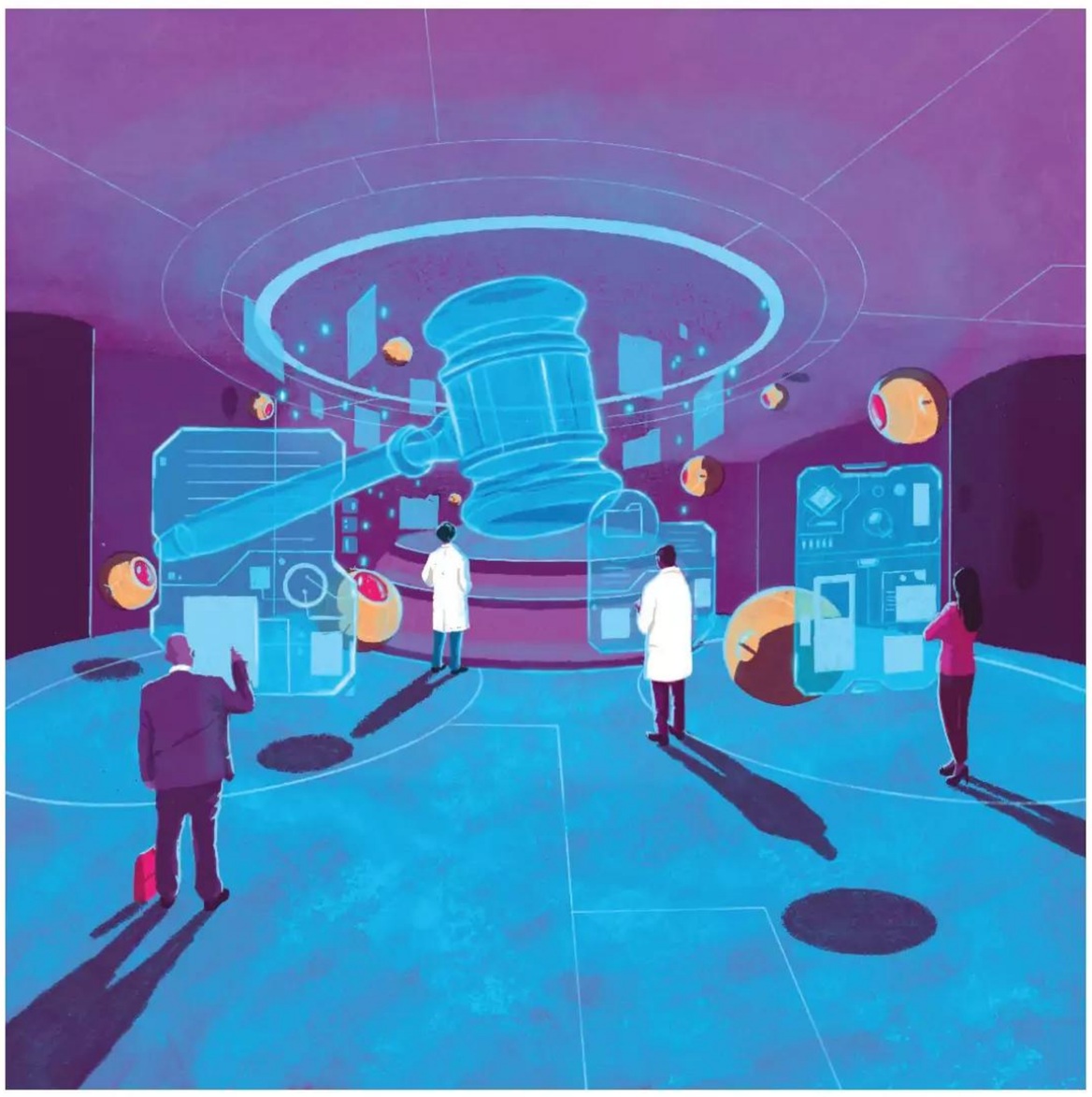
Speculative fiction authors try to predict the worlds that will arise from technological change. So should governments, says **Ray Nayler**

RECENTLY, something so dystopian occurred that it seems worthy of a cyberpunk novel. A woman who was blind was given an implant that allowed her to see again – and then, a few years later, the implant failed, so she became blind for a second time. Because the firm that invented the implant hit financial troubles and stopped supporting its products, there was no one to help. She still carries the dead implant in her eye, as surgery to remove it would be too risky.

How this happened is simple enough: tech companies sometimes stop supporting their products. Who is then responsible for the devices embedded in people's bodies? No one.

The question we should ask about someone being suddenly rendered blind again by a firm's decisions isn't "How did this happen?", but "Why would any government allow this to happen?". Some new technology can't be predicted, but much of it can. Cutting-edge medical implants, and the high stakes that would follow for people's bodily integrity, certainly weren't unpredictable.

Here are a few more examples: we knew for years that machine learning might infringe on the copyright of artists by snatching up and blending anything available on the internet, but nobody framed out a way to compensate creators for the theft of their intellectual property. And despite the fact that social media companies have become de facto communications utilities, often serving as the only method for broadcasting atrocities occurring in places that are hard to reach for traditional journalism, they have been allowed to decay into the unstable personal fiefdoms of attention-seeking billionaires.



SIMONE ROTELLA

Foresight from law-makers could have prevented many of these issues. To avoid them in the future, legislative bodies must learn what we writers of speculative fiction already know: predicting the near-future for technology is relatively easy, but the real job is more complicated than that. We must, then, imagine the worlds that come as a result.

The focus of speculative fiction isn't on science or tech itself. It is wider: it is on what effect a change will have on society. My novel *The Mountain in the Sea* examines what trying to communicate with a highly evolved octopus species on Earth might be like (spoiler: it is difficult), but also explores the impact of technological developments on real issues.

Governments should borrow from the speculative fiction playbook. "Parliaments of the future" – groups of technologists, social scientists, economists, legislators and perhaps even writers – should be formed to game out the effect of emerging technological developments and to prepare framework legislation ready to ensure better protection of human and consumer rights, as well as civic freedoms.

It isn't that governments aren't trying to predict the future – they are. It is that these predictions aren't linked back to creating better legislation, lack transparency and are over-reliant on the false promises of quantitative data and artificial intelligence. The future can't be "solved for". It isn't a mathematics problem. Predicting the impacts of change demands human creativity.

In an era of continuous technological change, it isn't enough for states to cobble legislation together after it is too late to stop, or at least help alleviate, the negative impacts of the "next big thing". We need to have legislation ready for the technology of 10 years from now.

You will be thankful for that when your neural implant stops functioning and you learn that a parliament of the future developed legislation ensuring your implant's proprietary technology became open source following its parent company's failure, and there are now a dozen ways to fix your cyborg brain. ▮

Ray Nayler is author of the speculative fiction novel *The Mountain in the Sea*

Our human story

Worst mistake in history? The notion that our ancestors' shift from a hunter-gatherer lifestyle to farming was disastrous for our health is well established. But is it correct, asks **Michael Marshall**

Michael Marshall is a science writer based in Devon, UK. He writes *New Scientist*'s monthly email newsletter Our Human Story, which is about human evolution. His book *The Genesis Quest* is about the origin of life on Earth and is now available in paperback.

Mike's week

What I'm reading
On a Sunbeam, *Tillie Walden's graphic novel about a young woman searching for her lost girlfriend in deep space.*

What I'm watching
I'm sorry to report that despite Cate Blanchett's performance, I intensely disliked Tár, *a film with all the momentum of a slug towing a neutron star.*

What I'm working on
The proposal for my putative second book. Apparently, I'm a glutton for punishment.

Up next week:
Chanda Prescod-Weinstein

STOP me if you have heard this one before: the transition to farming was a cataclysmic turn for the worse. Beginning around 12,000 years ago, some of our ancestors started cultivating crops, abandoning the egalitarian and sustainable hunter-gatherer lifestyle that had worked for hundreds of thousands of years. The result was poor health, limited diets, new diseases and unsustainable practices that have culminated with climate change and a sixth mass extinction.

This narrative has become well established. But like so many stories about our prehistory, I am not sure we should believe it.

Traditionally, anthropologists thought of prehistory in terms of progress. This meant the advent of farming was seen as an advance over hunting and gathering, which was older and so more primitive.

However, in the late 20th century, the assumption of progress came in for criticism: why is a farming society "better" than a hunter-gatherer one? Around the same time, research suggested that the first farmers had poor health compared with their hunter-gatherer ancestors.

Key evidence of this came from studies of changes to average height. People who are well nourished and healthy tend to grow taller than those who often go hungry. Crucially, the archaeological record indicated that the first farmers were shorter than hunter-gatherers.

The idea was summed up in a 1999 article by Jared Diamond. He described farming as the "worst mistake in the history of the human race", which is pretty unambiguous. The idea of farming as progress had been overturned.

You know there is a "but" coming, right? Last month, the journal *PNAS* published a special issue on the past 12,000 years. It included a study of changes in human body size by Jay Stock at Western University in London, Canada, and his colleagues. The research dramatically reframes the question of how switching to farming affected our health.

Stock's team compiled data on 3577 skeletons from 366 archaeological sites in Europe, Asia and North Africa. The remains span the period from 34,300 years ago to the present. There is obviously a lot of variation, but average body size gradually declines from 34,300 years ago until about 6000 years ago, when it increases again. This isn't what you would expect if switching from hunting and gathering to farming was bad for our ancestors.

"I have one more hypothesis: humans got smaller because they had overhunted big animals like mammoths"

The increase in body size around 6000 years ago might be linked to mutations enabling adults to drink milk. But why were people getting smaller for thousands of years before they started farming?

Let me state upfront that the paper doesn't offer a clear answer for this and I don't have one either. The researchers point out that communities didn't switch to farming overnight. Many early farmers still did some hunting and foraging. This muddies the picture.

We might also invoke climate change. Between about 110,000 and 12,000 years ago, Earth was in a colder phase. Temperatures reached their lowest point around 20,000 years ago. It is possible that the frigid climate made it harder for hunter-gatherers to get by. But that doesn't explain why body size kept shrinking after temperatures started warming up again.

I have one more hypothesis: that humans got smaller because they had overhunted big animals like mammoths, leading to a shortage of nutritious meat. In 2021, I reported on the work of Miki Ben-Dor at Tel Aviv University in Israel and his colleagues, who claimed that overhunting of large animals forced humans to gradually switch to other food sources.

It is conceivable that hunter-gatherers gradually denuded their environments of large animals, forcing them to rely more on smaller prey and on managing wild plants. This could explain why humans shrank for thousands of years. But just like the other hypotheses, this comes with major uncertainties. In particular, Ben-Dor and his team's claim that early humans drove megafauna declines is very much up for discussion.

Putting these difficulties aside, I do think the new study of human body size should prompt a rethink of our ideas about the impact of farming on our health. Diamond's claim it was the worst mistake our ancestors ever made now seems at best an exaggeration (I am pretty sure the invention of absolute monarchy was a worse idea).

We shouldn't take this argument too far. Farming didn't prompt an immediate increase in body size, so I don't think the study would support the opposite narrative of farming being unambiguous "progress". But maybe, instead of it being a silly mistake we then became locked into, it was the best possible choice at the time. ▮

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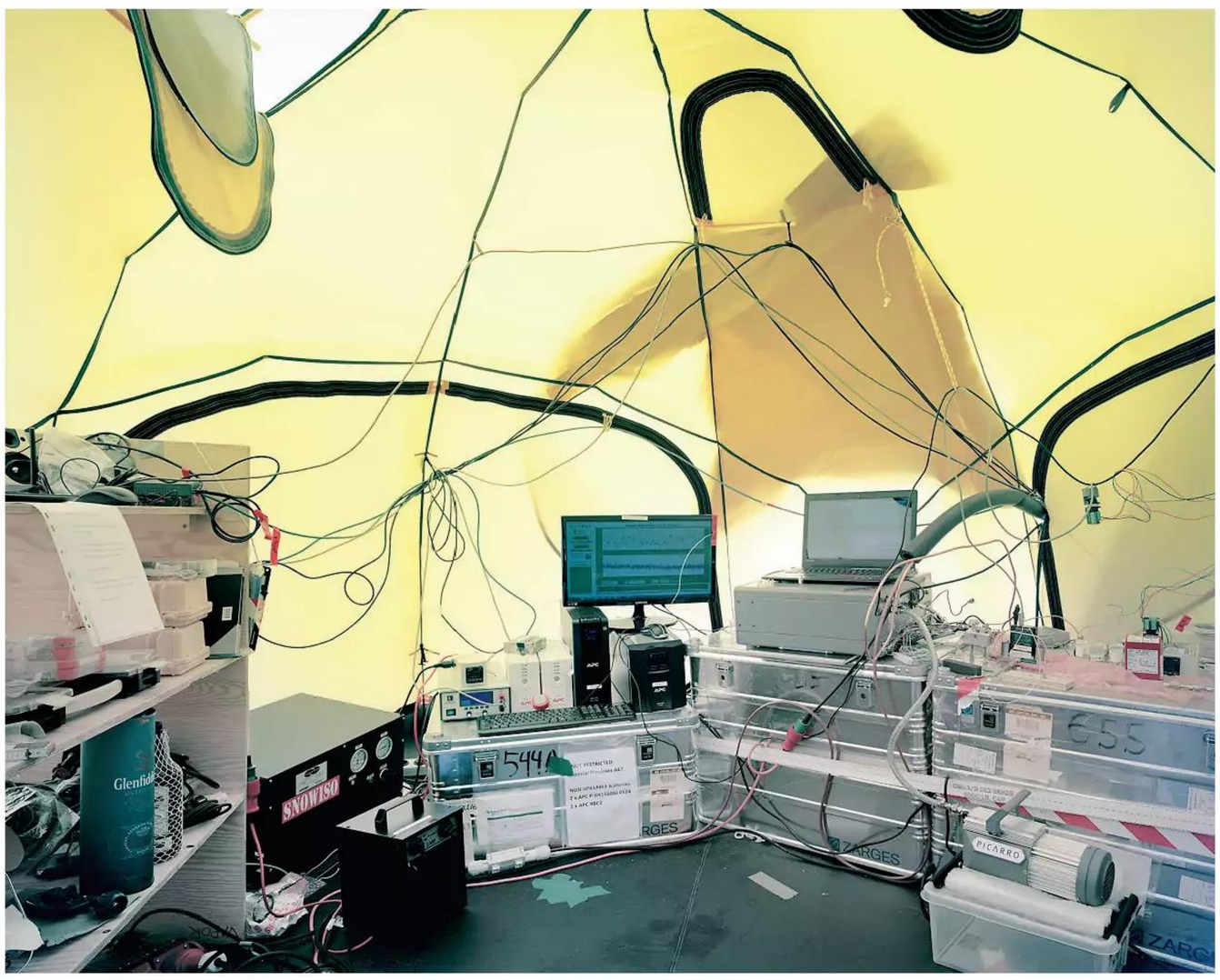
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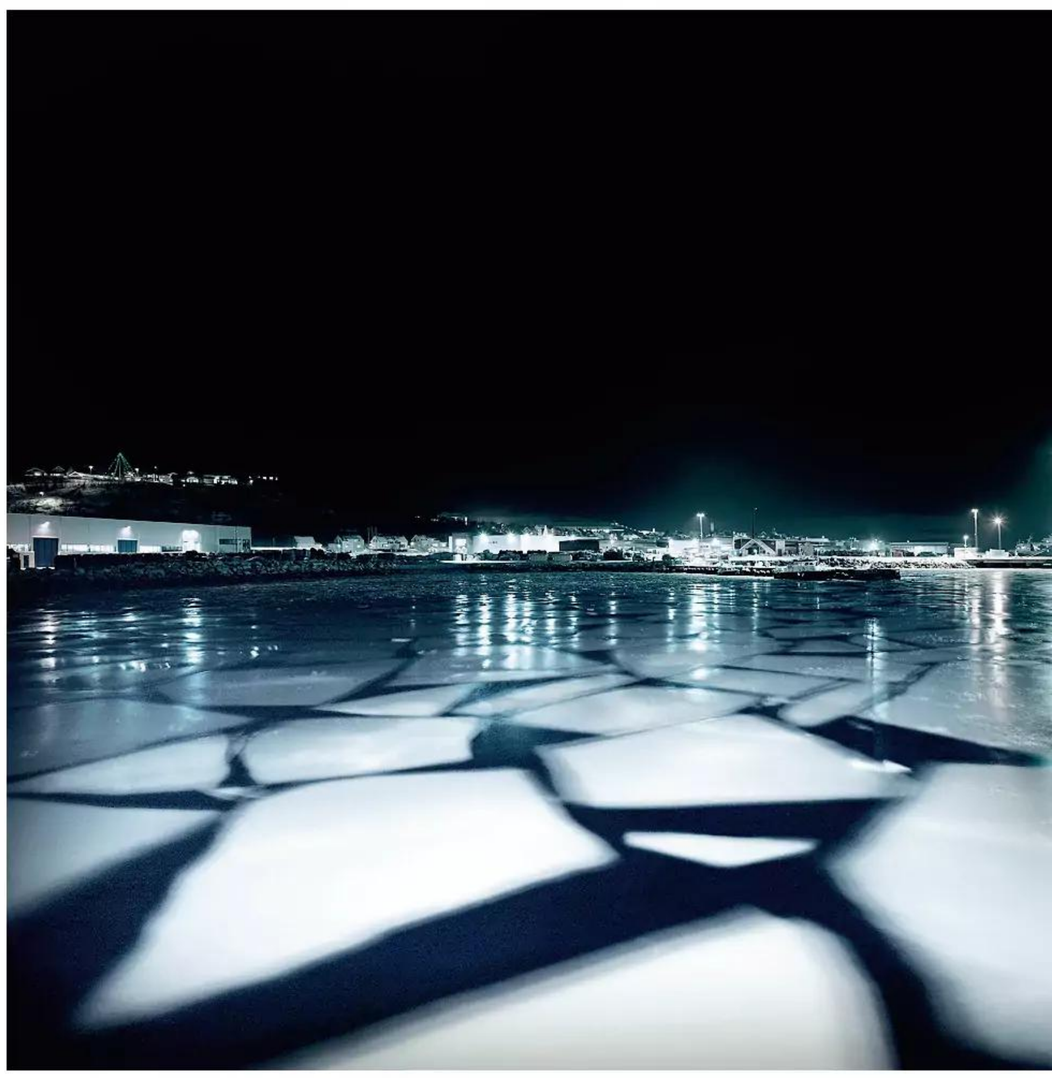

On thin ice

Photographer Gregor Sailer
Alfred Ehrhardt Foundation

THESE chilly and chilling images, taken within the Arctic circle, capture the economic and geopolitical tensions that are only growing in the region as global warming accelerates. They come from photographer Gregor Sailer's latest project, The Polar Silk Road.

Its title refers to new routes that are being carved out across the region to facilitate trade between the US, western Europe and east Asia. At sea, this has only become possible as more ice melts.

The Arctic is home to many research and military bases. The top row of photographs highlights military outposts. To the left is the Norwegian Observation Post 247, on the country's border with Russia. Next to it is an image of the deep-water, underground submarine dock at the Olavsvern naval base in Tromsø, Norway.

In the bottom row, far left, is equipment needed for the East Greenland Ice-core Project on the north-east Greenland ice sheet. This endeavour was created to drill through the sheet to find out how the flow of this frozen mass to the ocean will affect future ice loss.

For shipping to thrive in the frozen north, ports are needed, such as Kirkenes on the Barents Sea in Finnmark, Norway, shown centre bottom with broken sea ice just off the coast.

The final image is of the Miðnesheiði radar site in Iceland, part of NATO's air defence system, which now primarily monitors air traffic and directs aircraft.

The Polar Silk Road photographs are on show at the Alfred Ehrhardt Foundation in Berlin until 2 April.

Gege Li

Editor's pick

The 2000-watt challenge sparks a lot of interest

11 February, p 36

From Roy Harrison, Verwood, Dorset, UK

James Dinneen's article on the challenge of reducing our rate of energy consumption to 2000 watts encouraged me to put some numbers into a calculator.

Our car used 748 litres of fuel over a period of 381 days. Taking the energy value and density of diesel as 43.1 megajoules per kilogram and 0.832 kg per litre gives it a score of 816 watts. Our house used 3632 kilowatt-hours of electricity in the 336 days since a heat pump was installed, giving a further 450 watts, while the stovetop's 2 cubic metres of gas adds a further 3 watts. With flying and public transport both zero, this gives a total of 1269 watts, albeit only for the things directly under our control. This is divided between two of us, so 635 watts each.

However, this doesn't take into account the, at best, 50 per cent efficiency of gas-fired power stations or the 14 per cent losses in the electricity grid, and thus we have an overly rosy view. It gives a particularly rosy view of the heat pump, since its installation increased electricity consumption, but, in the absence of more wind, solar or nuclear power, it all came from gas-fired power stations.

From Robert Peck, York, UK

The difference between averaged power usage, as imagined in the 2000-watt challenge, and peak power usage is important. It is the latter value that grids must be designed to supply, with power stations ready to fire up to meet it, especially when renewable inputs are lacking. These stations are usually gas fired, and this makes ending our addiction to fossil fuels hard. New nuclear power plants could help us to meet the demand. Excess produced when consumers don't need it could be used as off-peak power for industrial tasks, such as the manufacture of some energy intensive products.

From Richard Oliver, Nottingham, UK

Dinneen switched from drying his clothes in a powered dryer to hanging them indoors. Does this really use less energy? Surely, the energy to evaporate the water is the same regardless. Of course, the best thing would be to hang clothes outside, but, where this isn't an option, the evaporation would cool a building and make any heating system work harder.

From Larry Stoter, The Narth, Monmouthshire, UK

One of the most significant long-term contributions people can make to cutting carbon emissions and energy use is to have fewer children.

Dark matter is just the pull of other universes

11 February, p 46

From Jeffrey McClure, Salado, Texas, US

There is a relatively simple solution to the question of dark matter – the unseen mass thought to be exerting an additional gravitational effect on galaxies.

In his book *The Elegant Universe: Superstrings, hidden dimensions, and the quest for the ultimate theory*, Brian Greene explains that string theory postulates that gravity can cross the barrier between universes. Again, according to Greene, our universe may exist immediately next to others, and the gravity from mass in those universes bleeds through into ours. As a result, galaxies in neighbouring universes are drawn into alignment with galaxies in ours, influencing the gravitational attraction we observe.

That idea seems to me to be the best explanation for dark matter.

Eel migration may have got longer very slowly

Letters, 11 February

From Nuala Lonie, Linlithgow, West Lothian, UK

Reader Chris Hall wonders what Darwinian forces might drive European eels to undertake a 12,000-kilometre journey across the Atlantic and back to breed. This could be an adaptation to the formation of the ocean about 150 million years ago via slow spreading of tectonic plates.

Perhaps eel ancestors had breeding grounds bordering the infant ocean. As the Atlantic got wider, the journey lengthened by a little every year. Selection would favour those that could cope with the increasing distance.

Many cultures don't regard nature this way

11 February, p 26

From James Fradgley, Wimborne, Dorset, UK

You say that "for much of recent human history, nature has been regarded as mere property... to be exploited". Many cultures don't see nature that way at all, and I suggest it is the Judaeo-Christian idea that we have "dominion over nature" that is the main problem.

Is this how our immune systems keep fighting fit?

4 February, p 43

From Jim McHardy, Clydebank, West Dunbartonshire, UK

Your feature on immunity states that the immune system wastes its resources attacking the cytomegalovirus pathogen, which persists nonetheless. If this virus rings our immune alarm bell so much, you might assume that the immune system would have evolved to kill it off.

Could this be like countries holding war games to keep their armies fit for purpose? Rather than being a drag on resources, the immune system may be using the stimulation from this virus to ensure it remains fighting fit.

I fear the spread of bird flu to many more species

11 February, p 8

From John Davnall, Manchester, UK

You report that mammals such as foxes have been infected by the current bird flu virus. This has been attributed to scavenging of the carcasses of infected birds.

It seems to me only a matter of time before other wild mammals – especially rats, as scavengers, and squirrels, as raiders of bird nests – become infected. These creatures can be prey for cats, which raises a fear of the virus coming into contact with people that way.

Pondering the limits of mammalian mutualism

4 February, p 44

From Virginia Lowe, Melbourne, Australia

You report that mongooses and warthogs display "the only known mammal-mammal mutualism in the world". That does seem to be true of land-based mammals.

I wonder if there are valid examples for marine mammals, such as seals leaving their young pups to be watched over in sea lion nurseries, or seals, dolphins and sea lions playing together. And what about orcas and dolphins cooperating with human fishers? ▮

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For the record

▮ **Andrew Rogoyski works at the University of Surrey, UK (4 February, p 25).**

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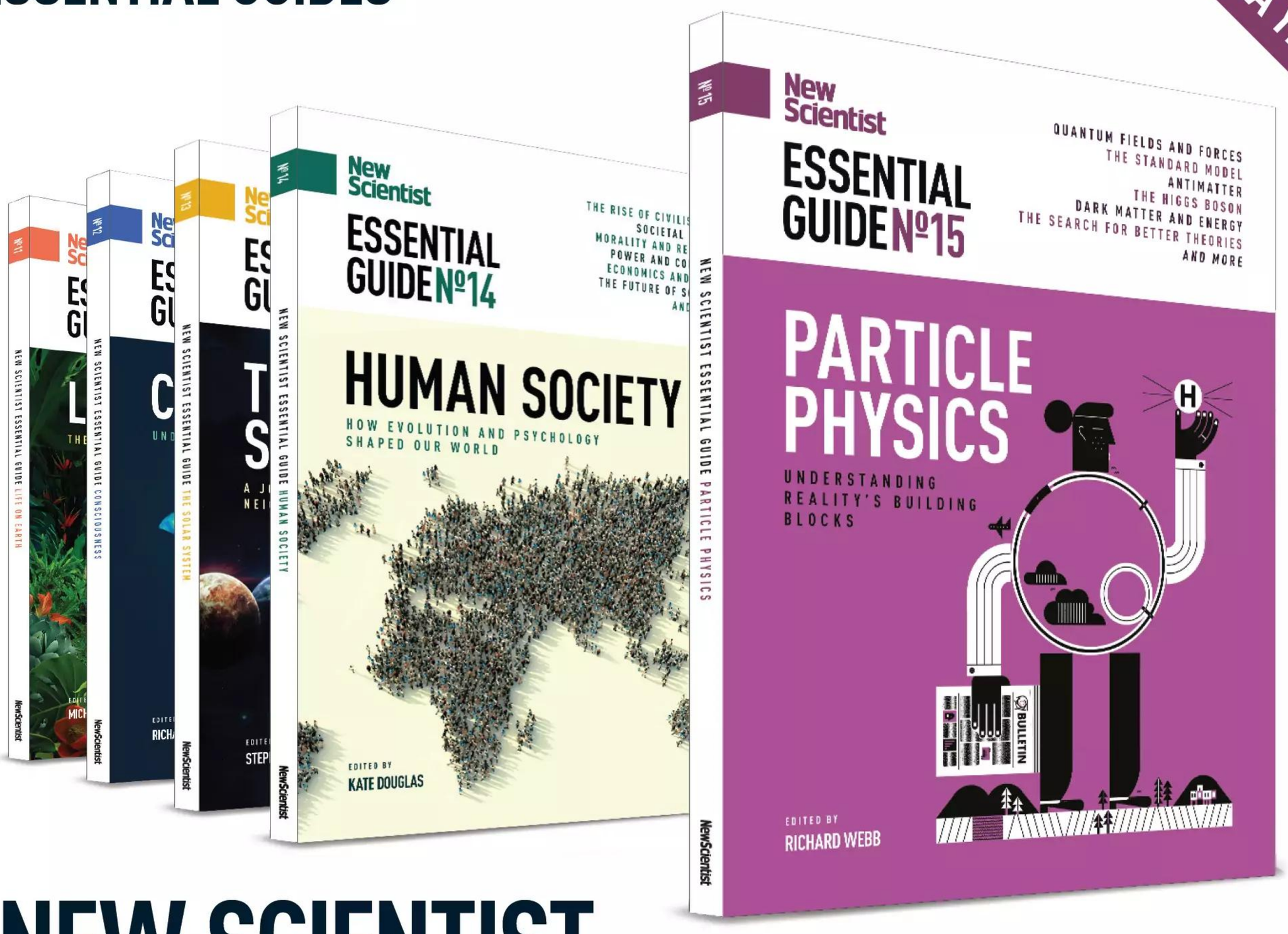

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The wonder of old trees

A history of ancient trees is a great idea for a book and makes an excellent read – when it stays on topic, says **Graham Lawton**

Book

Elderflora: A modern history of ancient trees

Jared Farmer

Picador

WHEN the Hardy Tree in the graveyard of St Pancras Old Church finally fell in December last year, London lost a unique and much-loved landmark. This ash tree was surrounded by upstanding headstones that had been moved there in the 1860s to accommodate a new railway line. Legend has it that the arrangement was created by a young Thomas Hardy while he was working as an architect on the construction of St Pancras station.

The Hardy Tree came to my mind as I read *Elderflora*, which is ostensibly a book about ancient and (sometimes) venerated trees, but is so much more – and often less – than that. It is a great idea for a book and the parts of it that stick to the script are an excellent read. But it is also a frustrating and confusing book that often doesn't seem to know what it is trying to achieve.

Jared Farmer, a professor of environmental history at the University of Pennsylvania in Philadelphia, begins his book with a tantalising premise. He wants to visit the remains of the longest-lived organism in the world, the stump of a Great Basin bristlecone pine (*Pinus longaeva*), which lived and died on Wheeler Peak in Nevada. When it was cut down in 1964, it was estimated to be at least 4862 years old, meaning it germinated around the time of the collapse of the 1st dynasty of Ancient Egypt.

Unfortunately, this excellent opening gambit soon gets lost in the forest of a meandering introduction, 26 pages of dense and overwrought prose that quickly goes off topic and stays there. The tone is exemplified by this utterly baffling and pretentious sentence: "By sharing stories of human relationships with alien organisms – for ultraterrestrials experience time and place (time in place, place in time) in ways so earthly they seem otherworldly – I hope to say something hopeful, or at least anti-hopeless, about linear time including the future." Nope, me neither.

"At its best, the book is a masterful blend of natural and human history – with an emphasis on human"

But I soldiered on and was rewarded. When he stays on message, Farmer is an entertaining and erudite guide to the world's oldest trees and what they mean to us. We meet the cedars of Lebanon, ancient olives, ginkgos (my favourite tree), the bizarre-looking baobabs and the venerable yews of English churchyards.

At its best, the book is a masterful blend of natural and human history – with an emphasis on the human. Farmer's elderflora aren't just amazing old organisms, but a backdrop against which human drama, hubris and decency play out.

At its worst, however, the book is a trudge through miscellaneous facts and brief encounters with long-forgotten people that fail to hang together. I was reminded of Arnold Toynbee's criticism of his fellow historians that too many of them treated history as just "one damned thing after another".

Despite the ups and downs, a strong theme runs throughout: the wanton destruction of old trees, especially during the rapacious colonial period of the 19th century. We read of European settlers in New Zealand, dreaming of commandeering the endemic conifer forests, logging them and converting them into pasture and eucalyptus plantations, then doing exactly that.

Similar grief-inducing stories of ruthless exploitation and self-appointed superiority litter the book. Farmer skilfully draws this line into the present day in the guise of climate change, which is both a modern form of colonialism and an imminent threat to many of the world's oldest and biggest trees, as well as the vital functions they perform within their ecosystems.

Farmer wraps up with the story of the ancient bristlecone pine cut down in 1964 under controversial circumstances. I was awaiting a moving account of his own visit to the stump of the tree, technically called WPN-114, but widely known as Prometheus. Spoiler alert: it disappointed me in its brevity when it could have made a magnificent end to a book about magnificent things. ▮

This Great Basin bristlecone pine (*Pinus longaeva*) in Nevada is more than 4000 years old

TAYFUN COSKUN/ANADOLU AGENCY/GETTY IMAGES

Dementia's other stories

A compassionate rethink of those who care for people with dementia is welcome, says **James McConnachie**

JORM SANGSORN/GETTY IMAGES

Book

Travellers to Unimaginable Lands
Dasha Kiper
Profile Books

PEOPLE who care for those living with dementia, says Dasha Kiper, are its "invisible victims", rarely discussed in the research literature and given little support. Kiper has made a career out of listening to them. At 25, she moved in with a 98-year-old Holocaust survivor in the early stages of Alzheimer's disease and, after completing a master's in clinical psychology, she spent 10 years counselling carers and running support groups.

Travellers to Unimaginable Lands: Dementia, carers and the hidden workings of the mind **is her first book. It tells the stories of people with dementia and of their carers. Modelling herself on Oliver Sacks, Kiper weaves psychological and neurological research into her own insights about the work of writers including Samuel Beckett, Franz Kafka, Herman Melville and Jorge Luis Borges.**

Kiper can write with a Sacks-like clarity. One carer "seemed coiled in place, as though it were painful to sit still", while her mother "paced back and forth, with an irregular, limping gait… and each shuffling step felt like an interrogation".

But where Sacks's cases are outlandish, Kiper's are desperately ordinary. Take Jasmine, who taped notes on doors and walls, imploring her mother not to take food out of the freezer, leave the house or be violent. Or Elizabeth, whose husband sometimes denied knowing her and would throw her out as a stranger.

"People always ask about the patient," Elizabeth tells Kiper. "Let me tell you something, the patient

The journey through dementia is a profound and disturbing process for the caregiver and the cared-for

is fine; it's the caregiver who's going crazy." Carers often mirror the behaviours of those they look after, Kiper notes, engaging in denial, distortion, arguing, blaming and endless repetition.

The key driver is what Kiper calls dementia blindness. Much in the way our brain fills in for our visual blind spot, so carers see the person they are used to seeing. Discussing this, Kiper refers to writer Nassim Nicholas Taleb's theory of narrative fallacies, philosopher Daniel Dennett's intentional stance and neuroscientist Michael Gazzaniga's left-brain interpreter – unconscious, evolved processes "responsible for sweeping inconsistencies and confusion under the rug".

Conspiring with these processes are our emotional biases, Kiper writes, including our evolved need for "mutually agreed-upon reality", which is most acute with those we are close to and in situations where we aren't in control. This creates what she calls the carer's dilemma: to "accept something less" than the person we knew means letting go of our idea of who they are, which risks dehumanising them.

Kiper's literary interpretations echo her radical leap: to see impossible situations from the point of view of the carer or family member. Melville's *Bartleby, the Scrivener* – the story of a clerk who rejects everything, saying he would "prefer not to" – is seen from his employer's viewpoint as he struggles to make sense of the situation, while being in many ways needier than his self-contained clerk. Kafka's *Metamorphosis* is read as a portrait of family dynamics taken to absurdity. Beckett's *Waiting for Godot* dramatises how "we create and acknowledge the possibility that clarity, meaning, and connection exist even when there appears to be only strangeness and futility".

These aren't just original readings, they have a compassion that bring Sacks to mind. Carers, Kiper writes, are "'tortured' in living rooms and kitchens, rooms that hold memories and trigger old patterns of behaviour, rooms that damn them to choose an unhappy or unnerving dynamic over no dynamic at all".

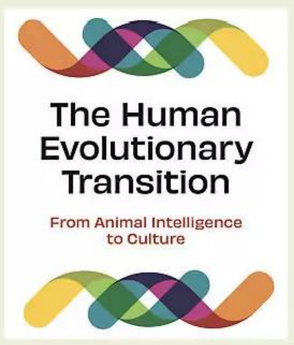
This is a wise book, and one that is unsettling in the best way.

James McConnachie is a writer and an editor based in London

Don't miss

Visit

Stolen Climate: Global perspectives of fire on Earth unites artists and scientists to explore wildfires in history and ecology, with a preview of art by Clinton Naina. It runs from 3.30pm GMT on 1 March at Science Gallery London.



Read

The Human Evolutionary Transition is the name Magnus Enquist, Stefano Ghirlanda and Johan Lind give in their new book to the rise of the uniquely strange and powerful human intelligence. On sale from 28 February.

Visit

The Patriarchs: How men came to rule is a talk based on a new book by science writer Angela Saini, chaired by former Australian prime minister Julia Gillard (above). At 7pm GMT on 2 March at the Royal Institution, London.

JAVIER TORRES/AFP/GETTY, TOLGA AKMEN/GETTY IMAGES

The film column

Life goes on

Life goes on In *Next Exit*, researchers have found strong evidence for consciousness after death and volunteers are needed to help study it – by dying. A disturbing, if underwritten, sci-fi film follows the fate of two of them, finds **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on Instagram at @simon_ings

MAGNET RELEASING

Teddy (Rahul Kohli) contronts his father (Marcelo Tubert)

FROM out of nowhere, a chink of light appears. With painful slowness, it grows stronger: we are inching towards a half-open door. Beyond the door, everything seems normal. A little boy plays a game of pretend. At least, that is what we think. Soon enough we learn what is really going on: he is playing cards with his dead father.

Nothing else in Mali Elfman's debut feature lives up to this unsettling opening, though there is a sight gag referencing Greek underworld legend that comes close: two would-be suicides rent a car from Charon vehicle rental.

This is Teddy and Rose, played by Rahul Kohli and Katie Parker. They are driving across the US to an appointment with Dr Stevensen (Karen Gillan), who has just provided evidence that some form of ghostly consciousness exists after death and is detectable. More study is clearly needed, and she is looking for volunteers willing to sign up for a painless euthanasia.

Teddy, a Londoner, has spent 10 years trying and failing to make it in the US. Being turned into a pioneer ghost (his transition from life to death monitored with all the latest gear) will at least give his life some meaning. Rose is weighed down by guilty secrets and just wants to be done with it.

Mind you, even Rose isn't as nihilistic as the man who, early on in the film, wanders in front of their rental car, and under their wheels, with a note pinned to his chest: "Thanks for the help."

"What do these newly discovered ghosts really want, as they stream into our world?"

Suicides and homicides become common, as heaven beckons and lives lose their preciousness and meaning. "Our trained mediums are standing by," a radio advert announces, offering contact with the newly visible dead. This is a world lost to itself, snared by fantasies of the hereafter.

But what do these newly discovered ghosts really want, as they stream into our world?

Not every haunting is as touching as that of the boy and his dead parent. Rose guzzles bourbon by the bottle to avoid seeing her mother watching her from inside the motel room TV. A friendly cop confesses to a thoughtless on-duty prank that killed a family of five. Not surprising, then, that he thinks "they're here to hurt us". Karma, a hitchhiker Teddy and Rose pick up out in the desert, has her own doubts: "Just because we can see them," she says, "doesn't mean we understand them."

It is at this point, about halfway in, that the viewer begins to wonder if this film has bitten off way more than it can chew.

Teddy admits that what he really wants out of his own managed death is for the news to get back to his absentee father: "I'd rather kill myself than live the life you gave me." This isn't a bad line, but what follows is horrific, and not in the scary sense: a stage-managed confrontation with Teddy's dad through an impromptu therapy session in a filling station.

The script rights itself, but having lost all confidence after this dive, it delivers, in the end, only a low-key retread of Joel Schumacher's 1990 flick *Flatliners*. (Judgement awaits; struggle gives life meaning; you know the rest.)

Next Exit is promising, but not good. It warps the world into a strange shape to ask valid and pressing questions about where the value of life resides. But it loses its way. If the writing exhibited half as much commitment as the acting, we might have had a hit. ▮

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

Film

Next Exit

Mali Elfman

Apple TV

Simon also recommends...

Book

Counter-Clock World

Philip K. Dick

This 1967 novel imagines a future in which time (or at least some biological processes) move in reverse. People awake in their graves, age backwards and eventually return to the womb.

Film

Brainstorm

Douglas Trumbull

A new headset lets you experience other lives – and deaths. Christopher Walken and Natalie Wood are the glue holding this strange project together.

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You are electric

Every cell in your body is a tiny battery, providing electricity with immense power to shape, heal and harm you. Meet your electrome, says **Sally Adee**

WHEN Dany Adams first played back the footage, there was nothing to see. The tadpole had developed enough of a tail to swim out of shot, leaving only a blank screen. "Oh well," she remembers thinking. "Another one bites the dust." But the camera had been running all night, so she dutifully rewound the tape on the off chance it had caught something interesting. Interesting didn't begin to describe what she saw. "My jaw dropped, right to the floor," she says.

The video showed a frog embryo busily dividing to become a tadpole. Then, this tiny, smooth blob began to light up. Electrical patterns flashed a series of unmistakable images across it: two ears, two eyes, jaws, a nose. These ghostly projections didn't last long. But 2 or 3 hours later, exactly where they had glimmered, the real things appeared: two ears, two eyes, jaws, a nose. Here, at last, was the proof she had been after in her role on a decade-long project undertaken by Michael Levin at Tufts University in Massachusetts. It showed that electrical patterns provide a blueprint that shapes a developing body, coordinating where to put its face and grow its other features.

Astounding as this sounds, it is just one of many roles that electricity plays in biology. There is mounting evidence that, as well as instructing development, electricity influences everything from wound healing to cancer. "Bioelectric gradients and communication are fundamental to being alive," says Levin. If we can map this "electrome" and learn to decode it, some astonishing consequences for our health would only be the start.

If you have ever spared a thought for bioelectricity, chances are that you were contemplating the nervous system. We have long known that a neuron's ability to relay messages hinges on electricity – specifically, a set-up that ensures different ions stay on different sides of nerve cell membranes. Neurons like to keep potassium ions inside and sodium ions outside. Both types of ion are positively charged, but, due to the vagaries of ion concentration gradients and head-exploding equations, the upshot is that the inside of a neuron is around 70 millivolts more negatively charged than the outside. This is called its resting potential.

Electric signalling

Although the resting potential is minuscule – around one-tenth the voltage that activates a transistor in the microchip that runs your phone – it is vital to the functioning of nerve cells. To maintain this voltage, the cell membrane is studded with tens of thousands of tiny channels through which sodium and potassium ions move, along with miniature pumps that kick out sodium interlopers. Stimulate a neuron and its ion channels open, potassium and sodium ions switch places and the voltage tumbles to zero – a process known as depolarisation. The pumps and channels rapidly restore the resting potential to -70 millivolts and the resulting voltage spike, called an action potential, moves along the nerve like a wave as other parts of the cell membrane become depolarised. This is how the nervous system relays all sensation and motion signals around the body, making action potentials fundamental to our ability to think, talk, move and perceive the world.

We used to believe that nerve and muscle cells were pretty much the only parts of the body that make meaningful use of electricity. But it turns out that the membrane around every one of your 40 trillion or so cells also acts like a little battery, using ion channels to maintain the cell's tiny voltage. Over the past couple of decades, new tools and insights have revealed that this bioelectricity, dubbed the electrome, has a huge range of roles in the body.

There is no better example than the way electricity shapes a developing body. We all recognise a regulation-issue human or chicken or fish when we see one. But how do the cells in a developing embryo know where to go to make that body, rendering all those fingers and beaks and fins in the proper place and dimensions? Since the 1960s, researchers have suspected that strange electrical pulses within fertilised eggs are important to their development. This conviction only deepened with advances in genetics. Decades of research into genomes have turned up little that could account for key aspects of an organism's shape. You will find plenty of genes coding ›

SPOOKY POOKA

for specifics such as height or the colour of hair, skin and eyes. But nothing tells you how many eyes. There is no gene for "two eyeballs, and would you mind popping them on the front of the head". The same is true for your legs, arms and ears. The genome alone can't configure the placement of any of these features.

By 2009, it was clear that shifts in electrical voltages determine which identity cells and even organs assume in development. Levin suspected that they also shape the face. But how to prove that? Existing tools from neuroscience – implanted or surface electrodes – only track fast events like action potentials, and usually not in a way you can see with the naked eye. Development takes place over a much longer timespan and across a whole organism, not just in a single cell. More to the point, a lot of tools from neuroscience are too invasive and destructive to use to study a developing organism.

One alternative was to use a voltage-reporting dye. Such chemicals translate electrical differences into a gradient of brightness, with high voltages appearing as bright white, low ones as black and anything in between showing up in corresponding shades of grey. Levin and Adams chose one that could be harmlessly infused into a fertilised egg, allowing them to track each electrical step in every cell of a developing embryo in real time. Frogs were an obvious choice to test the dye on because their development can be observed without having to contend with a uterus – but what is true for frogs in this case turns out to be true for all animals, including us.

The result was extraordinary. As the team members watched their footage that morning in the lab at Tufts, the dye revealed that the voltage of each cell was the cue for it to assume its particular identity. Initially, all the embryo's undifferentiated stem cells hovered around 0 millivolts, but, as the animal developed, its proliferating cells assumed a variety of voltages depending on the tissue they would form: -70 millivolts for nerve cells, a more forceful -90 millivolts for skeletal muscle, a flabbier -50 millivolts for fat cells and so on. These voltage changes, which could be seen as the ghostly glimmerings of facial features, formed the blueprint on which the developing tadpole was based.

Yet these shifts in voltage weren't just maps, they were instructions. Subsequent experiments revealed that they turned on the genes that got to work to create an animal's physical template. Messing with the electrical patterns disrupted the function of the ion channels and pumps that are crucial to maintaining the characteristic voltage of each cell type during development, resulting in radical physiological changes. Correcting the errant voltages during development fixed the problem. Alter a few of them deliberately and you can control body pattern: one study in frogs moved the place where the eyes grew from the face to the stomach.

Given the role of electricity in shaping a developing body, you might also expect it to be critical to maintaining that shape after an injury. This is indeed the case. The so-called current of injury – an electrical pulse produced when tissue is cut or otherwise damaged – was first reported in the 19th century, but ignored for more than 150 years. In 2011, Richard Nuccitelli, then at Old Dominion University in Virginia, built a device that could measure this current and found that it generates an electric field of around 120 millivolts per millimetre. This field acts as a beacon for the various cells that move in to repair damage and rebuild tissues. It is strongest right after an injury and wanes as healing occurs. People with a stronger current of injury heal faster than those in whom the signal is weaker. It also declines with age: you will have half the current at 65 that you had at 25.

Switching on healing

Meanwhile, other researchers, including Min Zhao, now at the University of California, Davis, and his colleagues, were doing experiments to manipulate the current of injury. They established its role as a control switch by demonstrating which gene networks it turns on, and they found that interfering with the relevant ion channels in cornea cells of the eye slowed healing, whereas electrical stimulation could speed it up. Zhao now leads a US Department of Defence initiative to track and manipulate the bioelectricity of healing, which aims to halve the healing time of severe injuries. Clinical trials are set to begin in 2024.

The ultimate goal of this line of research isn't just to heal an injury the way humans do –

TUFTS UNIVERSITY

"Tweaking the 'bioelectric code' has produced worms with second heads"

Ghostly electrical patterns (lighter patches) prefigure the placement of facial features in a developing frog embryo

Electrical nature

The "electrome" isn't just a human phenomenon. Bioelectrical activity predates nervous systems, mammals and even the animal kingdom. It is found in fungi and plants, and bacteria display electric signals that look like the oscillations found in the human brain. These appear to enable individual bacteria to cooperate to form biofilms and help them distribute nutrients. Learning how to disrupt these signals could help solve problems associated with bacteria, including antibiotic resistance.

Understanding the ancient and pervasive nature of bioelectricity will also give new insight into life itself and help us harness its powers to change the world around us. This is already happening, from the development of biorobots made of natural materials like frog cells to the creation of living architecture, such as fungus-based walls that can use bioelectric signals to sense pollution. We can't even begin to comprehend what progress it may spark in the future.

imperfectly, incompletely, with a scar – but to regrow limbs and organs the way some other animals can. This line of research is what Levin is best known for: tweaking the "bioelectric code" has helped him grow worms with second heads and regenerate frog legs at life stages when the animals can typically no longer regrow lost limbs. The work is now going on in mice and Levin has co-founded a start-up called Morphoceuticals with the aim of eventually adapting it to humans.

The potential benefits of understanding our electrome are even more dramatic when it comes to cancer. While working at Tufts with Adams and Levin, Brook Chernet discovered it is possible to use a voltage-reporting dye to detect when cells turn malignant. Cancer cells exhibit some intriguing electrical patterns. Notably, the transition from healthy cells is marked by a precipitous drop in voltage to around zero – similar to the lack of voltage that stem cells display. Meanwhile, Mustafa Djamgoz at Imperial College London had discovered that the voltage of cancer cells oscillates, just like electricity in a nerve cell. "These were bog-standard action potentials," he says. It turns out cancer cells need these to communicate with each other about their environment, especially about metastasis – their spread around the body – which is the main way cancer kills.

Scientists, including Djamgoz and Levin, hope to use ion channel blockers – currently the foundation of many heart medicines – to suppress these oscillations and stop cancers spreading. Indeed, new research suggests that people taking these heart drugs are more likely to survive cancer if they get it. And Chernet has found that, in frogs, pushing cancer cells' voltages back to those of healthy cells sends the malignancies into reverse. It is like an undo switch. Now, several compounds are in early-stage clinical trials with a view to tweaking membrane voltage to combat cancer.

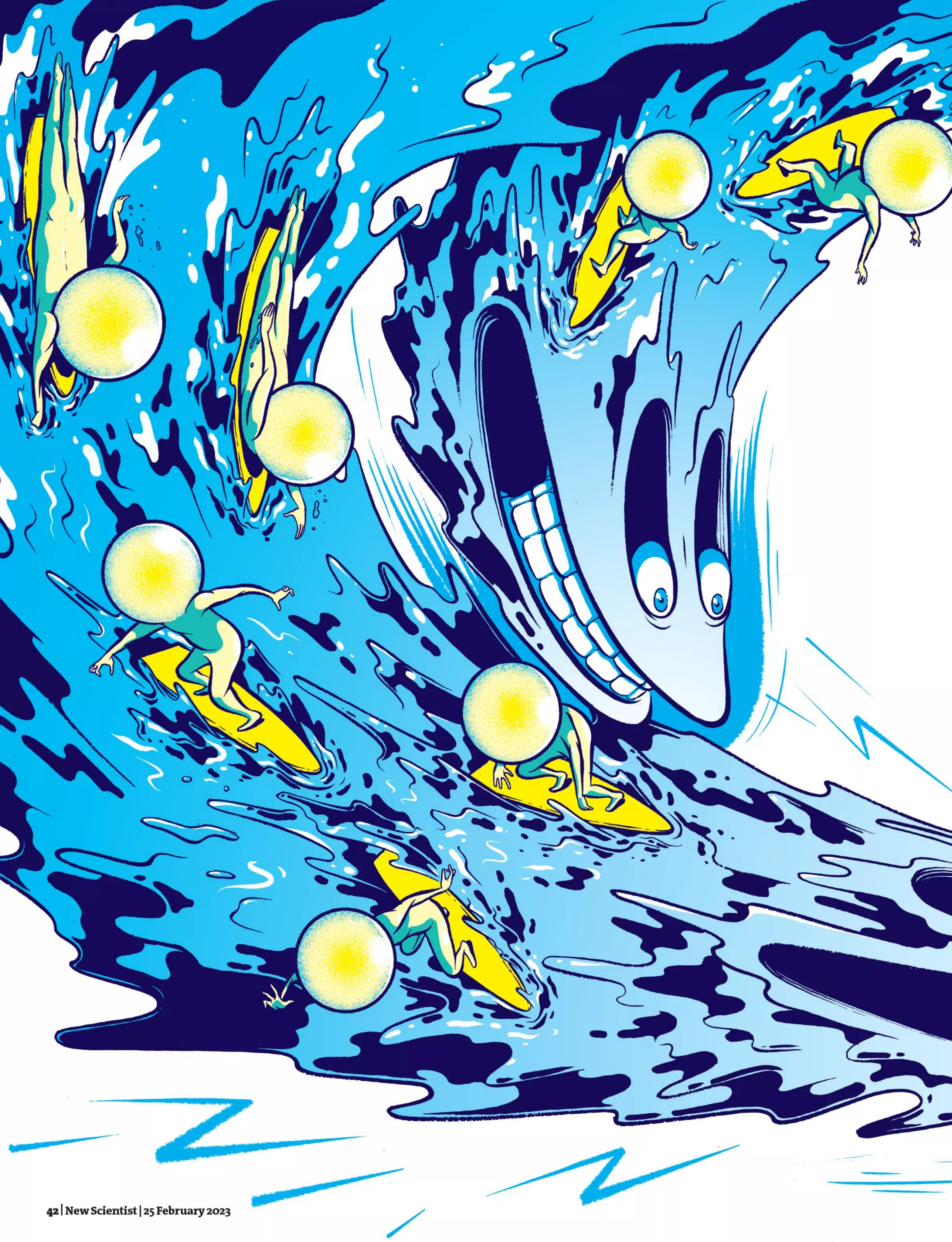
But cell membrane voltage is only one part of the electrome. Since bioelectricity entered the limelight, researchers have identified myriad new avenues to explore. For a start, cells that become cancerous also emit strange electrical currents as their metabolism alters. What's more, a weakening membrane voltage in the mitochondria that power cells seems to play a part in how we age.

Another surprise is that bioelectricity is involved in autoimmune conditions, including type 1 diabetes and rheumatoid arthritis, because of the way that nerves twine into our internal organs. The US National Institutes of Health is funding research to map this network of neurons, with a view to figuring out whether tweaking the signals they carry might help with everything from tinnitus to opioid addiction. The benefits to human health will only multiply as we expand investigations of the electrome beyond animals into other organisms (see "Electrical nature", left).

For her part, Adams is exploring the life-saving potential of the voltage-reporting dye that first allowed her to watch tadpoles taking shape. Chernet's discovery that it can pinpoint cancer cells means that surgeons removing a tumour could use the dye to ensure they have excised all the malignant tissue. Currently, around 10 per cent of operations leave cancerous cells behind and it typically takes more than a week to detect these. Spotting stragglers before the wound is closed up would be a game changer. Adams has been trying to make this a clinical reality. If it works, she envisages also using the dye as an early-warning system for skin cancers, where quickly and cheaply distinguishing benign growths from malignant ones could save many lives.

Our understanding of the electrome has sharply accelerated since Adams first viewed that jaw-dropping video. But the real potential is still to come, she says. "The research and insights emerging now will hopefully do for the electrome what molecular biology did for the genome: recognise its fundamental power in biology." ▮

Sally Adee is a freelance science journalist based in London. Her book *We Are Electric* is out now



A new wave of particle physics

A type of particle accelerator that sends electrons surfing on a surge of plasma might help us discover new physics, finds **Joshua Howgego**

TO GET to Edda Gschwendtner's experiment, you enter a small, brutalist building at CERN, Europe's particle physics laboratory on the outskirts of Geneva, Switzerland. You head into the lift and descend 50 metres into a vast underground chamber. After a series of yellow security doors, you must traverse a kilometre along a downward-sloping tunnel – which is why Gschwendtner typically uses one of the small white bikes parked inside the doors.

She is developing a promising kind of particle accelerator that might help us find new physics. Since the discovery of the Higgs boson in 2012, particle physics hasn't made much progress to speak of. So, thoughts are turning to machines that can help us probe reality in different ways.

The experiment Gschwendtner works on, called AWAKE, creates a wave of plasma – a gas of charged particles – and sends electrons surfing along it. While most colliders are getting bigger and pricier, this underground machine and its ilk, known as plasma wakefield accelerators, are compact. Don't be fooled by their size, though – they pack a punch. Compared with the likes of CERN's vast Large Hadron Collider (LHC), over a set distance, plasma wakefield technology can manage much stronger accelerations. "Up to a factor of 1000 more," says Gschwendtner.

It is proving effective. Over the past few years, AWAKE has had a string of successes in accelerating electrons over a distance of just metres. Last year, it passed a crucial test, and researchers are now gearing up to take it to higher energies. Gschwendtner and her colleagues hope AWAKE will provide the answers to some of the most intriguing mysteries in physics.

For a long time, particle physics was a successful business. Scientists spent decades cracking open the likes of atoms and protons to work out what their more fundamental ingredients are. These efforts delivered the standard model, a list of the basic constituents of reality, such as quarks, neutrinos, electrons and the forces that govern them. The last entry on the list – the long-predicted Higgs boson – was inked-in in 2012, discovered in the shrapnel created by smashing protons apart in the LHC.

Not a lot has happened since. That bothers physicists because, while the standard model is neat enough, there is a nagging suspicion that there must be more to discover. It can't explain why, for example, all the particles seem to come in three versions that are all exactly the same apart from their mass. Plus, the standard model has nothing to say about the identity of dark matter, the unidentified stuff allegedly hiding out in the cosmos, giving itself away only by its gravitational influence. Plenty of physicists think we need a new fundamental discovery to help work out what is missing.

This longed-for new physics could come in the form of a totally new particle, or it might be one of the particles we already know about behaving in an unexpected way. Both would be equally exciting.

For the former, we have "discovery machines" like the LHC, which uses magnets to accelerate beams of protons around its 27-kilometre ring before smashing them together at a hair less than the speed of light and examining the aftermath for hints of new particles. But proton collisions tend to create messy explosions of particle shrapnel that are tricky to interpret. This makes it fine for getting a glimpse of new particles, but unsuitable for spotting subtleties in the way they behave.

For that, we need a different type of machine. "Precision machines" can accelerate electrons, something that can't be done in circular colliders because electrons lose too much energy as they travel around the ring. Since electrons have no internal structure, they generate clean collisions that produce exactly what physicists want, with no mess. The current front-runners in this sphere are linear accelerators, which use electric fields to accelerate particles. But, like circular accelerators, they must be big. "If you want ›

RENAUD VIGOURT

to continue doing particle physics, discovering new phenomena at higher energies, well, we need longer accelerators," says Matthew Wing at University College London. On the other hand, plasma wakefield accelerators (PWAs) work in a completely different way to traditional circular and linear machines. This means they can be much smaller.

The idea for PWAs was born in 1979, when physicists Toshiki Tajima and the late John Dawson, both then at the University of California, Irvine, used a computer simulation to investigate what would happen if a laser were fired into a plasma. They found it would create a wave in the plasma and that electrons could be caught in the wake of this wave and accelerated with incredible efficiency. Like a surfer travelling down the side of a gnarly breaker, the particles get faster as they go.

It took a while for the idea to get off the drawing board, largely because for years lasers were too weak to generate useful plasma wakes. But in 2004, a trio of experimental results published simultaneously – known in the field as the "dream beam papers" – showed that laser wakefield acceleration really worked.

By this time, scientists had realised it didn't have to be a laser driving the plasma waves, it could be a beam of electrons. A breakthrough came in 2007, when researchers bolted a PWA onto the end of the SLAC National Accelerator Laboratory at Stanford University in California. The accelerator's electron beam was used to drive a plasma wave, and this wave accelerated other electrons in the beam. The result was impressive, effectively doubling the energy of the beam in a tube of plasma just 85 centimetres long.

One big problem remained with this set-up. To reach really high energies, researchers had to fit multiple tubes of plasma together, end to end, and re-energise the waves at each join by spurring them on with a fresh laser or electron beam. This approach, called staging, is incredibly finicky. Few have ever got it to work.

Several years later, physicist Allen Caldwell, now at the Max Planck Institute for Physics in Munich, Germany, had a bright idea. Instead of using lasers or electrons to drive the wake, you could use protons. Handily, CERN already provided an incredibly high-energy source of protons – they were so powerful, in fact, that you wouldn't need to bother with staging at all. "You could have the protons travel for hundreds of metres, maybe a kilometre," says Wing, "and they would still be very effectively driving a wake."

"These new accelerators could be used in the hunt for dark matter"

In 2013, the project was approved by CERN and the Advanced Wakefield Experiment (AWAKE) was born. The researchers wanted to use a beam of speeding protons from CERN's Super Proton Synchrotron (SPS), a kind of pre-accelerator to the LHC, to drive the waves in their plasma. That is why AWAKE is so deep underground, so it can be connected to SPS.

I went to visit Gschwendtner at CERN in November 2022. She took me down into the vault where AWAKE is held. The scale was incredible: like being in an underground cathedral made of concrete. To my left were the yellow security doors that guard the entrance to the tunnel leading to AWAKE. Sadly, we weren't able to go down the tunnel on the day because the levels of radiation were too high. I did have a quick go on one of the bikes, though.

Had we been able to see AWAKE itself, we would mostly have been looking at a 10-metre-long tube surrounded by electronic equipment. "This is already the longest in the world for a plasma accelerator," Gschwendtner told me. By 2018, Gschwendtner, Wing and their colleagues had demonstrated the protons could drive a wave and that electrons could be injected into the wake and accelerated. The results were a reminder of just how powerful this trick could be. The electrons were injected into the tube with an energy of about 19 million electron volts (eV) and accelerated to a whopping 2 billion eV, by the end of the tube, increasing their energy 100 times in 10 metres.

One nagging difficulty, though, was that protons from SPS come in bunches that are too long to form nice, tight waves in the plasma. Until 2018, the researchers were using a short laser pulse to break these bunches into smaller chunks suitable for creating a wave, a process called modulation. But that wouldn't have worked in a tube many tens of metres long. They needed a way to get the proton bunch to modulate itself.

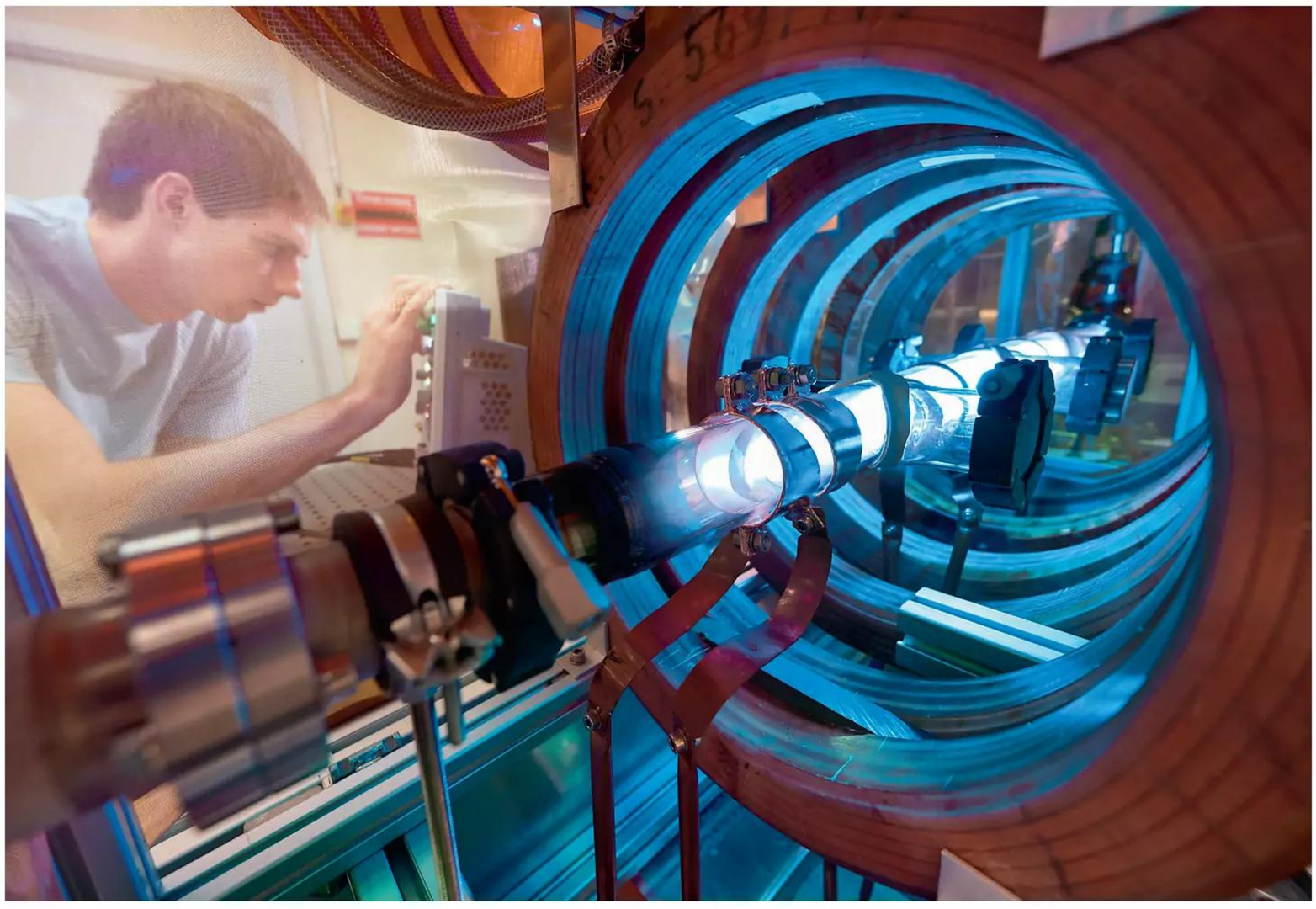
After painstaking work, they cleared this hurdle too. In 2022, the researchers published a demonstration of the proton beam breaking itself up into short micro-bunches. "These micro-bunches work in resonance to drive the wake, and that's when we can really get very strong accelerations," says Gschwendtner. "It is a big milestone."

What makes this exciting, says Suzie Sheehy, who works on accelerator physics at the University of Melbourne in Australia, is it shows this self-modulation process can be controlled. "Gaining control to high precision is the name of the game when it comes to accelerators," she says.

With that done, there are no more fundamental reasons why the technology can't be scaled up. Elongate the plasma tube and you should be able to speed up the electrons more and more. Wing's guess is that an increase from 10 metres to 30 metres would get us into interesting territory. "As soon as we start getting above 10 giga-electron volts [10 billion

FICHET, JACQUES HERVE/CERN

The results of proton collisions absorbed by screens at the LHC



ORDAN, JULIEN MARIUS/CERN

Testing the plasma tube used in CERN's AWAKE experiment

electron volts], you suddenly have an electron beam that isn't available anywhere else and has the potential to be interesting for all sorts of particle physics experiments," he says.

One way to use this technology might be to help answer the vexing question of where the universe's mass comes from. Only a small proportion of the mass of atoms comes from the particles inside them. Most of it emerges from the way particles called gluons – which carry the strong force, one of the fundamental forces of nature – bind to each other. "We don't understand this," says physicist Jon Butterworth at University College London. "How is the proton held together?"

Physicists suspect that we can work out the answers by firing very high-energy electrons at ions, charged atoms, and seeing how they are deflected by the gluons inside. This would help us map out what the gluons are doing in fine detail. A machine that could answer this and related questions, called the Electron-Ion Collider, is already planned at the Brookhaven National Laboratory in Long Island, New York. The aim is for construction to be completed in the 2030s. This particular collider won't involve PWA technology, but similar machines could in future.

Another prospect would be to use AWAKE in the hunt for dark matter. One idea is that this is composed of a "dark sector" made up of a dark equivalent of every particle we know of, including particles, or photons, of light. Being massless, dark photons wouldn't account for the gravitational effects we see from dark matter, but finding them would give us our first real evidence that the dark sector exists. Searches for dark photons usually work by making a beam of electrons hit a target, creating a beam of photons that could turn into dark photons – but only very rarely. AWAKE could help by boosting the power of the electron beam and the chances of seeing a dark photon.

A Higgs factory

Tim Nelson already works on searches for the dark sector at SLAC. He says PWAs could be useful for dark photon searches, but cautions that the first-generation machines may not offer significant advantages over conventional accelerators. "It certainly is a possible early application for PWAs, but it's not obviously a game-changer," says Nelson.

Arguably the most exciting use for PWAs, though, would be to study the Higgs boson. One promising avenue for new physics is the idea that the Higgs is more complicated than we have so far realised. It might come in more than one variety or perhaps interact with other particles in ways we haven't yet spotted amid the chaos generated when they are produced at the LHC. A precision collider aimed at studying the Higgs boson, known as a Higgs factory, would enable physicists to find out – and possibly crack open a new understanding of the standard model. But PWAs still struggle to reproduce multiple beams of the same characteristics in quick succession. For this reason, says Butterworth, they aren't a contender to power a Higgs factory quite yet.

Still, the future looks promising. Plasma wakefield accelerators might reach energies of tens of billions of electron volts in a few years. Although the LHC already reaches 13 trillion eV, "the gulf isn't as big as you might think," says Butterworth. In the LHC, it might only be one or two of the quarks that actually hit each other, which means the energy involved in a collision is straight away around 10 times less than the total energy of the proton. Even accounting for that, though, PWAs aren't likely to get to the kind of energies that the LHC can manage any time soon.

Meanwhile, electron-driven PWAs are coming on apace. Richard D'Arcy works on the FLASHForward experiment at the German Electron Synchrotron (DESY) facility. The experiment uses high-energy electrons from the main DESY accelerator to create waves in a tube of plasma, which then accelerate a second group of electrons to high energies. "We are becoming more and more focused on how you can meaningfully apply this technology," says D'Arcy. These electrons aren't high-energy enough for particle physics, but D'Arcy says they could form the basis of an X-ray free electron laser, essentially the world's most powerful kind of microscope. These are useful for looking in unprecedented detail at molecular processes, such as how molecules and proteins fit together to power metabolism.

When it comes to particle physics, the best bet is going to be AWAKE. "It's very exciting," says Gschwendtner. She and her colleagues are going to be working on that experiment for years to come, pedalling or scooting their way down the gently sloping tunnel at CERN. Each journey, and each new wave the electrons catch, will bring us closer to the new physics everyone is hoping for. ▮

Joshua Howgego is a features editor at *New Scientist*

The break-up

We increasingly know why monogamous animals "divorce" – and sometimes the reasons are linked to climate change, finds **Jasmin Fox-Skelly**

THEY seemed the perfect couple. Growing up in the same neck of the woods, they went their separate ways in adolescence, before reuniting and hitting it off. But after many years together, they seemed to just drift apart. Divorce soon followed.

This sad story may be all too familiar to many, but there is one important difference. The parties in this case aren't human. They are birds.

For years now, behavioural biologists have been aware that some animals – birds in particular – choose to pair up for years on end, often raising offspring together. Some researchers have also become fascinated by the fact that these couples can break up. Although scientists are generally loath to anthropomorphise, there are times when even they can't resist. This explains why the biological literature is full of studies analysing the factors that drive animal "divorce" in all manner of species, from albatrosses to penguins, beavers to seahorses.

Recently, as we have learned more about this, a surprising conclusion has emerged: under the right circumstances, animal divorce can be so beneficial that it might be an evolved trait. But on the flip side, we have also come to realise that divorce rates have the potential to spiral out of control so that viable breeding colonies may decline, dwindle and disappear. What's more, research has even identified a worrying new factor that might unexpectedly contribute to a sharp rise in this sort of divorce-driven crisis: climate change.

Many animals will never divorce, for the simple reason that it is unusual for them to form monogamous pairs. Only around 5 per cent of mammals do so, for instance. From an evolutionary perspective, this rejection of monogamy makes sense: animals typically stand to have more offspring that have the qualities needed to thrive by mating with multiple partners. As such, researchers have long wondered why monogamy exists – particularly among birds, where at least 80 per cent of species stick with a single partner.

A 2018 study pointed to several explanations for this evolutionary mystery. For example, if feeding offspring is so challenging that it requires the work of two adults, then males and females should benefit from remaining together after mating. Long-lived animals may also benefit from monogamy because it allows them time to perfect the art of rearing offspring together. This can be useful if environmental conditions deteriorate, because a long-term couple may be able to draw on their shared experience to cope.

To complicate things, we now know that there are different ways for animals to be monogamous. Towards the end of the 20th century, DNA testing showed that many "faithful" pair-bonding animals bend the rules: one partner may sneak off to mate elsewhere. Because of this, biologists now distinguish between genetic monogamy – in which animals live in pairs at least some of the time and breed only with their partner – and social monogamy, in which two animals cohabit and even raise offspring together, but may mate with other partners.

Both genetically and socially monogamous relationships can end in divorce – and break-ups aren't always triggered in the same way. For the lined seahorse (*Hippocampus erectus*), which is usually genetically monogamous, divorce appears to be the result of a memory lapse. A 2021 study found that if, after mating, seahorse pairs were housed in separate tanks, the female lost her preference for her male partner. When she was reintroduced to him after the birth of their offspring, alongside two other male seahorses, she seemed to have forgotten the pair bond and was as likely to mate with any of the three males.

In other cases, there is an active agent involved. Take the socially monogamous Eurasian beaver (*Castor fiber*). A 2017 study ›

PETE OXFORD/MINDEN PICTURES/ALAMY

Magellanic penguins will divorce if their nest isn't well protected from the weather

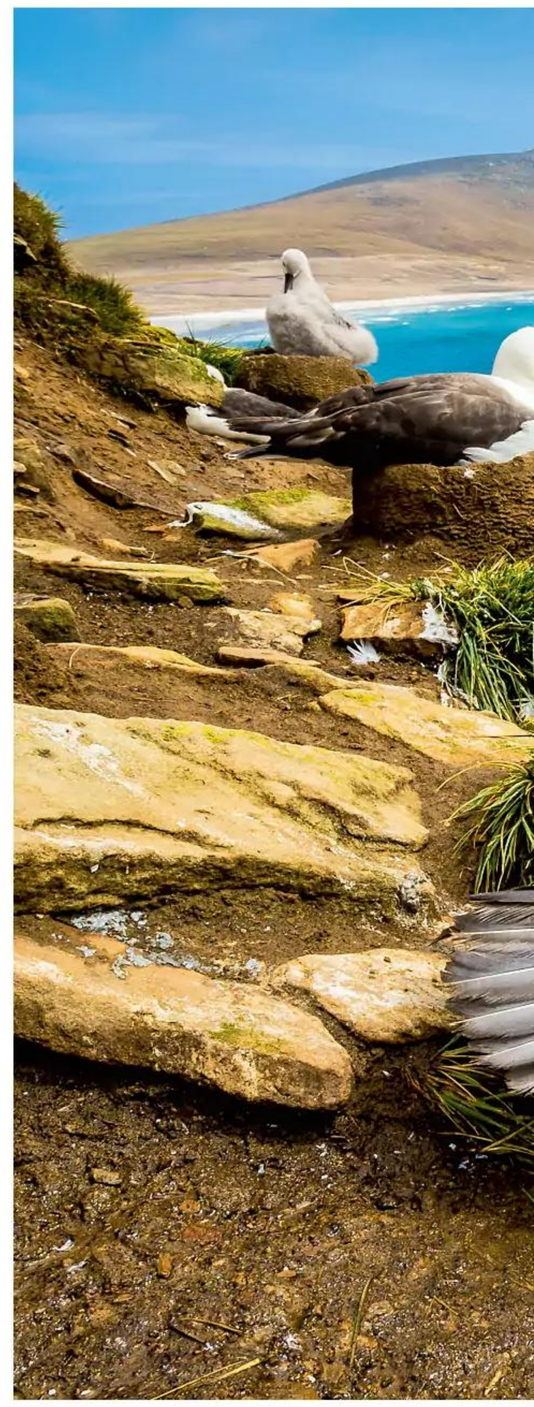
suggested that those in south-east Norway experience a seven-year itch: couples tend to break up after this time together on average. Often, divorce was triggered by the appearance of a new, younger rival – either male or female – that disrupted the relationship.

This phenomenon is sometimes called forced divorce, and a study published a few months ago shows it occurs in albatrosses too. Male wandering albatrosses (*Diomedea exulans*) living on the Crozet Islands in the southern Indian Ocean that were judged by biologists to be "shy" were more likely to experience forced divorce if a "bolder" male turned up.

"Just like with humans, there [is generally] a cue or trigger for divorce, something that causes them to decide, hey I'm going to leave my partner," says Antica Culina at the Ruder Boskovic Institute in Zagreb, Croatia, who has devoted part of her career to studying pair-bonding in animals.

According to Culina, the main cue is reproductive success, or lack of it: if you fail to rear offspring with a partner then you are more likely to split up. But recently, biologists have begun to recognise that it isn't just this that can prompt a monogamous pair to part.

MICHAEL PATRICK O'NEILL/ALAMY



A poor memory contributes to divorce in lined seahorses (above), while breeding failure is the most common divorce trigger for black-browed albatrosses (right)

Divorce rate spike

Every September in the Falkland Islands, some 500,000 pairs of socially monogamous black-browed albatrosses (*Thalassarche melanophris*) gather to breed and raise chicks. Francesco Ventura at the Woods Hole Oceanographic Institution, Massachusetts, and his colleagues tracked 424 female albatrosses over a 15-year period, recording whether or not they remained faithful to their partners.

They found that, as expected, divorce was most often prompted by breeding failure. Each female lays just one egg, and if it failed to hatch couples were over five times as likely to split up. Ventura's team also discovered a correlation between divorce and sea surface temperatures. For instance, between 2012 and 2016, sea surface temperatures weren't unusually high and divorce rates hovered below 4 per cent. But they rose to 8 per cent in 2017 when the sea surface around the islands was warmer than usual.

Ventura and his colleagues, who published their findings in 2021, also noticed something else. During these warmer years, which are thought to be a consequence of climate change, even some females that had bred successfully decided to up sticks and leave their partner.

"It's well established that one of the main reasons that albatrosses divorce is related to breeding success," says Ventura. "However, what we found was that regardless of this success or failure, and regardless of previous reproductive outcome, as sea temperatures increased, so did the probability of divorce."

Why? Ventura says that when seas are warmer there is less food available, meaning albatrosses have to travel further to get a meal. In seabirds, food shortages are known to raise levels of a stress hormone similar to cortisol. It is possible, he thinks, that a stressed and hungry female will suspect her partner is somehow to "blame" for her hunger – even though the reality is there is simply less food available. In other words, says Ventura, the environment may be misinforming decisions about whether to stay or go.

Recent research suggests this may be bad news for animals. Last year, Brian Lerch at the University of North Carolina, Chapel Hill, and his colleagues published a mathematical model of animal divorce. This revealed that there are circumstances in which evolution would encourage the practice.

The model assumed divorce is triggered by females who want to raise their reproductive success. It concluded that the more variability there is between male-held territories or

Some Eurasian beaver break-ups are triggered by younger rivals

BENNY337/SHUTTERSTOCK

INAKI RELANZON/NATUREPL

> "A study suggested that beaver couples in Norway experience a seven-year itch"

habitats – defined, for instance, by the availability of food or abundance of predators – the more likely it is that females will divorce their partners. This is because it is difficult to raise offspring on a poor territory, and so females stuck on one will be keen to upgrade by hitching up with a male on a better territory. Crucially, because of natural death rates across the colony, there should always be the possibility of those better territories becoming available, which makes divorce potentially worthwhile for the female.

"We found that the more that bad territories get worse or good territories get better, the more beneficial and likely it is that animals will divorce," says Lerch.

By implication, if climate change temporarily reduces the availability of food, as it did around the Falkland Islands, then females may conclude they are on a poor territory and that divorce is the right move.

While divorce can sometimes be beneficial to the individual, the model showed that as rates rise, it reduces the reproductive success of the colony as a whole. Lerch suspects this is because breeding pairs that have been together for many years have plenty of experience to draw on, so they have a higher chance of raising offspring successfully than a pair attempting to raise offspring together for the first time. "Our model showed that the total reproductive success of the population is likely to decrease as divorce rates increase," says Lerch.

Colonies in decline

This suggests that if climate change prompts a surge in break-ups across a population – and particularly if it breaks up experienced breeding pairs that have the best chance of raising offspring successfully – breeding colonies may go into decline.

The good news for the black-browed albatrosses on the Falkland Islands is that the breeding population is robust. There is no immediate likelihood that a spike in divorce triggered by warmer seas will lead to the demise of this breeding colony, says Ventura.

But for animal colonies elsewhere that are already shrinking, high divorce rates triggered by climate change could be serious, he says.

"There are sea birds that breed out on isolated colonies that are already among the most threatened vertebrates," says Ventura. "A disruption in normal breeding processes could be much more problematic for these populations."

A declining colony of Magellanic penguins (*Spheniscus magellanicus*) near Punta Tombo in southern Argentina may be vulnerable. These monogamous birds are picky when it comes to choosing a nesting site, and usually head straight to the same spot year after year. The penguins prefer to nest in bushes or burrows, which provide cover and protection from predators and the weather. Those with the best-protected nests are more likely to raise chicks.

A study published last year showed that long-term pairs divorced at higher rates if their nest was less protected than it had been the previous year. If climate change leads to die-back of the bushes protecting nests, then divorce rates will surge.

"The breeding failure might initiate a kind of negative feedback," says Eric Wagner at the University of Washington in Seattle, who authored the study. If pairs divorce and females find new partners, he says those new pairings may experience breeding failure because of a lack of experience raising offspring together. This will trigger even more divorce.

"The expectation is that access to food, and access to high-quality habitat, is likely to decrease in most species as a consequence of climate change," says Lerch. "There's good reason to expect that it will lead to more divorce in a lot of populations."

One computer model of an animal breeding colony suggested that, if either males or females are encouraged to divorce more frequently, viable populations have the potential to disappear – a process researchers dub evolutionary suicide.

All of which provides more evidence of the importance of acting to reduce the severity of climate change. We already appreciate that lowering carbon emissions will help humans and natural ecosystems avoid the more damaging effects of global warming. It turns out that action might also spare some animals from the ordeal of divorce. ▮

Jasmin Fox-Skelly is a science writer based in Cardiff, UK

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FRANK MARTELA

The back pages

Puzzles
Try our crossword, quick quiz and logic puzzle p53

***Almost* the last word**
Why do we have nerve endings in our teeth? p54

Tom Gauld for *New Scientist*
A cartoonist's take on the world p55

Feedback
Dive into the many non-gustatory uses for coffee p56

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

The science of cooking

Boil them in oil

Fat gets a bad rap, but it is key to making enjoyable foods like confit pork. You can also use the confit method for parsnips, says **Sam Wong**

Sam Wong is assistant news editor and self-appointed chief gourmand at New Scientist. Follow him @samwong1

What you need

800 g parsnips, peeled and cut into finger-sized pieces
1 bulb of garlic, cloves separated and peeled
500 ml extra virgin olive oil

The science of cooking appears every four weeks. Share your cooking successes with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistCooking

Next week

Stargazing at home

FAT is a controversial subject in food science. We have all been told from an early age that it is unhealthy and something we should try to eat less of. But as we have said in *New Scientist* before, the science that led us to fear it is deeply flawed, and many studies have found that cutting down on fat brings no clear health benefits.

In fact, fats are an essential part of our diet, a vital aid to cooking and key to what makes many of our favourite foods, such as chocolate, so enjoyable. To make smarter use of them, it helps to know a bit about their chemistry.

Animal and vegetable fats are composed mainly of triglycerides, molecules with three fatty acid chains joined onto a type of alcohol called glycerol. If the bonds between carbon atoms in the chains are all single ones, it is a saturated fat. If there are any double bonds, it is an unsaturated fat. An unsaturated fat with one double bond is monounsaturated; with more, it is polyunsaturated. Saturated fats are generally solid at room temperature, while unsaturated fats are liquid.

In unsaturated fats, the double-bonded carbon atoms can react with oxygen in the air. This oxidation reaction produces compounds that taste bad, gradually turning the fat rancid. The process is accelerated by light, so it is a good idea to keep oils in opaque containers or cupboards.

All fats can be heated much hotter than water can without evaporating, which makes them very useful for cooking. However, heating them accelerates oxidation and produces various chemicals that may harm our health. But these products don't reach concerning levels unless you reuse the same oil several times.

PHOTOCUISINE/VIEL, PIERRE LOUIS/STOCKFOOD

Some believe you shouldn't use olive oil for high-heat cooking, but studies have shown that both ordinary and extra virgin olive oil are stable at high temperatures and compare well with other oils. This is partly because they have a higher ratio of monounsaturated to polyunsaturated fat, so they oxidise less easily. They also have higher levels of antioxidants than other oils, which helps prevent the fat molecules from oxidising.

Deep-frying in hot oil is great for making delicious, crispy foods, but we can also use flavourful fats to cook foods slowly and gently, a technique called confit. The word comes from the French for preserved. Pieces of meat, such as pork (pictured), would be cooked submerged in fat and then stored in the fat to prevent spoiling.

The slow and gentle cooking in fat also keeps meat moist and helps to break down connective tissue, making it very tender. But vegetables can benefit from an extended bath in warm oil too.

To make confit parsnips, place parsnips, garlic and extra virgin olive oil in a baking dish and cover with foil. Cook in a fan oven at 160°C (320°F) for an hour, or until tender. You can reuse the oil, but don't reheat it multiple times. ▮

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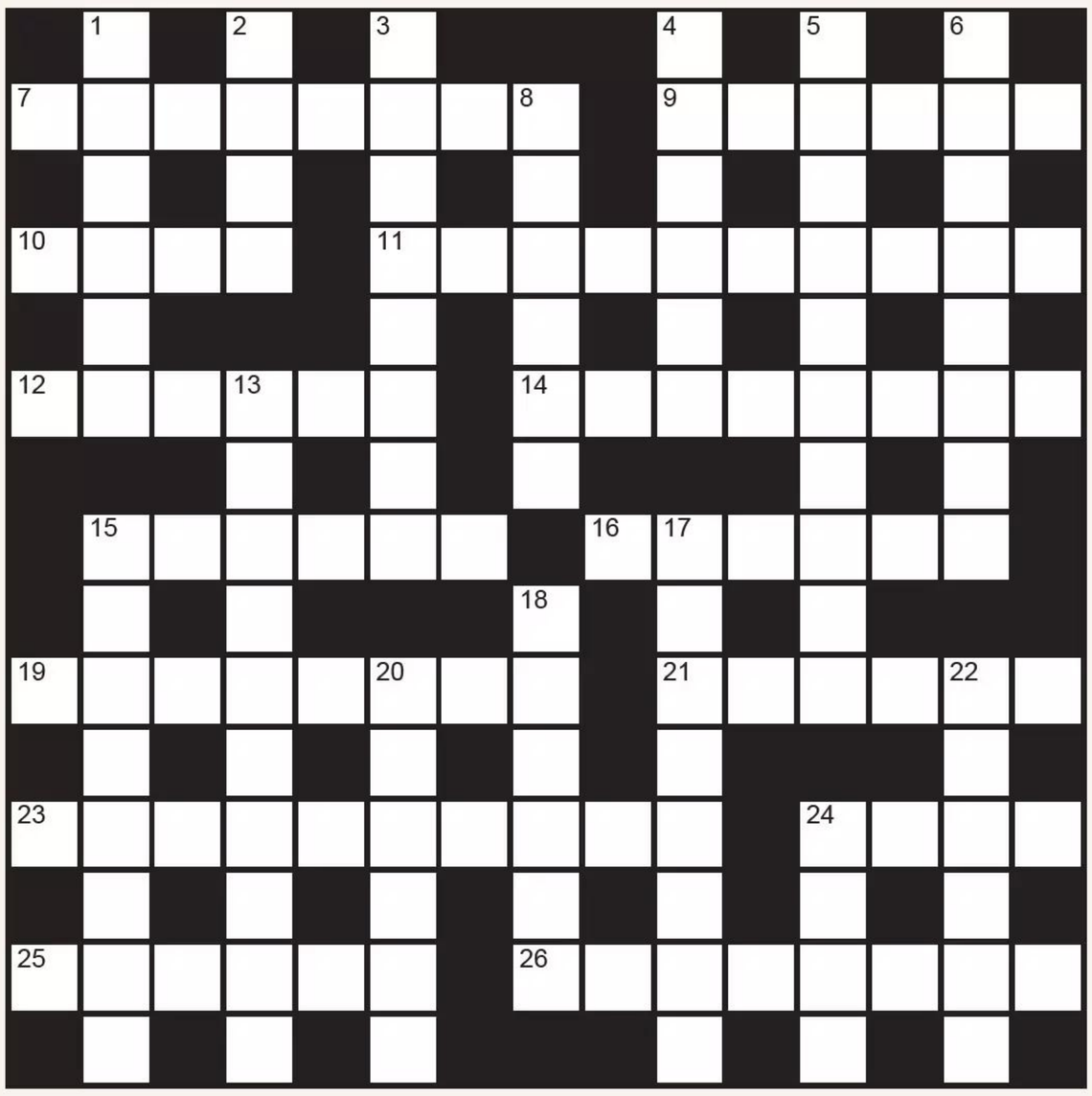
*Source: Google Analysis Jan–Dec 2021

Quick crossword #127 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

7 Rigid airship patented in 1895 (8)
9 Parasitic nematode of West and Central Africa (3,3)
10 Large feline (4)
11 City associated with an interpretation of quantum mechanics (10)
12 Measure of solar reflection (6)
14 < (4,4)
15 Automata (6)
16 Sex cell (6)
19 C_2H_4 (8)
21 Protective outer layer (6)
23 Ceiling mineral formation (10)
24 Value that appears most often in a data set (4)
25 Muscular taste organ (6)
26 Not adult (8)

DOWN

1 Radio antenna (6)
2 Circular motion around an axis (4)
3 Power outage; bout of amnesia (8)
4 Genetically identical organisms (6)
5 Flow of transmitted information (4,6)
6 Web browser's start location (4,4)
8 Adhesive incendiary (6)
13 Study of prenatal development (10)
15 Another word for 2 Down (8)
17 Diagram of the changing position of the sun (8)
18 Second NASA space-flight programme, established in 1961 (6)
20 Be greater than (6)
22 Milk organs of a ruminant (6)
24 Conglomerate formerly known as Facebook (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #190
set by Bethan Ackerley

1 Kohlrabi, choy sum and mustard plants are all members of which genus?

2 Where in the body would you find cementum?

3 In chemistry, a molecule that can't be superimposed onto its mirror image is known as what?

4 Georg Ebers is best known for bringing to prominence a medical document from which ancient civilisation?

5 Sakigake, Giotto and Suisei were among the probes sent to examine which comet?

Answers on page 55

Puzzle
set by Mary Ellis
#210 Action station

I have a train to catch! I was planning to drive or cycle to the station, but, to my dismay, I realise that my car has a flat battery and my bike has a puncture.

I look at the clock and realise that, based on past experience, if I were to set out right now and walk to the station, I would miss my train by 10 minutes. However, if I were to run at my top speed, I would be 15 minutes early. It is freezing outside and I don't fancy waiting on the platform for any longer than I have to.

It is too late to do any more calculations as I need to leave right now. I decide to run for half the distance and walk the rest of the way. But where are my running shoes? After a frantic search, I find them. I leave the house 2 minutes later.
Do I make it in time to catch the train?

Solution next week

Painful bite

Why do we have nerve endings in our teeth? They seem to serve no useful purpose.

***@jposamen**, via Twitter*
As our only fuel hatch, the mouth is pretty important. It needs detectors for infection, decay and problematic food that is too hot, hard or sharp.

Maria do Rosario Cassettari (dental surgeon),
São Paulo, Brazil
The nerve endings of the teeth may seem useless, but they are responsible for triggering an alert signal that prevents mechanical damage to the teeth, differentiating between hard and soft or hot and cold elements. Above all, they signal an urgency to the brain.

In other words, without the nerve endings, soup would be humanity's main meal.

Hillary Shaw
Newport, Shropshire, UK
Without tooth nerves you would soon have no teeth, just as without nerves in your fingertips you would soon have no fingers because you would be unaware of harm to them.

All food may contain unexpected hard bits: bone in meat, stones in fruit, grit in vegetables. Tooth nerves enable us to sense bite quality and distinguish between, say, a hard but biteable nut that we should eat and an unbiteable stone that we shouldn't.

"Without tooth nerves you would soon have no teeth, just as without nerves in your fingertips you would soon have no fingers"

Don Gibson (dental surgeon)
Yeovil, Somerset, UK
The nerve endings in teeth contain the stem cells that formed the enamel and dentine in the original tooth formation.

Treatment of dental decay has evolved hugely in the past 10 years, and wholesale decay removal, which has been usual practice for decades, is now in question. This is due to these stem cells being able to produce further dentine in response to attack by a decay front.

If the decay periphery is removed, the deeper nerve front can effectively self-heal due to these stem cells, with dentine reforming once an effective sealed filling of the decayed tooth stops sugar from reaching the infected deeper parts.

As a result, we can avoid root canal treatment and extractions.

BACHKOVA NATALIA/SHUTTERSTOCK

This week's new questions

Quick flight **Watching birds in the garden, their reaction times and alertness suggest that their brain processing speed is quicker than ours. Is this correct?** ***Colin Horwood,*** *Salthouse, Norfolk, UK*

Spent force **I fill a bucket with water from a tank by gravity, but what happens to the gravity?** ***Paul Leese,*** *Gqeberha, South Africa*

***@morley_darryl**, via Twitter*
To punish us for our poor decisions.

Shapely bake

How does a scone develop a "waist" as it rises in the oven?

Dominique Pechon
London, UK
Scones develop a waist because the heat at the top and bottom of the oven bakes the lower and upper surfaces of the scone first, before the side of the scone is baked and set. Adjoining scones also act to shield the side from the heat of the oven.

The rigidity of the bottom and upper baked surfaces prevents their changing shape to any marked degree, while the side of the scone remains softer and can flex as the dough rises during baking. The water in the scone dough escapes from the side as steam during the baking process. This draws it inwards to form a waist as the steam is lost.

The scones in the picture (below) look more like ones made on a factory production line* than ones made by hand by an artisan as they show a tear at the midpoint. This is because industrially made scones need a firmer dough to be able to go through the production line, and less liquid in the dough means that the sides will tear and not merely be drawn inwards during baking. Factory-made scones are also cut into hexagon shapes so no offcuts are produced.

The artisan scone is made using more water and milk in the dough, which isn't over mixed. This prevents gluten in the flour from developing strength, which would make a tough scone. This softer dough usually bakes without producing a tear on the side of the scone. The artisan scone is usually turned upside down when placed on a baking tray so that the upper surface is flat and aesthetically pleasing once baked.

GEOFF ROWLANDS

In an episode of the TV show *Downton Abbey*, scones that looked as if they were factory-made were served at afternoon tea. Given the amount of money spent on making the series, I was disappointed that they didn't

Birds seem to have faster reaction times than us, so are their brains faster than ours?

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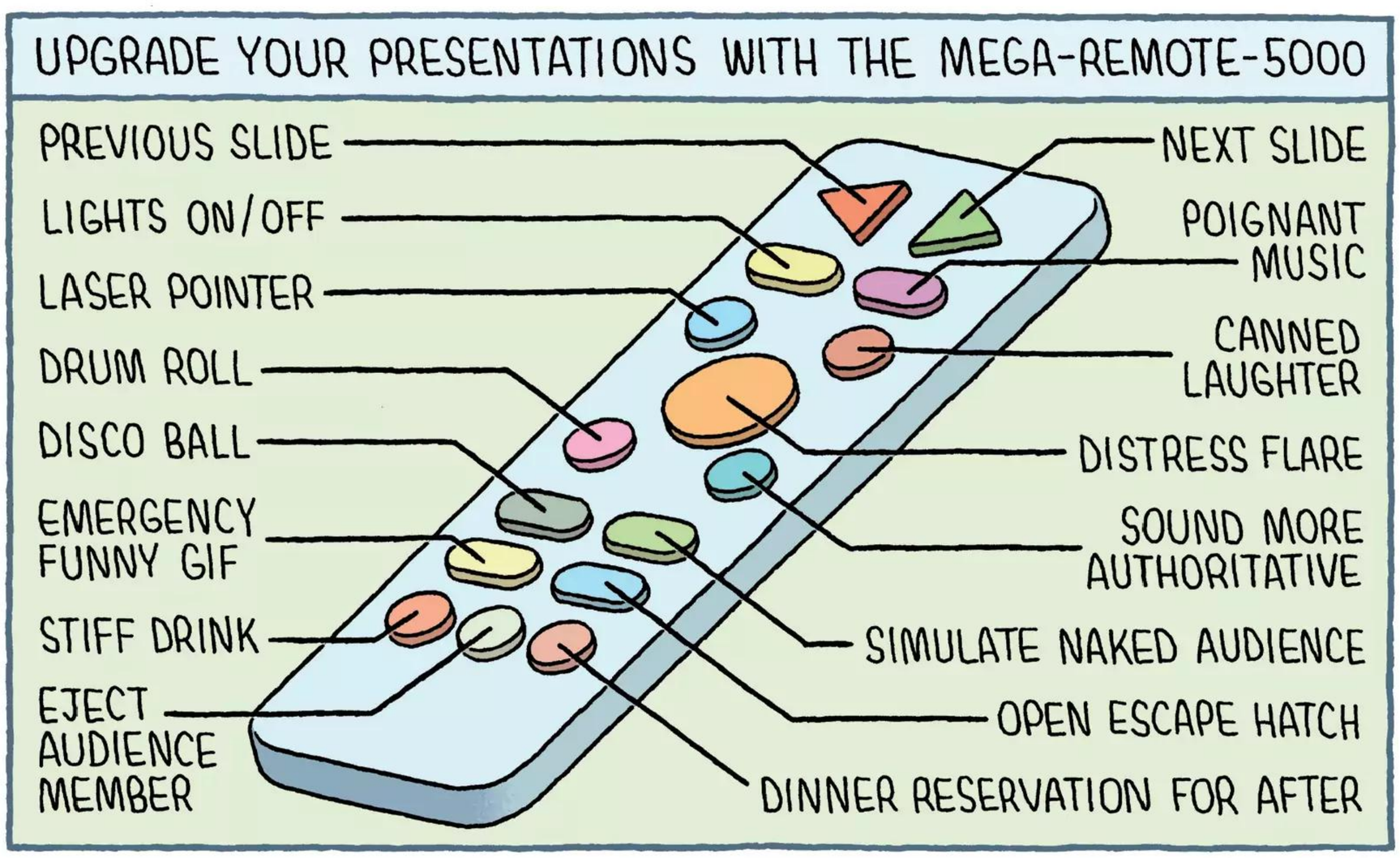
Tom Gauld
for New Scientist



appear to have made proper scones for that scene.

I trained as a geologist and mineral chemist, but ran the family bakery firm for 32 years.

*[*Editor's note: Geoff Rowlands, who posed this question, assures us his scones (pictured) were hand made! He says: "I expect that the hexagonal shape makes them look factory-made but, being an engineer, I made a set of hexagonal cutters to minimise the 'waste' when cutting them from the dough."]*

Turn of the screw

Why do loose screws only get looser and not the other way round, even if there seems to be no resistance to the latter? (continued)

Richard Brent
Tinamba, Australia
Some cars and trucks have left-handed threads on their left-hand wheels. This is so that, when the brakes are applied suddenly and the wheels stop or slow their rotation, angular momentum will try to tighten rather than loosen the wheel nuts.

If you need to change a tyre on such a vehicle, you will have difficulty unless you remember to turn the wheel brace in the correct direction.

"Your correspondence on why nuts tend to loosen has stimulated me to find out why shoe laces untangle and don't tighten"

Stuart Jameson
Solihull, West Midlands, UK
Threads can be designed to self tighten, for example on bicycle pedals. The left-hand pedal has a left-handed thread so that the pedalling action turns the pedal in the tightening direction.

David Kernick
Exeter, Devon, UK
Your correspondence on why nuts tend to loosen has stimulated me to solve my long-standing and frustrating problem of why shoe laces untangle and don't tighten.

A nut is held in place by the elastic expansion forces of the metal reacting against the friction of the helical thread. The elasticity can be felt in the final "bite" of torque when tightening a bolt. When the system vibrates, friction between bolt and thread is reduced and the bolt expands outwards. Once elastic contact has been lost with the metal, it is as likely to tighten as loosen. With shoe laces, the friction of the lace resists the elastic expansion of the opposing shoe eyelets, but unravels in a similar fashion.

Andrew Vevers
York, UK
I suffered from extremely tight wheel bolts on my Volkswagen Beetle and, like one of your previous correspondents, had to resort to a length of scaffold pipe to undo them. However, it wasn't because the bolts had inexplicably tightened. It was the apprentice in the tyre shop who had turned the torque setting on his power wrench up to maximum. ▮

Answers

Quick quiz #190 *Answers*

1 *Brassica*
2 In the mouth – it is the calcified substance covering the roots of teeth
3 Chiral
4 Ancient Egypt
5 Halley's comet

Cryptic crossword #103 *Answers*

ACROSS 1 Contestable, **8** Defog, **9** Aridity, **10** Chimera, **11** Congo, **12** Thrums, **14** Selfie, **17** Larks, **19** Nuclide, **21** Submenu, **22** Petri, **24** Tardigrades

DOWN 1 Cud, **2** Niftier, **3** Eagle, **4** Trajan, **5** Brioche, **6** Evian, **7** Pyroxene, **10** Catalyst, **13** Masseur, **15** Fainted, **16** Annuli, **18** Robot, **20** Caper, **23** ISS

#209 Postman's knock *Solution*

There are 257 houses in the road.

Experimentation will quickly establish that no two-digit number has the required property, so let's find a three-digit number whose digits are a, b and c in some order. We know that multiplying $a \times b \times c = 5(a + b + c)$, and since this product is a multiple of 5, one of a, b or c must be 5 (let's say it is c). That means $5ab = 5(a + b + 5)$, and hence $ab = (a + b + 5)$.

The values of a and b can be 2 and 7 or 3 and 4, meaning the house number could be 257, 275, 345 and so on. However, since only one house – the one at the end of the road – has this property, the number of houses on the road must be the smallest of these, which is 257.

Caffeine boost

Coffee is something to put into people; it is also something to put onto people. Though some folk choose to roast, brew and drink coffee, innovative scientists use the bean and its byproducts to make cosmetics.

Fernanda Maria Pinto Vilela and her colleagues at Brazil's Federal University of Juiz de Fora did a worldwide search for every recent patent that applies coffee to that purpose. They found patents for producing emulsions, gels, suspensions, solutions, powders, aerosols, sticks, creams, lotions, ointments, shampoos, serum, soaps, essences, masks and sprays – all of them meant to be dripped, rubbed or otherwise applied to human skin. Some are designed specifically for lips, some just for scalps, some only for the neighbourhood of the eyes.

Most of the new patents come from either China or South Korea. Here are some that drew special attention from the team: an unguent for the lower eyelid that "forms a breathable biological film in cooperation with oat sugar to lift the periphery of the eyes"; a cream "which can reduce lip wrinkles"; a "pure natural bath composition with a frosting effect" and a substance that "suppresses the generation of senile body odor". One of them includes "a formula that prevents hair loss and promotes hair and uses coffee powder obtained from grounded coffee".

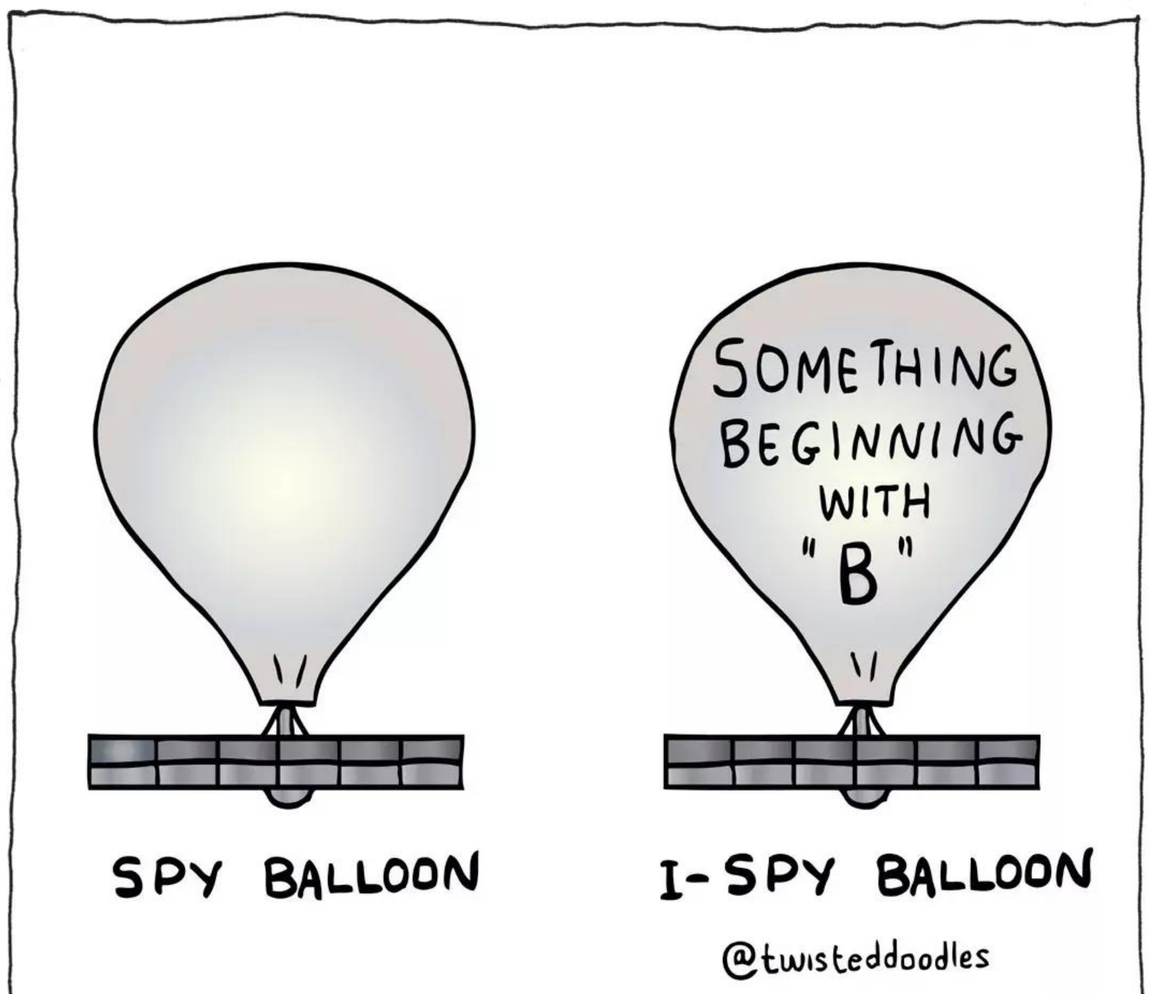
The Brazilian patent searchers published their roundup in the *International Journal of Cosmetic Science*. They note – lamentedly – that "although Brazil is the largest coffee producer worldwide", none of these patents come from Brazil.

A royal endeavour

Stimulated by the news about new inventions in coffee cosmetics, Feedback did a patent search for recent innovations in another of coffee's non-gustatory uses: coffee enemas. Six new patents for coffee enema technology were published during the past year, all in China.

This perhaps marks an international passing of the torch. Until recently, the UK led the world in exploring and promoting coffee enemas' benefits. The public face of that effort, the now former Prince Charles, recently assumed new professional duties. Unless someone else is appointed soon to carry on the work, UK industry and the general populace might soon face a coffee enema gap.

Twisteddoodles *for New Scientist*



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Abyss of infinite lunacy

The academic field called evolutionary psychology suffers from an image problem among scholars in general. There is a suspicion that much of the discussion there is just slick storytelling, with only skimpy evidence for the stories. Some reputations, complainers grumble, are more marketed than earned.

Even many marketing professors are known to keep their distance from evolutionary psychology. But they shouldn't, suggests Gad Saad, a marketing professor at Concordia University in Canada, in a study called "The marketing of evolutionary psychology", published in the *Journal of Business Research*.

Saad says: "Evolutionary psychology suffers from an image problem amongst marketing scholars, many of whom remain uninterested at best and hostile at worst in applying the evolutionary lens within their research programs." This is sad, Saad implies. He then explains, wordily: "The reality is that innumerable theoretical, epistemological, methodological, and applied benefits would accrue to marketing academics and practitioners alike by adopting the evolutionary framework within the science and practice of marketing."

Saad has published extensively. His papers include "Advertised waist-to-hip ratios of online female escorts: An evolutionary perspective", "Finger length ratio and attitudes toward several product categories" and a study about oxytocin, the so-called love hormone. That paper asserts: "Breastfeeding women serve as a group of particular interest when studying the effects of oxytocin, as they are under its influence," going on to say that "breastfeeding women are less prone to retaliate than men" when a company treats them, as customers, unfairly.

In a recent paper called "The corrosive effects of idea pathogens", Saad issues a battle cry against those who make foolish claims: "I use a neuroparasitological framework to argue that a superficially enticing set of idea pathogens have parasitised countless people in the West leading us resolutely towards the abyss of infinite lunacy."

Feedback on Howls

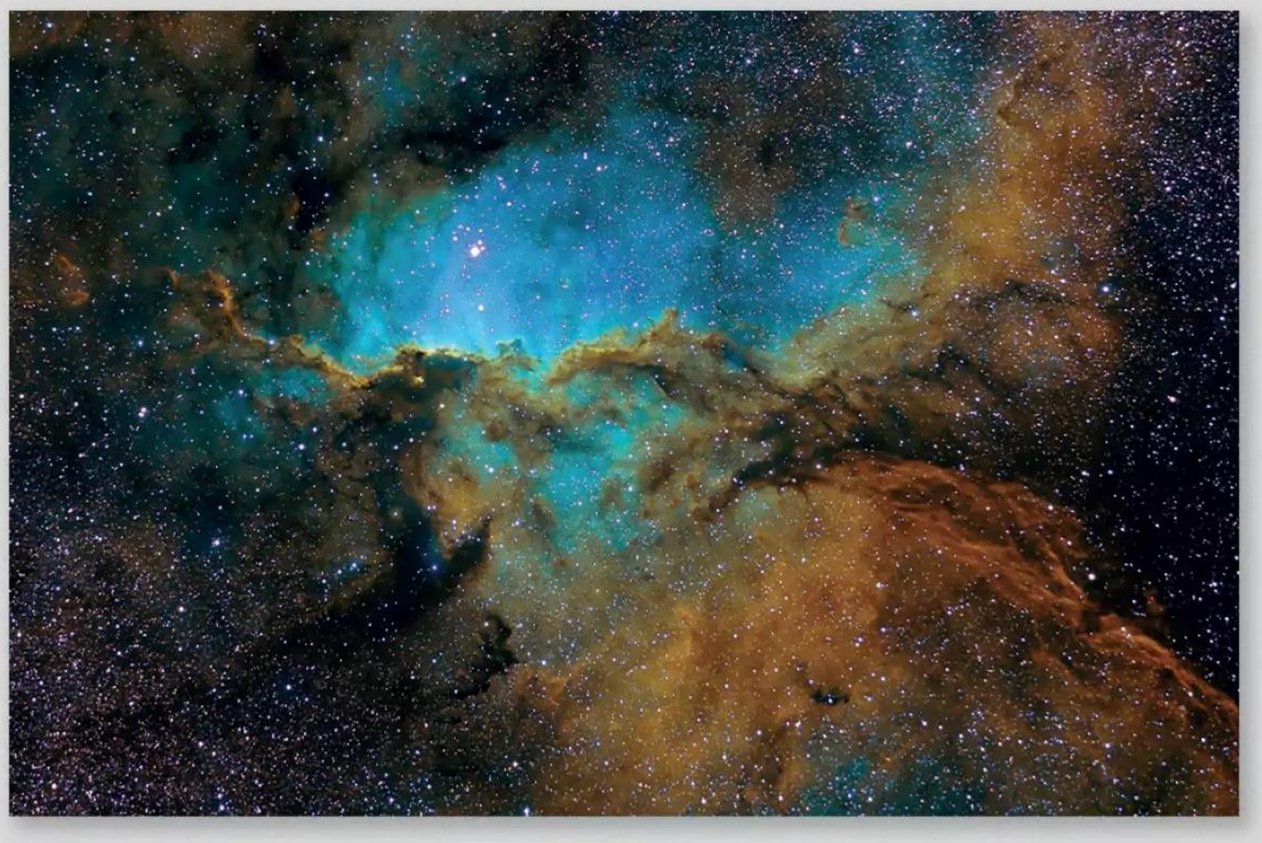
Physicist Michael Berry sent Feedback feedback about our recent glance at research papers by Howls, Howling and Howling, about howling and other acoustic phenomena. Howls – Christopher Howls – was once Berry's student. In fact, Howls's treatise, a joyful look at logarithmic catastrophes at acoustic horizons, opens: "This paper is dedicated to Sir Michael Berry in celebration of his 80th birthday."

Berry's own note is dedicated to another Feedback item. "I can also contribute to your mention of the 11-year publication delay [endured by ecologist Peter Shaw]. Longer is the interval between submission (1747) and publication (1763) of a paper by Thomas Bayes (he of the eponymous statistics)", published in *Philosophical Transactions of the Royal Society* . But "I would be surprised," says Berry, "if this 16-year delay is the longest". ▮

Marc Abrahams

GALAXY ON GLASS

SPECTACULAR WALL ART FROM ASTROPHOTOGRAPHER CHRIS BAKER



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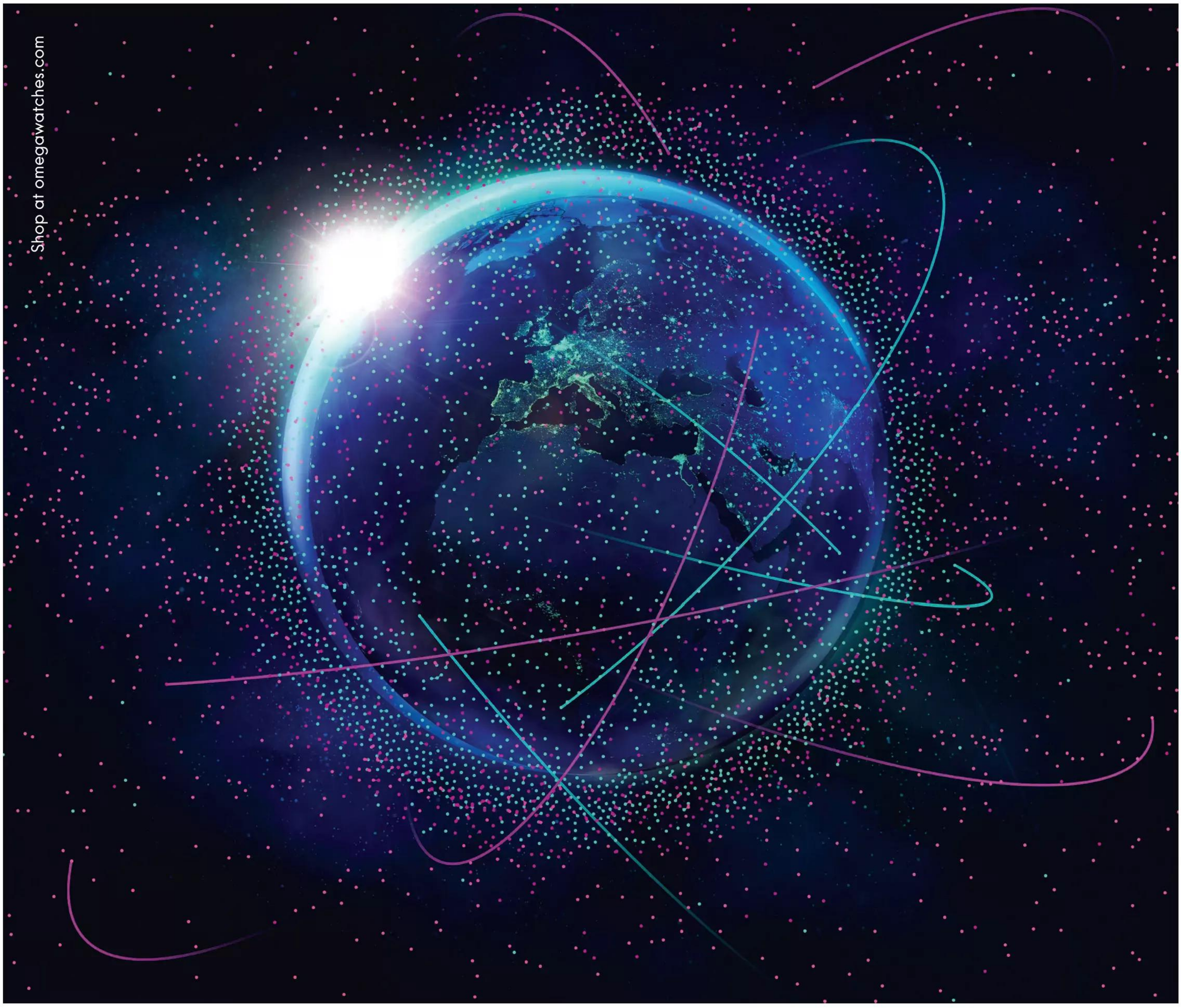

A MAP TO THE FUTURE

The future of space exploration is full of possibility. As innovation takes off, OMEGA is aiming for a sustainable tomorrow, where the path is clear in every direction. Continuing our proud legacy beyond Earth, we're now partnering with Privateer to keep track of the debris that currently surrounds our planet. By doing this, we can look confidently ahead, and ensure that nothing stops humanity from reaching the next frontier. Scan the code to learn more about the project.

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