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IS NOT THE REALITY THAT EXISTS

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DAVID BALL / ALAMY STOCK PHOTO

A fishy business

Taking back control must not mean a return to overfishing

FOR patriotic Brits, fish – especially cod – are highly symbolic animals. Not only does the UK national dish feature them deep fried in batter, they also serve as a potent symbol of "us" versus "them". The affront of other European countries restricting how much British trawlers can catch helped sustain a sense of national grievance that found its highest expression in the vote to leave the EU.

Even before joining the EU's Common Fisheries Policy, the UK's appetite for flaky white fish was at the mercy of other countries. Those with long memories will recall the Cod Wars of the 1950s, 60s and 70s, when the UK and Iceland faced off over fishing rights in the Atlantic. Last summer's English humiliation on the football pitch wasn't a first: Iceland won easily then, too.

No wonder, then, that the news of North Sea cod gaining sustainable status (see page 23) was greeted with glee in the UK. No longer will Brits have to rely on cod caught in the Barents Sea by Icelandic, Russian and Norwegian vessels. Expect a surge of triumphalist patriotism as fish and chip shops and supermarkets boast of selling "British Cod".

Cod, of course, aren't British. If anything, they are the fabled "citizens of nowhere" so derided by the prime minister, Theresa May, during the recent general election campaign. And like those rootless anti-patriots, fish have become pawns in the culture war that increasingly defines British politics.

A few weeks before the cod decision, environment secretary Michael Gove announced that the UK would be quitting the London Fisheries Convention (possibly the first time that a state has left an international agreement named after its own capital city). Signed and sealed in pre-EU days, this treaty allows signatories to fish in each other's territorial waters. It is why boats from these 11 European states can fish as close as six nautical miles from the UK coast, and vice versa.

"No longer will Brits have to rely on cod caught in the Barents Sea by Icelandic and Norwegian vessels"

Gove, unsurprisingly, sold this as "taking back control" and, ominously, said it would allow British boats to catch more fish. That seems unlikely given they will lose access to the coastal waters of much of Western Europe – unless Gove envisions massively upping the take from UK waters.

The UK will also be leaving the Common Fisheries Policy, allowing it to take back control of all waters up to 200 nautical miles offshore, or the midpoint between the UK coastline and that of its neighbours.

For now this is all largely symbolic, playing into the Brexit narrative of the plucky maritime nation throwing off its shackles of oppression. It also turns fish into a useful bargaining chip in the Brexit talks.

But as with Brexit, the symbolic bones will have to be clothed in legislative flesh. Gove must at least acknowledge that without the Common Fisheries Policy, sustainable North Sea cod wouldn't be back on our plates. It was EU legislation that largely forced fishing fleets to adhere to scientifically sound quotas and allowed stocks to bounce back.

Instead, Gove chooses to portray EU policy as the problem, calling it "an environmental disaster". He is clearly throwing red meat – or rather wet fish – to the strongly pro-Brexit fishing lobby. But at some point the UK government is going to have to explain how it will use its new territorial and political freedoms to keep fish stocks from collapsing again, or British cod will be back off the menu. ■

JAMES SCHWABEL/ALAMY STOCK PHOTO

All shook up

Yellowstone shakes

IT'S shaking so much, it could be renamed Jellystone. Since 12 June, about 1400 quakes – most of them tiny – have been recorded in Yellowstone National Park in the western US.

The earthquake "swarm" is occurring in the Hebgen Lake area. In 1959, a major quake in this region killed 28 people. But geologists monitoring the activity don't think another big one is on the cards.

"Usually, you don't get swarms before a big quake like that, and it's too soon after the 1959 quake for enough strain to build up for a repeat," says Jacob Lowenstern of the US Geological Survey in California, who heads the Yellowstone Volcano Observatory. "You'd be looking at the order of 200 years or so for enough strain to accumulate."

"This is a large swarm but it is not the largest swarm we've recorded in Yellowstone," says Jamie Farrell at the University of Utah in Salt Lake City. "Earthquake swarms are fairly common in Yellowstone."

What's more, the chances of significant activity associated with the Yellowstone supervolcano are slim, says Farrell. "There is no indication that this swarm is related to magma moving through the shallow crust," he says. "The bottom line is that visitors should definitely not be worried about an impending volcanic eruption of the Yellowstone volcanic system."

Lowenstern says the swarm is still active at a low level. "It could go on for another month."

Ocean parks diluted

AUSTRALIA wants to allow commercial fishing in 80 per cent of its marine reserves, up from 64 per cent at present. If environment minister Josh Frydenberg wins approval for his proposal, announced last week, Australia will become the first country to scale back its ocean protection measures.

"It makes no sense to cut protections when the Great Barrier Reef is already under pressure"

Marine parks make up 36 per cent of Australian waters, forming areas closed to oil and gas exploration and with restrictions on commercial fishing.

Under the proposed changes, one of the hardest-hit reserves will be the Coral Sea marine park adjoining the Great Barrier Reef off Queensland.

Strict regulations apply in this zone of 1 million square kilometres – including a fishing ban in half the area – because it is one of the few regions in the world where tuna and sharks thrive.

Frydenberg is proposing cutting the no-fishing areas of the marine park by 53 per cent " to enable a continued Australian tuna fishing industry based out of northern Queensland".

But commercial fishing could have profound knock-on effects, says Darren Kindleysides at the Australian Marine Conservation Society. "The Coral Sea is the cradle of the Great Barrier Reef – it replenishes it with new life," he says. "It makes no sense to cut protections when the reef is already under pressure."

Blood donation

ENGLAND and Scotland are to ease their rules on blood donation for gay men and sex workers.

Since 2011, men who have sex with men have been allowed to give blood, but only after a period of 12 months without sexual activity. This is now set to be reduced to just three months.

All donated blood in the UK is checked for HIV and hepatitis B and C. A review of scientific evidence found that, thanks to more reliable screening tests, three months is long enough for an infection to become detectable in the blood.

For the same reasons, sex workers – previously banned from giving blood – will be able to do so three months after their last sex act, as will people who have had sex with a partner at high risk of contracting HIV.

"This means we in the UK have a world-leading blood donation policy, based on the latest scientific evidence, and we hope other countries follow suit," says Alex Phillips of UK HIV charity the Terrence Higgins Trust.

TEPCO

A nightmare view of failure

Meltdown glimpsed

A SUBMERSIBLE robot has spotted what could be melted nuclear fuel in Japan's Fukushima Daiichi power plant.

Following the magnitude 9 Tohoku earthquake in March 2011, a tsunami damaged emergency generators that would have provided power to keep the plant's reactors cool. This failure led to nuclear meltdowns and explosions that damaged the reactors' containment systems.

Three reactors sank into 6 metres of water, releasing radioactive material.

Finding and removing the nuclear fuel is an essential part of decommissioning the plant. But the area is still too contaminated for humans to explore, so robots are being used to survey it.

The clumps of what is likely to be submerged melted fuel were spotted in video taken by one robot over three days, said a representative of the firm that operated the plant.

The whole clean-up process could take decades and cost tens of billions of dollars.

Dark web busts

TWO of the biggest criminal dark web markets were shut down last week by a law enforcement sting. Between them, AlphaBay and Hansa were responsible for the trading of over 350,000 illicit goods, including drugs, stolen documents, cybercrime malware and weapons (see page 12).

Anonymity on the hidden online networks that form the dark web makes it hard to track down traders – unless you control the dark markets they use. So last month, Dutch police and Europol gained control of Hansa, with the FBI getting hold of AlphaBay a few weeks later. Though it is difficult to trace users on the dark web, buyers regularly give their own email addresses when making purchases on dark markets. So the authorities were able to harvest the email addresses 10,000 people used to sign in, before shutting everything down.

If those people were involved in large-scale criminal activities, they can soon expect a knock on their door. Europol described the exercise as one of the most "sophisticated takedown operations ever seen in the fight against criminal activities online".

US health spending

US GOVERNMENT proposals to spend less on global health research will be bad for many countries – but perhaps worst of all for the US.

Between 2007 and 2015, the US spent $14 billion on global health research, according to the Global Health Technologies Coalition (GHTC), a group of organisations that promote such efforts, including the Gates Foundation.

According to the GHTC analysis, for each of those dollars spent, 89 cents remained in the US, paying for US researchers and their work. This investment is calculated to have created 200,000 jobs and added $53 billion to US economic output.

"What really struck me was that every taxpayer's dollar spent on basic research generates an additional $8.38 of industry investment over eight years," says GHTC director Jamie Bay Nishi.

But president Donald Trump's proposed 2018 budget, published in May, revealed plans to cut federal funding for programmes described as providing "little return to the American people". The health budget was titled "Putting America's health first". The GHTC estimates that the cuts associated with these plans add up to around $5 billion.

Laws for little drones on the way

THE UK government just got tough on toy drones. Those heavier than 250 grams will soon have to be registered with the Civil Aviation Authority, just like commercial drones, and their owners must take safety tests to ensure they grasp the basics.

The regulations are a response to a 22 July report on what happens when airliners travelling at low altitude collide with different sized drones.

Not many studies had been done, even though near misses have sharply increased from 6 in 2014 to 70 two years later, the report said.

Researchers launched drones from gas guns at real aeroplane and helicopter windscreens. They used the results of this and computer models to extrapolate the expected damage in different conditions.

They found that certification designed to protect aircraft from bird strikes was not enough to keep helicopter windscreens or tail rotors safe. Drones have lots of metal parts that become shrapnel. The news was better for airliners. Windscreens held up at the low speeds typical of take-off and landing, for impacts with drones under 4 kilograms.

However, some surprises emerged: for example, the smallest drones may do the most damage, even to airliner windscreens. The 400-gram class of toy drones often don't have plastic covers over exposed metal motors and batteries, making these parts more dangerous in a collision.

BRUCE BENNETT/GETTY IMAGES

Near misses on the up

60 SECONDS

One step ahead

Why do we rarely fall over when we walk? Snatching just a glimpse of the terrain ahead during a stride seems to be enough to make sure our foot hits the ground in the right place on the next footfall, avoiding any accident (*PNAS*, DOI: 10.1073/pnas.1611699114).

SpaceX kills Red Dragon

Elon Musk has said his firm is altering its Mars plans, which no longer include the Red Dragon lander. The craft's trip to Mars had already been postponed to 2020, but now it won't make it there at all. A replacement design may be unveiled as soon as September, he said at a conference.

Wet blanket

Water is spread right across the moon, trapped in volcanic rocks. Lunar samples from the Apollo 15 and 17 missions had revealed water trapped in glass beads. This new satellite survey suggests that tiny pockets of water in minerals make up a substantial store that could be useful for a future colony (*Nature Geoscience*, doi.org/b9wk).

Dystrophy milestone

Gene therapy has safely treated Duchenne muscular dystrophy in an animal model. The disease, caused by a faulty version of the dystrophin gene, leads to muscle degeneration, and is usually fatal by age 30. But inserting a healthy, shortened version of this gene into 12 dogs with the condition stabilised their symptoms (*Nature Communications*, DOI: 10.1038/ncomms16105).

Overfat outbreak

Belly bulges are the latest threat to global health. Over 90 per cent of men and half of children in the US, New Zealand, Greece and Iceland are thought to have unhealthy amounts of abdominal fat – far more than previously thought. Being "overfat" raises the risk of diabetes, stroke, heart disease and cancer (*Frontiers in Public Health*, doi.org/b9wz).

DIANA HARONIS/GETTY

Helpful, but lasers might be better

Reawakening memories

Alzheimer's may not wipe our memories clean finds **Alice Klein**

FORGOTTEN memories have been reawakened in mice with symptoms resembling Alzheimer's disease. The feat suggests the condition may not destroy memories, but instead impair our ability to recall them.

It has long been assumed that Alzheimer's completely erases memories. The disease involves clumps of proteins accumulating in the brain, where they are thought to destroy the neurons that store our memories.

But work by Christine Denny at Columbia University and her team suggests memories may not be wiped by Alzheimer's disease, but instead become harder to access. What's more, they can be artificially reawakened.

The finding could be revolutionary, says Ralph Martins at Edith Cowan University in Australia. "It has the potential to lead to drug development to help regain memories," he says.

To examine how memory is affected by Alzheimer's disease, the researchers developed a way of visualising individual memories in mouse brains. They genetically engineered mice so that neurons glowed yellow when storing a memory, and red when recalling one. Two sets of these mice were created – one that was healthy, and one with a condition resembling Alzheimer's disease.

"This technique could be revolutionary. It may lead to drugs that help us regain memories"

Both sets of mice took a memory test. First, they were exposed to a lemon scent and given electric shocks. Then, a week later, they were exposed to the same lemon scent. Most of the healthy mice immediately froze in anticipation of being shocked. But almost half as many of the Alzheimer's-like mice froze, suggesting they did not remember the link between the smell and shock so strongly.

This behaviour matched what the team saw in the hippocampi of the mice – the brain regions that record memories. In healthy animals, the red and yellow neurons overlapped, showing that the mice were retrieving the lemon-shock memory from the same place it had been stored. But in the Alzheimer's mice, different cells glowed red during recall, suggesting that they were calling up the wrong memories.

This might explain why people with Alzheimer's often experience false memories, says Denny. For example, many people with the condition incorrectly remember where they were during the 9/11 attacks. These new findings suggest this may be because they are retrieving information from the wrong brain cells.

Using a genetic engineering technique called optogenetics, Denny's team went on to reactivate the lemon-shock memory in the Alzheimer's mice. By shining a blue laser down a fibre-optic cable into the brain, they were able to stimulate the yellow memory-storing neurons, prompting the mice to freeze when they smelled lemon (*Hippocampus*, doi.org/b9w8).

Memory reboot

This shows that "lost" memories may still exist in the brain, and can be recovered. For now, optogenetics cannot be used in people because it isn't yet safe or practical to tinker with our neurons or stick lasers in our brains. But in future, targeted drugs or techniques like deep-brain stimulation may help people with Alzheimer's access forgotten memories, says Denny.

However, mouse Alzheimer's models do not perfectly reflect the condition in humans, warns Martins. The number of neurons that die in Alzheimer's mice is far lower than in people, he says.

But there are already clues that lost memories can be reawakened in people with Alzheimer's, Martins says. "Music is the best example, which has attracted a lot of attention as a way for retrieving memories of the past in these patients – so it makes sense."

If something like Denny's technique can be made to work in humans, it could have other uses, such as helping witnesses remember crime scenes. We may even be able to tap into memories from early childhood.

However, it's unlikely we could selectively reactivate memories, because we wouldn't know which neurons they were stored in, and some neurons may hold multiple memories, says Denny. "You would not want to bring back bad memories too." ■

Tides could set alien biological clocks ticking

WORLDS with a permanent day and night side aren't obvious places to look for extraterrestrial life. Apart from having extremes of temperature, such planets would make it hard for a biological clock to get going.

Now, Avi Loeb and Manasvi Lingam at Harvard University have shown that if these worlds have oceans, tides could be what life gets into sync with its world.

We used to think that having no day-night cycle would make it hard for life to emerge, due to the lack of a circadian clock. On Earth, such clocks play a key role in several biological contexts. It's possible aliens don't have them, but how life could evolve without one is tough to imagine.

"There is abundant evidence that biological clocks are essential to modern life on Earth, and that they may have evolved very early in the history of life on Earth, either in cyanobacteria or in other single-celled organisms," says Jennifer Macalady at Pennsylvania State University.

Loeb and Lingam's study shows tides could be the timekeeper. If a planet that always keeps the same face pointing at its star has an elliptical orbit, the change in distance as it circles would create the back and forth pull needed for tides (arxiv.org/abs/1707.04594).

Tides would form ponds as they go out, and can also help dissipate heat, mimicking periodic evaporation caused by a rising and setting sun. Each cycle would concentrate chemicals essential for life. Eventually, life could evolve with days and nights governed by the ocean's flow. Even on Earth, certain fish and crabs have biological clocks set by the tides rather than the sun.

Loeb and Lingam considered planets around dwarf stars like the nearby Proxima Centauri or TRAPPIST-1. These worlds orbit much closer to their stars than Earth does to our sun. For such a planet, its star's gravity would tug much more at its near side than the far side, causing it to show the same face to its star all the time.

On such a "tidally locked" world, the side facing away from the star could be too cold for life, while the side facing it could be too hot. Life might develop on the border – the zone experiencing a constant "sunrise" or "sunset".

WIN-INITIATIVE/GETTY

Time and tide help life get going

"Work like this is important to inform our understanding of how life might evolve on the planets around other stars," says Matt Burleigh at the University of Leicester, UK.

Loeb and Lingam say algal blooms would change how the planet reflects light, in sync with the tides. But detecting that might be tricky, says Jaymie Matthews at the University of British Columbia in Canada.

"Even if tidal blooms in an alien ocean are more extensive than in Earth's, they are unlikely to be global," he says. "And they are not long-lasting, so the signature in the spectrum of exoplanet light will be diluted and intermittent." **Abigail Beall** ■

Drones and AI make for better bird-spotting

DON'T cry fowl. A test using fake ducks to stand in for the real thing has found that when it comes to counting birds, drones (plus AI) beat humans.

Jarrod Hodgson and his colleagues at the University of Adelaide in Australia had tried using aerial images from drones to count seabirds. They found that the drones gave a more comprehensive view of the colonies than people could get while doing a ground-based census.

However, neither method gave an exact count of the individual birds. "We couldn't test for accuracy," says Hodgson. So he bought many hundreds of plastic duck decoys to simulate a flock of greater crested terns on a beach in South Australia.

After the team set the fakes up on the beach, drones began taking aerial photographs of the "colonies", one of which had more than 1000 plastic ducks. Humans counted the fake birds in these images, and also made counts from vantage points on the ground.

The highest-quality photos yielded counts that were more than 90 per cent more accurate than those made from the ground.

The team also developed a machine learning system to count the proxy birds in the images automatically. After training, it proved to be about as accurate as humans. The work was presented at the International Congress for Conservation Biology in Cartagena, Colombia, this week.

"There's immense potential for this to become a more mainstream method," says Norman Ratcliffe at the British Antarctic Survey in Cambridge, UK, who has also used drones to help gauge numbers of seabirds in colonies. He points out that aerial images can also let ecologists monitor the outline, position and habitat of a colony over time.

"Many hundreds of plastic duck decoys simulated a flock of greater crested terns on a beach"

Bird strike is a risk when using airborne vehicles for such research, although Ratcliffe says some ground-based counts can be destructive, too, if eggs or nests are disturbed.

In the UK, the Royal Society for the Protection of Birds is already using drones to monitor seabirds. Principal conservation scientist Mark Eaton says drones could reduce the need for boats to venture near dangerous cliffs for humans to survey the birds.

"This has limited the number of years in which complete colony counts have been possible," says Eaton. Now, the sky's the limit. Chris Baraniuk ■

Stem cell boost slows down ageing

Jessica Hamzelou

YOUR brain may be to blame for your ageing body. A small cluster of stem cells in the brain seems to help mice stay young, and injecting extra stem cells helps them live longer. One day anti-ageing drugs might be able to replicate the effect in people.

Ageing is a complicated process, involving DNA damage, chronic inflammation, and worn-out cells, but we don't yet know which of these has the biggest impact on ageing. Dongsheng Cai at the Albert Einstein College of Medicine in New York has been investigating the role of the brain in ageing, since it controls most of our bodily functions.

His team previously found that the hypothalamus, which releases hormones that affect other organs, seems to affect how mice age. By interfering with a molecular pathway in the hypothalamus, the team extended the lifespan of mice by 20 per cent.

Cai's team wondered whether stem cells here might influence ageing. Although stem cells in the hypothalamus create new neurons throughout life, the team noticed that mice start losing them in middle age – about 10 or 11 months old. By the time mice are 2 years old – around 70 in human years – the cells are basically all gone, says Cai.

Mice age faster if these stem cells are destroyed. "There was a decline in learning and memory, coordination, muscle mass, endurance and skin thickness," says Cai. The mice died a few months earlier than untreated animals.

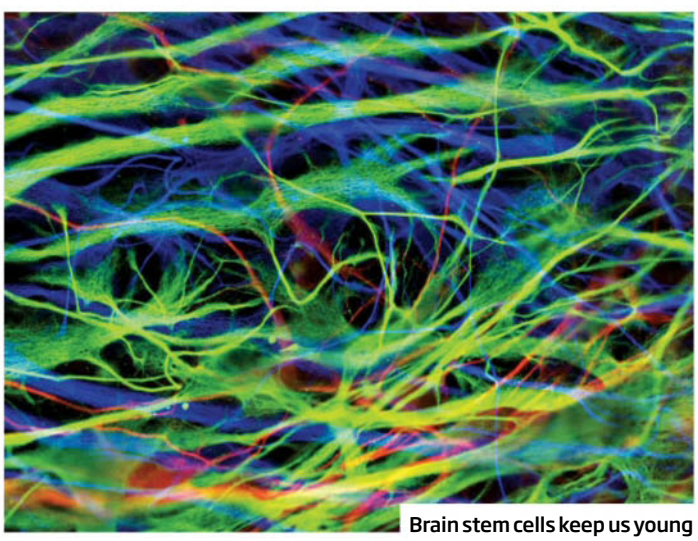
But injecting the hypothalamus with extra stem cells, taken from the brains of newborn mice, slowed down this premature ageing, and gave mice an extra two to four months of life (*Nature*, DOI: 10.1038/nature23282).

First the team had to modify the stem cells so that they kick-started an anti-inflammatory pathway in the mice, otherwise the cells died and the injections didn't work. This suggests that it may be inflammation that usually causes the death of stem cells in the brain as we age.

The team found that the injected stem cells secreted a particularly large amount of microRNAs. These are small molecules that can affect the way genes work, and the types of microRNA in our blood are known to vary according to age. Cai isn't sure how the stem cell microRNAs might be working, but they seem to reduce biological stress and inflammation, he says.

Cai thinks his team's findings could one day lead to a treatment for ageing. Once the microRNAs have been identified, it might be possible to develop drugs that mimic their effects, he says.

This may have the potential to become a therapy in about 30 years, says Richard Faragher at the University of Brighton, UK, who says other teams are already working towards microRNA drug treatments. An alternative strategy would be to target inflammation more generally. "I can see us taking multiple approaches," says Faragher. ■



SILVIA RICARDI/SPL

Brain stem cells keep us young

Tiny robots swim the front crawl in blood

IT'S no Michael Phelps, but this tiny robot swims the front crawl at 10 micrometres per second. It would take about two months for it to swim a lap in an Olympic swimming pool – in that time, Phelps could swim almost 5 million lengths. But the bot is fast for its size and strong enough to get through viscous liquids, like blood, to deliver medicine from inside a vein.

The front crawl is the fastest way for humans to swim. So Tianlong Li at the Harbin Institute of Technology in China and his colleagues built their swimming robot to mimic that motion.

Each bot is 5 micrometres long and has three main parts linked by two silver hinges. Its gold body is flanked by two magnetic arms made of nickel. Alternating the direction of a magnetic field around the bot causes its arms to rotate and propels the nano-swimmer forward (*Nano Letters*, doi.org/b9wh).

"It's exciting due to its speed and its really small size, just about the same size as a blood vessel," says Eric Diller at the University of Toronto in Canada who researches micro-robots. "It's small enough basically to go anywhere within the body."

Because bodily fluids are more viscous and difficult to swim through than water, the researchers also tested their nano-swimmers in serum. The bots only swam 5.5 micrometres per second, but that's still faster than many other similar mini-machines.

For targeted non-invasive medicine delivery, these nano-swimmers could be coated with medicine, injected into the bloodstream and roughly steered by external magnetic fields.

However, they are too small for just one to carry enough medicine to actually help. "Maybe a thousand of them would be necessary," says Diller. "There's no way to keep track of all of them, so there are a lot of questions about safety and toxicity."

"A single nano-swimmer could be injected into an eyeball to take medication directly to the retina"

They will have to be made of biodegradable materials before they can be used in the bloodstream. But Diller says that bots for use in the urinary tract or the eyeballs could begin clinical trials within the next five to 10 years. Injecting a single swimmer into an eyeball to deliver medication directly to the retina and then removing the bot would be far simpler than letting a swarm of them swim through the entire circulatory system.

We don't know how fast Phelps could swim in blood – thankfully, his recent race against a great white shark didn't provide a testing ground. But since you can't inject him into your bloodstream, these nano-swimmers will have to do. Leah Crane ■

Mega-swan once called New Zealand home

IT'S the original All Black. New Zealand was once home to a hulking, semi-flightless black swan that died out shortly after humans first arrived from Polynesia in the 13th century.

The existence of a prehistoric New Zealand swan has long been contentious. Legends from the Moriori people tell of the Pouwa – a large swan-like creature. But some palaeontologists have suggested this may refer to the Australian black swan (*Cygnus atratus*), which occasionally flies across the Tasman Sea.

Now, Nicolas Rawlence at the University of Otago and his colleagues have used genetic techniques to confirm the mega-swan's existence.

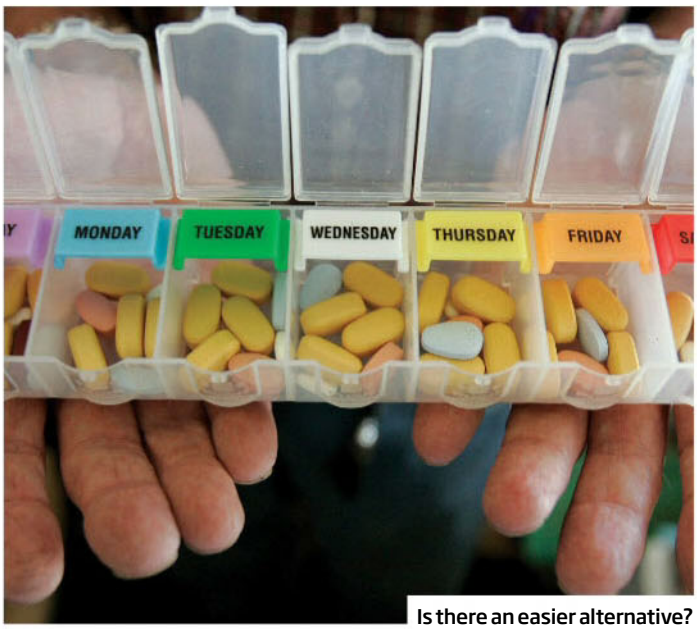
The researchers compared DNA from 47 modern Australian black swans and 39 ancient swan fossils uncovered in New Zealand. Many of the fossils came from the isolated Chatham Islands located 650 kilometres east of New Zealand's mainland, home to the Moriori.

The analysis suggests the mega-swan split from *C. atratus* about 1 to 2 million years ago. "We think Australian black swans flew to New Zealand at this time and then evolved into a separate species – the Pouwa," says Rawlence.

His team reconstructed the general appearance of the Pouwa from its fossils. They found that it was about 20 to 30 per cent heavier than modern Australian black swans, and would have weighed up to 10 kilograms (*Proceedings of the Royal Society B*, DOI: 10.1098/rspb.2017.0876).

"You can think of the Australian black swan as a lean football player and the Pouwa as an angry, hulking, rugby forward," says Rawlence.

The fossil record shows the Pouwa went extinct around AD 1450, less than 200 years after Polynesians first colonised New Zealand. Since there were no environmental shifts at this time, the only logical explanation is that humans brought about their demise, says Rawlence. Alice Klein ■



DAVID GOLDMAN/THE NEW YORK TIMES/REDUX/EYEVINE

Is there an easier alternative?

Long-acting injections could keep HIV in check

PREVENTING and managing HIV infection could become as easy as an injection in the buttock.

To keep the virus under control, people who have HIV take large numbers of antiretroviral therapy (ART) pills every day. These keep the virus at low levels in the blood, reducing the chances of it being passed on. Pre-exposure prophylaxis (PrEP) drugs, on the other hand, help protect people who are at risk of contracting the virus – for example, people whose partners are HIV positive.

While PrEP isn't yet widely available on the National Health Service in England, some people have been sourcing it online – a trend that may explain falling rates of new HIV infections in gay men in England.

But tablets aren't always practical, says Michael Brady of the Terrence Higgins Trust, an HIV charity in the UK. "Many people living with or at risk of HIV infection would prefer an injectable alternative," he says – both because it's more convenient, and easier to stick to.

Now two studies presented at a conference of the International AIDS Society in Paris this week suggest injectible regimes could work and may not be too far off.

A two-year trial in 286 people with HIV found that 94 per cent of those who had injections of long-acting ART every eight weeks had the virus under control – defined as having less than 50 copies of the virus per millilitre of blood. A monthly form of the injection was effective in 87 per cent of those who had it, while standard ART pills worked for 84 per cent of those who took them (*The Lancet*, doi.org/b9wb).

"Although the painful shots need to be given periodically, most people prefer this to daily dosing"

"This is a big step forward," says Mahesh Mahalingam of the United Nations Programme on HIV/AIDS, who wasn't involved in the research. "It will help remove the challenge of taking tablets every day and significantly improve the quality of life of people living with HIV."

The treatment is a suspension of two antiretroviral drugs called cabotegravir and rilpivirine. When injected into the buttock, the drugs collect between muscle fibres and slowly leach out into the bloodstream. "A single dose can last for 48 weeks or more," says Peter Williams of pharmaceutical firm Janssen, who helped lead the project. Although some reported soreness at the injection site, almost all participants were happy with the injection compared with taking pills, says Williams.

A similar approach may also work for PrEP. A separate trial administered injections of cabotegravir alone to nearly 200 low-risk people who don't have HIV. Half the participants received injections of a higher dose every three months, while the other half received a lower dose every two months.

The team running the project monitored the levels of cabotegravir that made it into the volunteers' bloodstream for up to two years. They found that people receiving the more frequent, lower dose had levels of the drug in their blood that matched those seen in people who take PrEP pills every day.

"This is a step in the direction we've been leaning for some time," says Anthony Fauci of the US National Institute of Allergy and Infectious Diseases in Bethesda, Maryland, who was involved in the PrEP injection trial. "It's very clear that PrEP works, but some people have problems taking a pill a day. This way, you don't run out of anything."

"These two studies form the next crucial step towards the first effective long-acting drug combination," says Mahalingam. "Although the painful injections need to be given periodically, most people in trials say they prefer this to the inconvenience of daily dosing." **Andy Coghlan** ■

‘Old’ DNA ups odds of salmon survival

Aylin Woodward

THERE’S something fishy going on. Juvenile Atlantic salmon with shorter telomeres – normally considered a sign of poor health – have a higher chance of surviving the epic migration from their home river to the sea and back again.

Telomeres act as caps on the ends of chromosomes, preserving the DNA after cells divide. But the telomeres shrink with each division and eventually become so short the cells can’t divide any more. In humans, shortened telomeres are associated with cardiovascular diseases and cancer in adults, and are thought to reflect overall health.

No wonder Darryl McLennan at the University of Glasgow, UK, and his colleagues were puzzled by their results. In the spring of 2013, McLennan’s team tagged over 1800 juvenile salmon, or smolts, in the Blackwater river in northern Scotland just before they migrated to the sea.

The team also took a small fin tissue sample from each fish to measure the telomeres.

In the autumn of 2014 and 2015, when McLennan expected the salmon to return to the river to spawn, his team trapped the tagged fish and took a follow-up fin tissue sample to measure telomere length.

They only managed to catch 21 of the original salmon and the survivors were more likely to have set out on their migration with shorter telomeres.

“When we started this project we hypothesised the juvenile salmon with shorter telomeres would have a reduced lifespan – we found the complete opposite,” McLennan says (*Functional Ecology*, doi.org/b9vh).

It’s an unexpected result, but Terry Burke at the University of Sheffield, UK, points out that the analysis ultimately relies on data from very few of the original salmon: only about 1 per cent made it back to spawn. He would like to see the study replicated before we can say with confidence that young salmon with shorter telomeres outperform their peers carrying longer versions.

What’s more, Burke points out that there might be other ways of explaining why McLennan’s team found a result that runs contrary to popular wisdom.

“We’re not observing these fish dying from illness, but mostly from predation or being caught at sea,” he says. In other words, the selection pressures at work might not relate to telomere length at all.

McLennan, however, thinks it’s possible that fish with shorter telomeres really do fare better. Salmon undergo physiological changes to prepare themselves for the taxing migration. He thinks that fish who invest more energy into preparing themselves for life at sea may do so at the cost of maintaining their telomere length. ■

FLPA / ANDREW MASON/REX/SHUTTERSTOCK

Migration: a taxing business

Just snap your meal to find the recipe for it

EVER eaten a dish you didn’t know the name of and wished you had the recipe so you could recreate it at home? Soon you might only need a picture of it, thanks to a machine learning algorithm that looks at photos of food and predicts the recipe.

Nick Hynes at Massachusetts Institute of Technology and his colleagues trained the algorithm on one million recipes, each with an illustration of the finished result, from dozens of cooking websites. Given a fresh photo of a dish, the system picked the right recipe 65 per cent of the time.

Even without access to the recipe, the AI can work out from a photo what ingredients a food contains. Fed an image of biscuits, for example, it knows they are likely to include flour, eggs and butter. But it can’t necessarily tell how the ingredients were prepared – whether onions were stewed or fried, for example – although Hynes hopes it will gain this ability in future.

The AI struggles to recognise hidden ingredients in a sushi roll, but is particularly good at finding recipes for cookies and muffins, Hynes says, because they are relatively popular online. The team presented the work last week at the Computer Vision and Pattern Recognition conference in Honolulu, Hawaii.

Hamed Haddadi at Queen Mary University of London is impressed, and hopes an improved version of the algorithm could help track calorie intake. App such as MyFitnessPal already do that, but users have to manually input what they eat. “The bigger goal is to accurately tell how many calories there are in a specific dish,” he says, something a visually guided AI might one day be able to do.

For now, Hynes’s AI is not too good at recognising the subtleties of dishes. Given a photo of an aubergine lasagne, for example, it’s more likely to dish up a generic lasagne recipe rather than a specific one. This could be improved, Hynes says, if users also specified a couple of hard-to-see ingredients when providing a photo.

“The AI struggles to recognise what’s hidden in a sushi roll but is good at finding recipes for cookies”

The dream of complete recipe recreation from a single snap is still a while away, says Haddadi, but app makers are already working hard on the problem. In May, for example, Pinterest added dish recognition to its app. Now if you take a photo of a meal with the app, it will identify certain ingredients and offer recipes that feature them. The company plans to use the technology to help food brands advertise to Pinterest users.

Matt Reynolds ■

US guns sold in Europe via dark web

Timothy Revell

THE veil on the hidden world of weapons sales on the dark web was lifted last week.

This first detailed glimpse came with the publication of a report from the RAND Corporation, which reveals an alarming pattern: the majority of vendors are based in the US and are willing to ship worldwide, with Europe the biggest source of profit. Lax gun laws in the US are undermining stricter rules elsewhere.

And while absolute numbers are still small – accounting for less than 1 per cent of items sold on the dark web – transactions go far beyond simply putting a gun in the mail. From manuals on how to create explosives to detailed instructions on how to disassemble and ship a gun to various overseas destinations, the information and technology available to buyers is well placed to facilitate lone-wolf attacks.

The report is "a good overview of the current situation", says Julio Hernandez-Castro at the University of Kent, UK.

The dark web is a subset of the internet that requires specific software to access so that users can remain anonymous. Not all items for sale there are illegal, but the promise of anonymity makes it easier to subvert the law. "It could revolutionise how normal people purchase firearms," says lead author Giacomo Persi Paoli.

This anonymity makes buying or selling items risky: the person at the other end of the deal could be a scammer or the police. It is also what makes studying the dark web tough. So the authors hedge that the report is best interpreted as an estimate.

Nonetheless it paints a revealing picture. Over half of the weapons for sale are from the US, with the revenue from Europe five times higher than from domestic sales through the dark web.

This raises concerns that more people will be able to purchase illegal guns. "It's trivial to get on the dark web. You just register with a market and start browsing as if you were on Amazon," says Hernandez-Castro.

To purchase an illegal firearm previously, you had to contact a gang involved in arms trafficking. Convincing a gang member that you weren't with the police was tricky, and they might scam you.

To help build trust between buyers and sellers, dark web marketplaces allow them to review transactions the way they would on eBay or Amazon. Many dark marketplaces even offer payment protection.

Vendors on the dark web have also honed their delivery tactics. They may often disassemble weapons into many parts that are sent in different packages. Some parts are embedded in less conspicuous items like old stereos or printers.

"We need to get better at spotting weapons sent in the post to stop the flow," says Hernandez-Castro. ■

WIN-INITIATIVE/GETTY

Purchased on the dark web?

Our eardrums move in sync with our eyes

SEE, hear. Our eardrums appear to coordinate with our eyes to shift our hearing in the direction we are looking. Why this happens is unknown, but it may help us work out which of the objects we see are responsible for the sounds we hear.

Jennifer Groh at Duke University in Durham, North Carolina, and her team have been using microphones inserted into people's ears to study how their eardrums change during saccades – the movement that occurs when we shift visual focus from one place to another. You won't notice it, but our eyes go through several saccades a second to take in our surroundings.

Examining 16 people, the team used the microphones to detect changes in ear canal pressure that were probably caused by middle-ear muscles tugging on the eardrum.

These pressure changes indicate that when we look left, for example, the drum of our left ear gets pulled further into the ear and that of our right ear gets pushed out, before they both swing back and forth a few times.

How our moving eardrums affect the sounds we hear isn't yet known, Groh says. They may prepare our ears to hear sounds from a particular direction.

The changes to the eardrums began as early as 10 milliseconds before the eyes started to move, and continued for a few tens of milliseconds after the eyes stopped (*bioRxiv*, doi.org/b9v8).

"We think that before actual eye movement occurs, the brain sends a signal to the ear to say 'I have commanded the eyes to move 12 degrees to the right'," says Groh.

Never before has the position of the eyes been seen to have an effect on the ears, says Dave Bulkin at Cornell University in Ithaca, New York.

"We think that before the eyes move, the brain sends a signal to the ears to say where the eyes will go"

One theory for why the eyes and ears move together in this way is that it helps the brain make sense of what we see and hear.

The discovery could lead to better hearing aids, which currently amplify all sound equally, regardless of where it is coming from. The brain of a person with normal hearing can focus on sound from someone they are talking to in a restaurant, while ignoring a conversation at a nearby table, says Groh.

"I could imagine a mechanism being incorporated into hearing aids that picks up signals of eyes moving to a new location and tries to amplify the sound at that location," she says.

Aylin Woodward ■

Beyond the Black Disk

On August 21st, 2017, the United States will be treated to an event that hasn't been seen in 99 years: a coast to coast total solar eclipse. By that night, photographs of the blackened sun and its extraordinary corona will fill the Internet, but for those looking for something a little different, there are more eclipse day wonders to look out for 'beyond the black disk.'

For CuriosityStream's new series *Eclipse Across America*, a documentary film crew teamed up with leading eclipse chasers, astronomers, and NASA scientists to travel and explore the path of the August eclipse. What they returned with is a preview of the different eclipse phenomena that will be on display that day and an inside look at how scientists are using this event to help us understand not only our home star, but the countless others in our universe.

Inside an approximately 70-mile wide track stretching from Oregon to South Carolina (known as the path of totality) you will have a chance to witness the fully-eclipsed sun and its corona glowing around its edge. This view of the sun's outer atmosphere is truly one of a kind in our solar system, making this August's eclipse a "can't miss" event for citizen scientists and astronomers alike. But in the seconds leading up to the corona coming out, there will be plenty more to see... if you know where to look.

The experience of a total solar eclipse is really the experience of being in **the shadow of the moon.** As serene as those moments of totality may appear, this shadow is actually travelling more than 1000 mph! That motion may be difficult to sense from ground-level, but from a high point within the path of totality--a mountaintop, a butte, or even a hill with a clear, wide view of its surroundings--you will have a chance to look down and witness that shadow racing across the surface...weather permitting, of course!

As that shadow speeds toward you on the ground, the so-called **'diamond ring'** phenomenon will be revealed up in the sky. The moon's cratered surface yields a bumpy, uneven silhouette so when it passes in front of the sun on August 21st there will be a moment when one final beam of light finds its way through one of these imperfections on the moon's edge. From Earth, this beam will glow like a sparkling gem on the edge of a dimly lit ring. But even this tiny fraction of the sun's light will be far too bright to observe with bare eyes. Make sure you're still wearing your eclipse glasses for this one.

While the diamond ring will only be visible from inside the path of totality, **Baily's beads** will be best experienced just along the edge of that path. One example--at the Gateway Arch, in St. Louis, Missouri, the alignment between the observer, the moon, and the sun will be ever so slightly shifted off center. Looking up from the base of the Arch, the moon will cover more than 99.95% of the sun's surface, and similar to the diamond ring effect, trickles of light will find their way through the moon's canyons and imperfections. But instead of a single gem of light, the result here will be the appearance of a luminous, beaded edge that you will be able to see through your eclipse glasses far longer than anyone stationed near the center of the path of totality.

And then, for those in the path of totality, comes the corona. It will be stunning, guaranteed. Even seasoned eclipse chasers don't always have the words to describe the power of the experience. Will you?

To learn more about the total solar eclipse, and preview this epic event with cutting-edge special effects, watch the new 4-part series *Eclipse Across America* now only on CuriosityStream.com/*watcheclipse*.

Play with shadows to signal aliens

Leah Crane

HELLO from the other side of the galaxy. If there are advanced alien civilisations in the Milky Way, we ought to be thinking about how to introduce ourselves to them. The vastness of interstellar space makes that difficult, but a simulation suggests that stars could feasibly be used as lighthouse beacons.

Just as rail systems use flashing lights as signals, we could one day alter the light shining from our sun, like waving a hand in front of a torch to encode a message.

One way to do that is to build a planet-sized sheet in orbit around the sun, by lassoing swathes of asteroids or mining a chunk out of Mercury. Another, more feasible, idea is to add a message encoded in laser light to Earth's silhouette as it passes in front of the sun, an event called a transit.

Yes, it would be tricky. But if aliens were attempting to make contact, we could eventually cooperate with them to create a galactic communications network. "Eventually" here means at least 300,000 years, according to a simulation by Duncan Forgan at the University of St Andrews, UK (arxiv.org/abs/1707.03730).

Forgan modelled 500 points in the galaxy, each representing a civilisation that can manipulate its planet's transit in a visible way. That's relatively conservative; some researchers estimate there could be millions of alien societies that advanced. He determined how long it would take for each point to be lined up to see a transit at another point, slowly building a web across the galaxy.

Chatting with them all would need a kind of relay network to avoid celestial obstacles. "If you want to communicate with someone on the other side of the galactic centre, there's lots of stuff in the way – dust, stars, a big black hole – so you can take the long way around using the network," says Forgan.

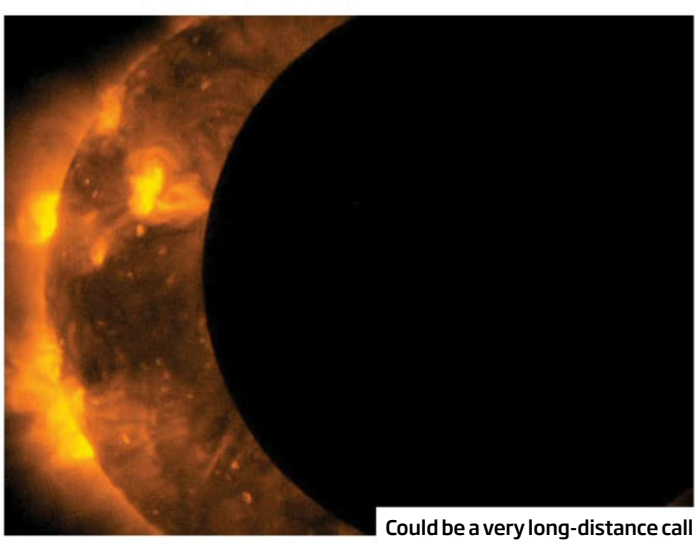
To spot extraterrestrial signals, you would generally have to be looking in just the right direction at just the right time. So Forgan focused on planets transiting their stars, because this happens regularly. If the orbit of another world is suitably aligned so that we can see it passing in front of its sun, then we could simply track such events, provided the inhabitants are able to alter the look of these transits as a signal.

In other words, the predictable orbit of a planet around its star helps us know when to look for any message being transmitted. "It's a way to synchronise our watches," Forgan says.

Constructing any kind of orbiting object enormous enough to signal with would take a lot of work, though, and that makes it an unlikely eventuality, says Avi Loeb at Harvard University. Even if we could build something suitable, we might decide to apply our talents in other ways. "Once a civilisation is advanced enough to have the technology to build megastructures, it's much more likely to leave its planet," he says.

If future humans decided to listen for alien responses to our signals, they would have to wait generations. "Each signal would take thousands of years to travel back and forth," Loeb says. "In cosmic time that may not be that long, but you need patience." That's not to mention the interstellar politics involved in setting up a galactic network.

The upside of communication with transit is that we already have missions such as the Kepler space telescope watching for planets passing in front of their stars. If other planets are seeking to make contact in this way, we won't have to do any extra work to detect them. ■



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Could be a very long-distance call

Robot physio helps people walk again

ARTIFICIAL intelligence is helping people regain their mobility after a stroke or spinal injury. A robot harness overseen by a neural network offers tailored treatment that has improved people's ability to walk normally.

In the past, several physiotherapists were needed to physically support and guide each person through the process of learning to walk again. As staff are expensive, robotic harnesses were introduced. But they offer limited help and can even cause gait problems if abnormal movements aren't spotted.

Rather than simply supporting a person's weight, as existing harnesses do, the new smart RYSEN system can also correct gait by pushing people forward or back, or side to side.

It collects information on leg movement, stride patterns and muscle activity from body sensors and feeds it into an algorithm. This allows the system to provide assistance tailored to how the person walks by deciding how much force to apply to their trunk to produce a natural gait.

"The algorithm evaluates the optimal amount of body weight support for each patient," says Grégoire Courtine, one of the team at the Swiss Federal Institute of Technology in Lausanne who created the harness. This helps them rebuild lost muscle mass and relearn posture and movement, while also retraining their brains to handle the delicate balance between gravity and forward motion that walking requires.

"The smart harness system can correct people's gait by pushing them forward or back, or side to side"

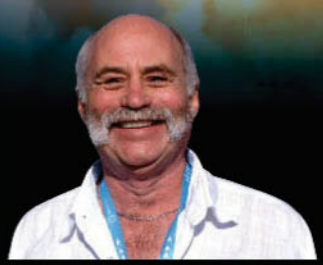
The new system improved the in-harness gait of people following a stroke or a spinal injury. And after a single, 1-hour training session with the harness, people with spinal cord injury showed immediate improvement in their gait out of the harness over those given no physio session at all (*Science Translational Medicine*, doi.org/b9t9).

The next goal, says Courtine, is to commercialise the harness alongside further clinical trials. Nicole Kobie ■

NEW SCIENTIST DISCOVERY

Space flight: A history

A two-week, action-packed tour in the US with astronomy and space experts



Nigel Henbest

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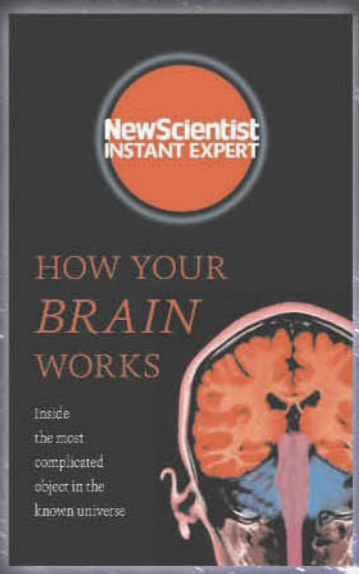

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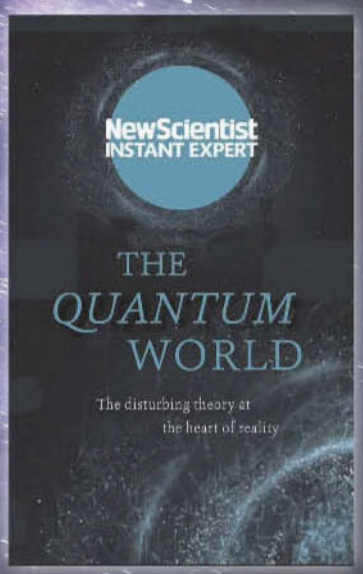

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PETER MULLER/PLAINPICTURE

First dogs may have been extremely sociable wolves

SURVIVAL of the friendliest, perhaps? The ancestral wolves that evolved into domestic dogs may have carried genetic mutations that made them socialise more readily with people. What's more, these very genes are implicated in excessive sociability in humans.

Bridgett vonHoldt at Princeton University and her colleagues tested the behaviour of 18 domestic dogs and 10 wolves. All had an identical upbringing, with constant human contact.

The researchers gave each animal a score for hypersociability, or extreme friendliness, towards humans. As expected, dogs scored higher than wolves.

The team then sequenced a region of each animal's genome they had previously identified as playing a role in sociability. They found four genetic changes that seemed to match well with social behaviour – including two in genes called *GTF2I* and *GTF2IRD1* (*Science Advances*, doi.org/b9vc).

Mutations in these genes are known to cause the hypersociability associated with Williams syndrome in humans.

Given that certain wolves carry the "friendly" mutations, the study suggests the domestication of dogs began with friendlier individual wolves. "It seems to make sense that this could be the foundation of the interaction between humans and wolves," says vonHoldt.

Smart drug harnesses placebo power

ADDERALL may boost students' brainpower a bit – but it's mostly a placebo.

The attention deficit hyperactivity disorder drug is a popular study aid among US college students, around a third of whom have used prescription stimulants for non-medical reasons. To see if it might improve academic performance, Rachel Fargason at the University of Alabama at Birmingham and her team set up a trial in 32 people.

Each took a batch of 31 tests four times. On two occasions, they knowingly took medication or a placebo. On two other occasions, they were told they had taken a placebo when it was Adderall, or told they had taken medication when it was a placebo.

Adderall produced a slight improvement on two tests of memory and attention. But simply believing they were taking medication – regardless of whether they were – improved performance on six tests (*Alcohol and Drug Dependence*, doi.org/b9sr). "Expectation seemed to have more of an effect on objective performance than the actual medication state," says Fargason.

Neither drug nor placebo boosted performance in more complex tests, suggesting they wouldn't improve learning.

Venus's dunes like those on sea floor

SAND dunes that form on our ocean floors could help us understand the landscape of Venus.

Beneath its thick atmosphere, the surface of Venus is much hotter and at a higher pressure than that of our planet, making its land surface hard to interpret.

In the 1990s, spacecraft identified sand-dune-like structures on Venus. Lynn Neakrase at New Mexico State University and his team think they can be understood by looking at dunes that form on the floor of Earth's oceans.

For instance, the dunes on Venus seem unusually short – just 40 to 80 metres tall. Underwater dunes also have a low profile (*Aeolian Research*, doi.org/b9vf).

"There are many similarities between what has been studied in marine settings on Earth and the possibility for bed forms on Venus," says Neakrase.

Spider's web lures nocturnal moths

YOU might call it a web of deceit: the webs made by one spider exploit a visual effect to lure nocturnal insects to their doom – offering the first evidence that webs can attract nocturnal prey.

The lace sheet weaver (*Psechrus clavis*) lives in subtropical Asian forests. It builds its large horizontal webs just above ground level in shady spots.

I-Min Tso at Tunghai University in Taiwan and his colleagues noticed that the silk is highly reflective, giving the web a whitish appearance that may be visible to insects at night.

They removed spiders from their webs and used charcoal to blacken some of them: such webs attracted significantly less prey (*Animal Behaviour*, doi.org/b9vg).

Tube robot sneaks round corners

IF A garden hose were possessed by a demon, it might look like this. A new tube robot can unravel at 35 kilometres per hour to a maximum length of 72 metres, changing direction at will. It even has the ability to turn handles.

Unlike most robots and animals, plants move by growing. It's a slow process, but in this way a plant can easily get round corners or into tight spaces.

The new robot does the same thing, only faster. It has up to three chambers that, when filled with air, force extra material to unfold. By controlling the airflow in each chamber, the robot can change direction (*Science Robotics*, doi.org/b9st).

So what tasks would you set for a plant-bot? It can extend into three dimensions up structures like radio antennas, lift heavy objects such as a 75-kilogram crate and operate valves. In future, tougher versions of the robot could be used to help with search-and-rescue missions.

"We hope to automate manufacture of the robots so that dozens of them could cost almost nothing," says Elliot Wright Hawkes, who developed the robot at Stanford University in California. He also sees potential for using it in certain types of surgery, including to guide medical catheters.

L.H. BLUMENSCHEIN

Simple test to predict your risk of developing Alzheimer's

A BLOOD test can now detect whether plaques are building up in your brain – a sign you may develop Alzheimer's disease.

People with Alzheimer's tend to have clumps of beta-amyloid protein in their brains. Until now, the only way to monitor plaque build-up has been through expensive PET scans, or invasive spinal tap procedures.

Now Randall Bateman at Washington University in St Louis and his colleagues have developed a blood test that family doctors could use during health check-ups. "This kind of test could be used to screen many thousands of patients to identify those at risk for Alzheimer's disease, and to start treatments before memory loss and brain damage," Bateman told the Alzheimer's Association International Conference in London last week.

The test measures the relative amounts of different forms of beta-amyloid in blood to see whether plaques are likely to be building in the brain. The team developed the test by comparing ratios of beta-amyloid types in 41 people's blood – some of whom had Alzheimer's – with PET scans showing how much beta-amyloid had aggregated in their brains.

The hunt for drugs to combat Alzheimer's continues, but there is evidence that lifestyle changes such as doing more exercise and having a healthier diet can reduce the risk of developing the disease by as much as 30 per cent.

A blood test could reassure some people that they aren't at risk, while identifying others who might benefit from lifestyle changes.

Why the mud eel has a wonky face

TALK about a crooked character. A small eel appears to have evolved the lopsided look of a flatfish – perhaps a sign that it has evolved a flatfish-like way of life.

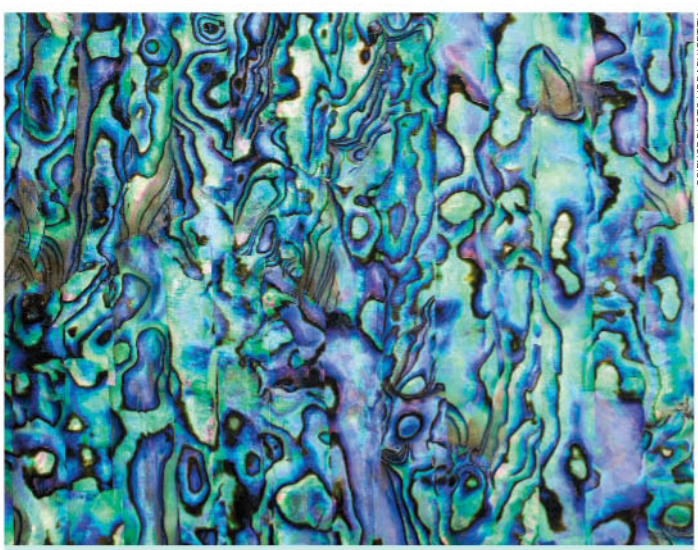
Past analyses of mud eels suggested they are adapted for burrowing, but two eels caught off the coast of Guinea in West Africa tell a different story.

"As soon as I picked one up, I knew we had something special," says Christopher Martinez at the University of California, Davis. "The connection to flatfishes was immediate."

Flatfish have become totally asymmetrical, with their features shifted to the upward-facing side, allowing the fish to lie in wait for their prey.

The mud eels have also developed asymmetrical features. Most notably, the eye on one side of the body has shrunk and almost vanished underneath a layer of flesh. Perhaps this is because the eels have also evolved into ambush predators (*Journal of Fish Biology*, doi.org/b9t5).

It is not yet clear whether the eels belong to a previously identified species – *Pythonichthys macrurus* – or represent a species we have never seen before.



SCIENCE PHOTO LIBRARY/GETTY

Nano-armour mimics mother-of-pearl

IT'S a technicolour dreamcoat for your crisp packet. An airtight new material mimics mother-of-pearl, also called nacre: it is remarkably tough without being brittle or dense.

Luyi Sun at the University of Connecticut in Storrs and his colleagues made an artificial nacre that is 60 per cent stronger than stainless steel. Plastic coated in it was over 13,000 times less permeable to gases than on its own. What's more, when the team tried to set it on fire, it scorched where the flame was in contact, but didn't ignite (*Science Advances*, doi.org/b9s4).

The material mixes a type of clay that sheds layers when exposed to ultrasonic pulses, a sticky polymer and water. The researchers dipped plastic strips in the mixture and hung them up to dry. As the liquid flowed down, nanometre-thick sheets of clay aligned like neatly laid bricks. Finally, they dried it in an oven.

The film could replace aluminium coatings used in food packaging that can leak into the environment, causing health problems. A nacre-like film that is even more impermeable than this one could also protect cellphone batteries from combusting.

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Time for a smart fix

Tech giants are making phones harder to repair, so we're chucking them sooner. This must stop, says **Matt Reynolds**

THE battle to create the perfect smartphone is a never-ending struggle, involving some of the world's most famous tech companies, like Apple and Samsung. But the pursuit of thinner, faster, lighter designs has an ugly side. The devices we lap up with each big release are growing more expensive to repair. Phones, it seems, are becoming disposable by design.

It doesn't have to be this way. An unlikely coalition of gadget fans and farmers is campaigning for the right to fix what we own.

This year, law-makers in 12 US states have proposed so-called "right to repair" bills that would force firms to release repair manuals and tools to the public. The European Parliament has also called on member states to put in place greater repair rights, with a debate due later this year.

The tech giants are fighting back, lobbying hard to keep these laws off the books. Is this just an issue for the hardcore tinkerers to worry about? Or should we all be demanding the right to fix our phones and other gadgets?

You might be scared to swap out that busted screen yourself (see "DIY with a little help", below), but opening up the repair market could save you a chunk of change. Manufacturers get a second chance to dip into customers' wallets by pressuring owners into using their own services or authorised third parties. "That's a huge cash cow," says Corynne McSherry of the digital rights non-profit Electronic Frontier Foundation.

Break the screen of an iPhone 7 and Apple will charge you $129 for a repair, unless you've already paid $129 for a two-year extended warranty. Some other out-of-warranty repairs can cost as much as $319 – a hefty sum for a phone that costs $649 new. In many cases, opting for a cheaper third-party repair automatically invalidates the phone's warranty.

Apple insists that its own repair services do a better job than third parties using unofficial parts and tools. A spokesperson claimed that iPhones are so complicated that Apple couldn't guarantee repair shops would get it right, even if it provided instructions and tools.

"An unlikely coalition of gadget fans and farmers wants to help people fix what they own"

That's not the experience of Rahil Syed, who works at an independent phone repair shop in London and successfully fixes up to a dozen devices a day, most of them iPhones. Apple's practices are harming his business, he says. When the iPhone 7 was released in September 2016, he had to turn customers away for three months until he could get unofficial parts from China. "Apple doesn't want to help us at all," he says, although the firm does allow people to sign up as authorised repairers.

And it's not just phone companies. Some faults in modern tractors can only be repaired using troubleshooting tools that manufacturers won't sell to farmers. Their only choice is to pay the high call-out fees manufacturers and authorised repair shops charge.

Farmers in the US are also fighting for the right to repair their own equipment, but tractor-maker John Deere is lobbying against bills in Kansas and Wyoming, and it's working. Despite support from Democrats and Republicans, right-to-repair bills have been shelved in every state where they were proposed.

Gay Gordon-Byrne of US advocacy group The Repair Association isn't deterred. Many state legislators are planning on bringing right to repair back to the table next year, she says. And if one or two states pass a bill, that could be enough to encourage others to take the plunge.

She is hoping to recreate the success of a campaign that shook up the US car industry in 2012, when Massachusetts passed a right to repair law forcing vehicle makers to hand over diagnostic and repair information. Manufacturers later committed to doing the same in all 50 states.

Despite its objections to the proposed bills, it looks like Apple is starting to take note of the right to repair movement. In June, the tech giant outlined plans to put screen-repairing machines in

JEWEL SAMAD/AFP/GETTY IMAGES

DIY WITH A LITTLE HELP

Want to fix your own gadgets, but don't know where to start? Most repairs are easier than you might think, and replacement parts are readily available to buy online.

"The average person could switch out a component," says Janet Gunter. In 2012 she co-founded the Restart Project, a London-based charity that helps people learn how to mend their own devices instead of throwing them away.

But if you're really not comfortable doing it all by yourself, you could pop down to a community workshop instead. At the Restart Project, local volunteers teach people how to fix faulty electrical appliances and gadgets, and the organisation hosts repair events all over the UK to encourage people to keep devices out of landfill.

Other community-run repair shops are springing up across the world. The Repair Café concept was launched in Amsterdam in 2009 and has since spread to over 1300 venues globally, so there may be one near you. Once a month or so, they set up in coffee shops or community buildings and open their doors to anyone who needs help with repairing broken items.

With fixed-term mobile contracts and new models every year, it's easy to get sucked into thinking that our smartphones need replacing regularly, Gunter says, but a simple upgrade like a battery replacement could double a device's lifespan. "It's really a personal choice," she says.

Gadgets are great till they go wrong

400 authorised third-party repair centres in 25 countries by the end of the year. It has also changed its policies so that unauthorised screen repairs no longer void an iPhone's warranty in the US.

But token gestures like this won't shift the tide in favour of consumers. As more appliances like fridges and TVs become "smart", manufacturers are set to have even more influence over repair options, not less.

Get your hands dirty

Thankfully, there is an alternative – if you're willing to get your hands a little dirty – with a growing number of people creating online repair manuals.

"Smartphones are a really integral part of our lives and they break all the time. Of course consumers are going to figure out how to fix them," says Julia Bluff of iFixit, a website that hosts nearly 30,000 user-generated repair guides and sells suitable kits for thousands of gadgets.

Whenever a major smartphone is released, iFixit's community of DIY repairers rush to disassemble it and publish a repair guide within days. Would-be menders have their work cut out, though. In June, iFixit partnered with Greenpeace on a report looking at which brands produce the most or least fixable gadgets. Only Fairphone, Dell and HP make spare parts and manuals available to the public, the report found.

Often the trickiest part of the repair is getting inside the device, Bluff says. Microsoft's Surface laptops are notoriously difficult to crack. "They are glued together so they are not serviceable. You break the device apart in order to get into it," she says.

They aren't the only ones. The battery is glued into some HTC phones, making it nearly impossible to replace without damaging it internally. Apple phones and laptops are sealed with tamper-resistant screws that ordinary screwdrivers can't undo. When Apple made this change, repair experts scrambled to reverse-engineer a screwdriver capable of turning the unique screws.

These anti-consumer practices also hold back third-party recycling efforts. When Syed replaces a cracked iPhone screen, it's generally only the layer of glass on top that is damaged, but as this is glued to the display electronics, he has to replace the entire thing, chucking the broken screen into a drawer.

Every now and then, Syed bundles them off to a factory in China where the glass is peeled off and replaced. These fixed screens are then sent back to Syed in London to mend other phones.

The system is surprisingly closed-loop, in an industry where many devices eventually end in landfill, leaching toxic chemicals into the soil. According to the UN, in 2014 the world threw away almost 42 million tonnes of e-waste, an amount projected to rise to 50 million tonnes by 2018.

We can't just blame the tech giants, however – there's also our apparent lack of enthusiasm for greener electronics. Take the Fairphone 2, released in 2015. It has seven removable parts, allowing owners to swap out and upgrade screens or cameras. In 2016, LG and Motorola followed suit with their own takes on modular smartphones. But these devices have not sold well, and Google has shelved its own plans for a low-cost modular phone.

"We junk a phone after a couple of years instead of looking at sustainability. That has got to end"

Perhaps because many people pay for their phone via a monthly contract, rather than paying a £600 upfront cost, we're happy to junk it after a couple of years without thinking about sustainability. That has got to end.

"Environmentally speaking, we can't afford to have disposable electronics," says Bluff. That means it's down to consumers to force the electronics industry to switch to more repair-friendly designs. "We need to be putting more pressure on manufacturers and voting with our dollar." ■

See them coming

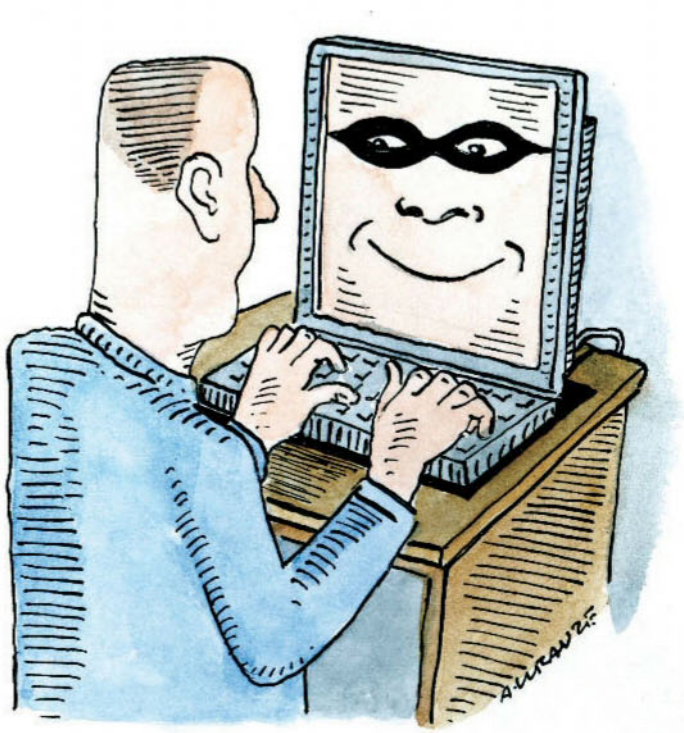
With fraud levels at a record high, we urgently need a lesson in how to spot a con artist at work, says psychologist **Marc Swogger**

RECORD numbers of people are falling prey to fraudsters. Snake oil salesmen have adapted well to the 21st century. They still run scams in the street, but increasingly exploit the internet and cellphones to find victims.

The latest concerns focus on online dating, where incidents of fraud are soaring. In the UK that has prompted MPs to demand a ban on "catfishing", the use of fake profiles to snare romance seekers, often to dupe them out of money.

Most victims don't want to discuss the experience for fear of being thought of as reckless or daft. However, I'm happy to pass on what I have learned, having been swindled several times and having interviewed con artists.

I was more intrigued about how I was caught out than ashamed, and this intrigue led me to the study of psychopathy, a common condition among swindlers.



As a graduate student in clinical psychology, I interviewed lifelong con artists who had been jailed. I found that they tend to think a lot of themselves.

Braggadocio may be seen as endearing or dismissed as healthy confidence or benign insecurity, but grandiosity is common in these fraudsters and unabashed boasting is a red light.

When a con artist is face-to-face with you, they don't just speak; they create a disarming show that combines intense eye contact and fast-talking with dramatic facial expressions, rhythmic gestures and the charm of an easy smile. As a stranger on the street, they may disorient you by approaching in an overly sudden manner with unearned familiarity.

In a job interview or on a date they sprinkle in a lot of disarming flattery and vague reference to assumed commonality, creating

Rise up, rise up

A new climate lawsuit will increase the heat on fossil fuel giants, says **Sophie Marjanac**

IT IS a potentially historic move: the coastal Californian counties of Marin and San Mateo, together with the City of Imperial Beach, have each filed a lawsuit against some of the world's largest fossil fuel producers.

The claims allege that by extracting, marketing and distributing oil, coal and gas, the companies engaged in activity that caused rising sea levels and will continue to do so. This is part of an international trend in climate change litigation: more and more lawsuits want to hold governments accountable for the mounting losses and damage attributable to anthropogenic climate change.

So why California and why now? The state is particularly at risk from higher sea levels caused by rising mean global temperatures. Marin county says it has already experienced severe flooding during the highest spring tides and storm surges. The lawsuits seek damages that would contribute to the costs of adapting to coastal erosion and flooding, including upgrading infrastructure. In addition, the vacuum in federal climate policy created by the Trump administration might actually make state courts more willing to take an active role.

"They allege oil, coal and gas companies engaged in conduct that has caused rising sea levels"

What hope of success? One big challenge will be establishing causation, which usually means proving that "but for" the conduct of the defendants, the harm wouldn't have happened.

In this case, evidence is cited that the companies being sued were responsible for the extraction and sale of fuels that released 20 per cent of the world's greenhouse gas emissions from 1965 to 2015, and that they had prior knowledge of the climate risks that created.

the illusion that you are on the inside of something special.

Your emotional reactions might include bemusement, unease, confusion and excitement. Notice your reaction. It is your cue to take a breath and a step back.

The con depends on a show to distract. Instead, grounded and aware of your feelings, focus on words alone. Rather than nuanced and measured, they are peppered with superlatives. The con artist may also contradict themselves – it is hard for them to keep track of what they have said. Uncoupled from their crackling confidence, their claims raise questions.

If someone says they have authored 300 publications, why don't they turn up in a search? If they say they are rich and have a promising patent, why ask for money? If they own a mountain… wait, who owns a mountain?

As the validity of the story falls apart, note that the person communicating with you isn't just charming, amusing and eccentric, but also potentially dangerous. When you see it this way, you can quickly move on. They will too. ■

Marc T. Swogger is an associate professor in the department of psychiatry at the University of Rochester, New York

Whatever the decision in California, it is clear that climate change litigation is on the increase. Courts are more willing to adjudicate in relation to these difficult questions, as they did in the case of the tobacco industry in earlier decades.

It is useful to recall that even though lawsuits back then weren't always successful, they did shift public opinion and drove the cigarette industry towards a political and financial settlement with government. ■

Sophie Marjanac is a law and policy consultant for ClientEarth, which fights environment-related cases

INSIGHT Sustainable fishing

JEFF J MITCHELL/GETTY IMAGES

Eyeing an uncertain future

Brexit could push cod into dangerous waters

Debora MacKenzie

NORTH SEA cod is back on the menu. Those were the headlines in the UK last week as the Marine Stewardship Council (MSC), an international body that certifies whether fish sold to consumers was caught sustainably, gave its approval to a fish once feared to be headed for extinction.

So is cod now guilt-free? Can the UK go back to enjoying its national comfort food – cod and chips – with a clear conscience?

First, about the guilt: it was never wrong to eat cod as such. Brits ate sustainably managed cod from Norwegian and Icelandic fisheries even as North Sea catches plummeted after 2000.

"The vast majority – around 95 per cent – of cod consumed in the UK is caught in the Barents Sea and off Iceland, where stringent measures have ensured good management of cod stocks," says Andy Gray of Seafish, which oversees UK fisheries.

Last week's verdict means all cod that UK consumers buy should now be sustainable. But this is a fragile victory, produced by a management system the UK plans to leave, the European Union's Common Fisheries Policy (CFP).

Fishing communities voted solidly for Brexit as many of them think the EU is to blame for smaller catches. "That isn't true," says Robin Cook at the University of Strathclyde in Glasgow, UK, who worked on the MSC verdict.

This erroneous belief partly arose because the EU set up the CFP in 1983, around the time overfishing was starting to bite. Catches fell and quotas tightened – but the European policy didn't cause the problem, says Cook.

Fish like cod swim freely between national waters, so countries that share a stock must divide up catch quotas to prevent overfishing. North Sea cod quotas existed before the CFP, but overfishing was rampant as no one was punished for exceeding them.

"Is cod now guilt-free? Can the UK go back to enjoying its national comfort food with a clear conscience?"

That changed when the CFP was introduced, but EU fisheries ministers still initially set quotas based more on politics than science.

Then, from 2002, the CFP set multi-year management goals for stock sizes, which meant quotas had to stay closer to scientific guidance. It also stopped EU fishing fleets growing. "The CFP is why the North Sea cod recovered," says Cook.

If Britain leaves the CFP, the fishing industry could again demand bigger catches than scientists advise. UK politicians may have trouble refusing, though other countries might have something to say about that.

"If Britain starts managing shared stocks like cod in ways that don't meet CFP standards, the EU can impose sanctions," says Cook, like cutting imports of British mackerel or scampi, which are much more valuable than cod. The political wrangling, however, is unlikely to be good for the fish.

And cod face other risks. They like cold water, so climate change is forcing them north. Cod haven't recovered in the southern part of the North Sea, and future impacts are unknown.

"Given the many uncertainties, a go-slow approach is advised," says Sherrylynn Rowe at Memorial University of Newfoundland, Canada, where a recovering cod stock also faces premature pressure to fish.

All this means last week's MSC certification for North Sea cod may not be permanent. It is a monument to the resilience of nature, and the ability of scientists, politicians and industries to – sometimes – achieve great things. But cod isn't out of the water yet. ■

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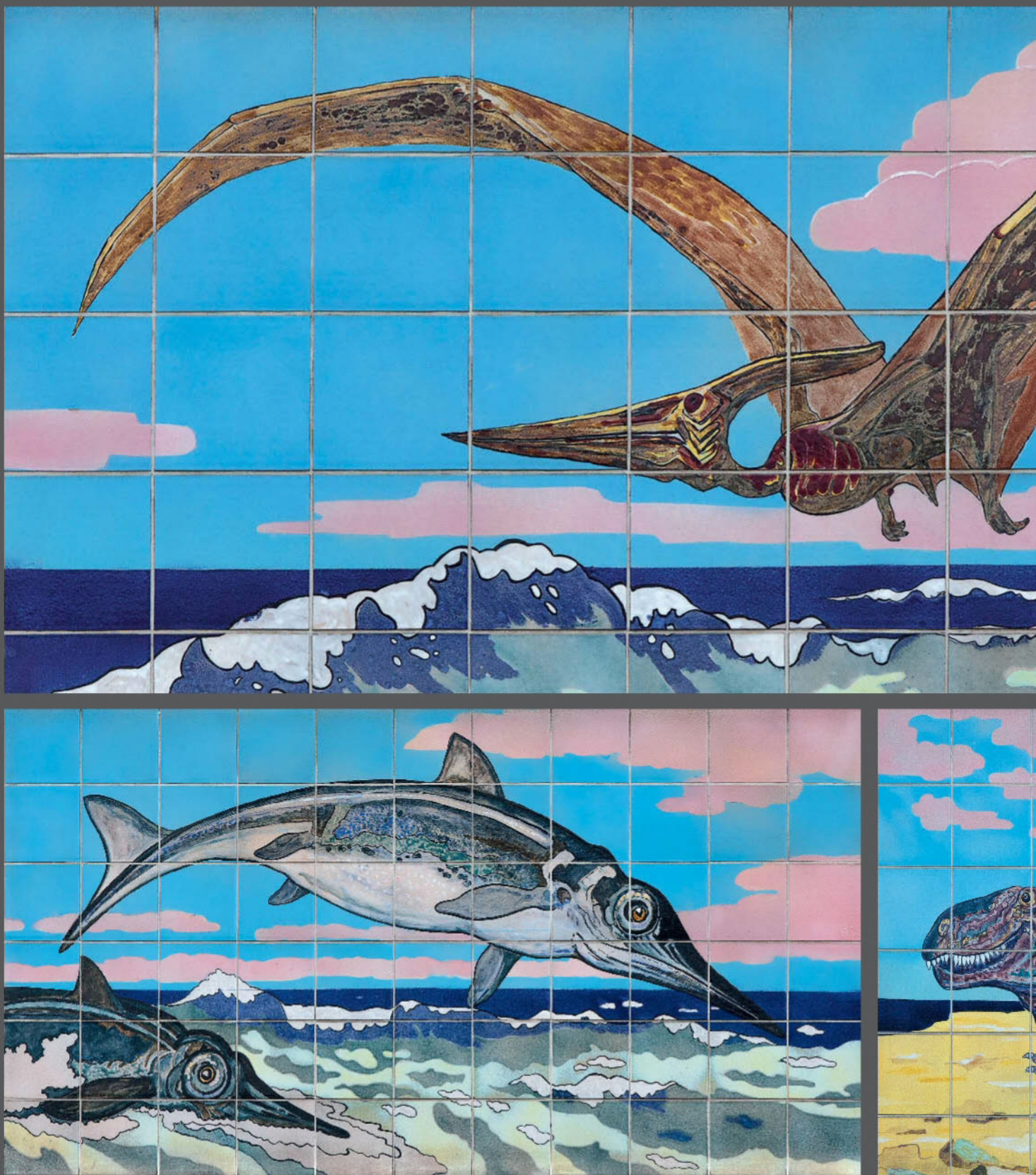
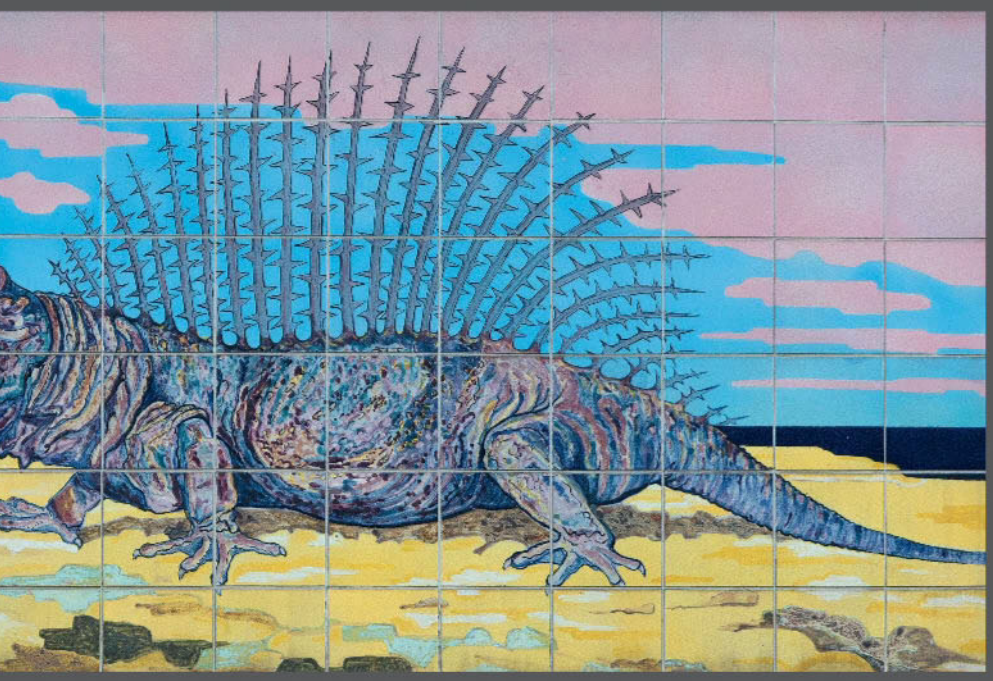




Palaeoart reborn

THESE colourful images of prehistoric creatures may not be completely scientifically accurate, but then they were created to delight, not teach.

In gorgeous art nouveau technicolour, ichthyosaurs are depicted soaring over the waves like dolphins (bottom left). Also on display are an airborne pteranodon (top) and a land-dwelling edaphosaurus (bottom right), shown with spines rather than a sail as it is usually drawn nowadays.

The originals of these images once adorned the walls of an aquarium in Berlin, in murals created by Heinrich Harder in 1913. They were lost when the aquarium's walls were destroyed by bombs in the second world war. Then, in 1977, the original plans for five of Harder's murals were discovered in a desk drawer at the rebuilt aquarium and a plan was hatched to recreate them. The aquarium's director took out adverts asking Berlin residents if they had any photos of the murals from the time. Using the plans, photos and remaining tile fragments, the murals were born again – and these images show the results.

These photos are just a few examples taken from the book *Paleoart*, which charts the undocumented history of the genre of the same name. Starting in England in 1830, this involved the artistic depiction of prehistoric animals based on the prevailing science at the time. Clare Wilson

Source

Paleoart: Visions of the Prehistoric Past
by Zoë Lescaze and Walton Ford (Taschen)
Images: © Aquarium Berlin. Artist: Heinrich Harder, photo by Waldemar Brzezinski

The new shape of reality

An exquisite geometric structure could put a bizarre twist on space-time, says **Anil Ananthaswamy**

FOR years after the physicist Richard Feynman died, his 1970s yellow-and-tan Dodge minivan lay rusting in a garage near Pasadena, California. When it was restored in 2012, special effort was made to repaint the giant doodles that adorned its bodywork. They don't look like much – simple combinations of straight lines, loops and squiggles. But it is no exaggeration to say these Feynman diagrams revolutionised particle physics. Without them, we might never have built the standard model of particles and forces, or discovered the Higgs boson.

Now we could be on the cusp of a second, even more far-reaching transformation. Because even as Feynman's revolution seems to be fizzling out, physicists are discovering hints of deeper geometric truths. If glimpses of exquisite mathematical structures that exist in dimensions beyond the familiar few can be substantiated, they would seem to point the way to a better understanding not just of how particles interact, but of the nature of reality itself.

It was a hard road that led to the standard model, this monumental theoretical construct that describes all the particles of the quantum world and the forces that act on them, except for gravity. The starting point came in the 1930s and early 1940s, when physicists investigating quantum electrodynamics, the theory of how charged particles and electromagnetic fields interact, embarked on calculations of "scattering amplitudes" – the probabilities of different outcomes in a given particle interaction. But the calculations proved maddeningly difficult. For a while they seemed impossible.

Then along came Feynman. In 1949, he showed an intuitive way to tackle the calculations, using doodles that could literally be drawn on cocktail napkins. Take, for example, the interaction of two electrons. The electrons are depicted by two straight lines that are approaching each other. But before the lines meet, the electrons interact by exchanging a "virtual" photon, drawn as a squiggly line, causing the two straight lines to move apart. The two electrons have repelled each other.

This is the simplest and most likely interaction. But for a full picture, you have to come up with all possible Feynman diagrams a given interaction could have, capturing all the different ways in which the particles can influence each other. One of the electrons might emit and absorb a virtual photon, for instance, creating a squiggly loop, which can interact with itself to generate more loops. The basic procedure is that you turn each possible diagram into an algebraic formula and work them all out to get the scattering amplitude.

The more virtual particles, the more complicated the calculations. So why invoke virtual particles at all? It does seem strange

given that they are not real particles.

A real particle is essentially a consistent ripple in an energy field, one that persists over time. But when real particles interact, they can cause temporary ripples in underlying quantum fields, such as an electromagnetic field. These are called virtual particles, and they are used in Feynman diagrams for several reasons.

The first is that dealing with them rather than with fields makes the maths more tractable. The other great advantage is that they help physicists visualise everything as the well-defined interactions between point-like particles, as opposed to the hazy goings-on between particles and fields. This fits nicely with the intuitive principle of locality, which holds that only things in the same spot in space and time can interact. Finally, the technique also helps enforce the principle of unitarity, which says that the probability of all outcomes should add up to 1.

Sticky like gluons

Feynman diagrams worked beautifully when applied to photons and electrons, and became a staple of physics, being used to predict the outcome of experiments to astonishing precision. But once physicists started to tackle quantum chromodynamics, the theory of interactions involving quarks and gluons – the basic components of the protons and neutrons at the heart of atoms – things got sticky. There were so many virtual particles, and ways each interaction could happen, that every calculation using Feynman diagrams required "heroic efforts of computation", says Jacob Bourjaily at the University of Copenhagen's Niels Bohr Institute in Denmark.

This much became obvious in the 1980s, when the US was building the ill-fated Superconducting Super Collider in Texas. It was going to smash protons into each other, so it was imperative to understand the interaction of gluons, which hold together the quarks that make up protons. But it seemed impossible. "Their complexity is such that they may not be evaluated in the foreseeable future," one group of physicists wrote at the time.

Then there was an unexpected turn of events. In 1986, Stephen Parke and Tomasz Taylor from Fermilab near Batavia, Illinois, used Feynman diagrams and supercomputers to calculate the likelihoods of different outcomes for interactions involving a ›

SKIZZOMAT

total of six gluons. A few months later, they made an educated guess at a one-line formula to calculate the same thing. It was spot on. More than 200 Feynman diagrams and many pages of algebra had been reduced to one equation, and the researchers had no idea why.

What was clear was that virtual particles were a big part of the problem. "Every single Feynman diagram is a fantasy," says Bourjaily. A fantasy in the sense that we have no way of observing the virtual particles they depict. What we do know is that the wild proliferation of mathematics required to account for them are very real, resulting in ridiculously unwieldy calculations.

Almost 20 years passed before another clue arrived. In 2005, Ruth Britto, Freddy Cachazo, Bo Feng and Edward Witten were able to calculate scattering amplitudes without recourse to a single virtual particle and derived the equation Parke and Taylor had intuited for that six-gluon interaction.

This time there was a lead on what the BCFW method might mean. It was inspired by a view of space-time called twistor theory, which had been developed in the late 1960s and early 1970s by Roger Penrose at the University of Oxford. The primary objects of this theory are not particles, but rays of light, or twistors. "You can think of the universe as built up out of these rays, and points of space and time emerge at the places where these rays meet," says Andrew Hodges, one of Penrose's colleagues at Oxford.

Hodges showed that the various terms used in the BCFW method could be interpreted as the volumes of tetrahedrons in twistor space, and that summing them up led to the volume of a polyhedron. The trouble was that his insight only worked for the simplest, most likely interaction of gluons with specific properties. For more complicated particle interactions, the resultant geometric objects were utterly bewildering. Their connection with real particle dynamics was intriguing, but the maths was too difficult.

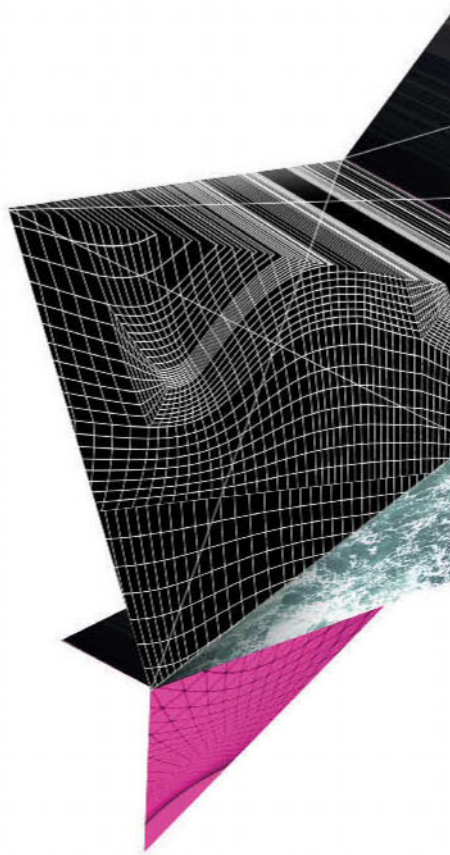
It took Nima Arkani-Hamed and his team at the Institute of Advanced Studies (IAS) in New Jersey, including his then students Jaroslav Trnka and Bourjaily, to join the dots. Building on the seemingly esoteric work of pure mathematicians, the team arrived at a mind-boggling conclusion: the scattering amplitude calculated with the BCFW technique corresponds beautifully to the volume of a new mathematical object. They gave a name to this multi-dimensional concatenation of polyhedrons: the amplituhedron.

IT SOUNDS CRAZY, BUT...

History shows that radical new ways of thinking about reality are well worth grappling with. Take Newton's laws of motion. Given the position of a particle and all the forces acting on it, you can show deterministically – by describing cause and effect – how it goes from point A to point B. But there is another way to think about the particle's path. It's called the principle of least action. It says that a particle will take the path that minimises a quantity called classical action, which is the average value of the particle's kinetic energy minus its potential energy along the path.

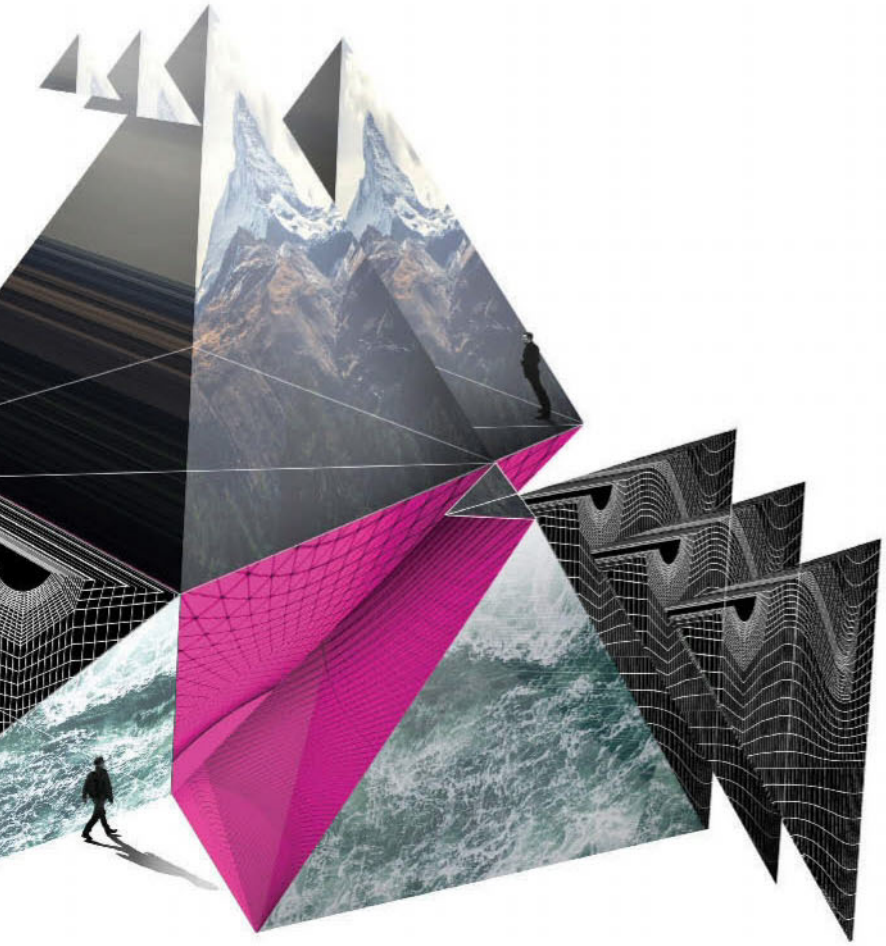
This principle felt weird to minds trained in classical physics. "[No one] thought that particles smelled around all possible paths and took the one that minimised this silly number," says Jacob Bourjaily of the Niels Bohr Institute in Copenhagen, Denmark. "It's a very weird starting point for classical physics." What's more, the theory appears non-deterministic because a particle's trajectory isn't obvious at the onset. Nonetheless, the principle of least action makes the same predictions as Newton's laws, suggesting that determinism is emergent, and the calculations involved are easier.

Significantly, this way of thinking about reality was more in tune with the emerging quantum mechanics, and led to things like Feynman diagrams (see main story), which opened the door to the subatomic world. The hope now is that a strange mathematical structure called an amplituhedron, which does the same things as Feynman diagrams but in a counterintuitive way, may lead physicists towards a greater prize.



It's best to think of the amplituhedron not as a real object but as an abstraction. It's a mathematical structure that gives us an elegant way to encode the calculations that tell us how likely a particle interaction is to play out in a certain way. The details of the interaction, meaning the number and properties of the particles involved and the forces involved, dictate the dimensions and facets of the corresponding amplituhedron – and that contains the answer. So there are actually many amplituhedra, one for each possible way in which a set of particles may interact.

The contrast with Feynman diagrams is stark. On one hand you may have to draw a thousand diagrams and use supercomputers, on the other you can get the same answer by calculating the volume of a single geometric object, even if the maths involved is far from trivial. "It translates the physics problem into a purely mathematical problem – calculate the volume of that object," says Trnka, who is now at the University of California, Davis.



It may transform physics, too – potentially nudging the door ajar to a unified theory of everything. That's because the amplituhedron does not embody unitarity and locality, those core principles baked into reality as described by Feynman diagrams. Scattering amplitudes that obey the laws of locality and unitarity do emerge from amplituhedra. But unlike in Feynman diagrams, the amplituhedron does not start with space-time that has these properties. "The thing that you calculate will be unitary and local," says Trnka. "It's a consequence of the geometry."

If so, locality is not a fundamental feature of space-time but an emergent one. That amounts to a radical rethink of reality (see "It sounds crazy, but…", left), and one that could finally help us with a solution to one of the biggest questions in physics: how gravity behaves at the very smallest scales.

Locality and gravity don't sit well together. In order to precisely determine what happens at a given point in space-time, you have to zoom in closer and closer and examine smaller and smaller intervals of time. Quantum mechanics says that as one gets increasingly precise, the energy fluctuations in that region of space-time become bigger. Now, energy is mass, and mass has gravity, so incredibly high amounts of mass in a very tiny region of space ends up forming a black hole, which makes it impossible to see what's going on – and dashes any hopes of insight about the quantum nature of gravity. So, if gravity and quantum mechanics have to coexist, locality has to go.

> "Ultimately, space-time and quantum mechanics might emerge as one"

The amplituhedron suggests that it can, potentially clearing the way for a quantum theory of gravity. That would finally let us understand what really goes on inside black holes and maybe even at the moment of the big bang – secrets of the universe that are theoretically impenetrable today.

If Arkani-Hamed is correct, that might just be the start. "If we are going to lose something as dramatic as the idea of space-time, it's very unlikely that it leaves any of physics unaffected," he told the audience at the String-Math 2016 conference in Paris, France. "It must show up everywhere. It must show up even in situations where we think we understand things perfectly well."

Naturally, there is a catch. Over the past few years, Arkani-Hamed and his colleagues have demonstrated that the amplituhedron works for a "toy" model of particle interactions that involves supersymmetry, a theory in which all standard model particles have partner particles. But the standard model, our best description of reality, is not supersymmetric.

If that sounds like a killer blow, it isn't. "The toy model is closer to reality than any other toy that people have played with over the last three decades," said Arkani-Hamed in a talk at the IAS in April this year. Indeed, for some of the simplest, most likely particle interactions, the calculations using the amplituhedron agree with results obtained using standard calculation methods. Crucially, the new method holds for all four-dimensional theories of massless particles, supersymmetric or otherwise. The standard model has its origins in this class of theories, so it's entirely plausible that it will work there too. "This correspondence with geometry is a general thing," says Bourjaily. "It's a statement about four-dimensional theories."

Now the challenge is to extend this geometric way of thinking to more realistic models of particle interactions, and ultimately include gravity by doing away with locality. It's not going to be that simple, though. Which might be why Witten, who is also at the IAS, is simultaneously impressed and circumspect. "Perhaps [the amplituhedron] is the closest we have to a unified picture, at least of some of the questions," he says. "There have been so many surprises in the study of these scattering amplitudes that it is rather hard to speculate on future directions. But it is pretty clear that there is a lot still to discover."

Arkani-Hamed is confident that, ultimately, we will see that space-time and quantum mechanics emerge as one. "In this baby example that's exactly what happens," he said in Paris. "There is no way in this geometry to decouple the piece which is space-time from the piece which is quantum mechanics. It's all one and the same aspect of the underlying positive geometry." ■

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STEPHEN ALVAREZ/NATIONAL GEOGRAPHIC CREATIVE

Awesome awe

The overused superlative is truly apt for an emotion that gives us superpowers, finds Jo Marchant

HAVE you ever been stopped in your tracks by a stunning view, or gobsmacked by the vastness of the night sky? Have you been transported by soaring music, a grand scientific theory or a charismatic person? If so, you will understand US novelist John Steinbeck's response to California's giant redwood trees, which can soar more than a hundred metres towards the sky. "[They] leave a mark or create a vision that stays with you always," he wrote. "From them comes silence and awe."

Philosophers and writers have long been fascinated by our response to the sublime, but until a few years ago, scientists had barely studied it. Now they are fast realising that Steinbeck was right about its profound effects. Feeling awestruck can dissolve our very sense of self, bringing a host of benefits from lowering stress and boosting creativity to making us nicer people.

Yet in the modern world, the value of the word awesome has plummeted – almost anything can now acquire the epithet. At the same time, we risk losing touch with the most potent sources of awe. The good news is that there are ways to inject more of it into our everyday lives. You needn't be religious. All you need is an open mind – although a willingness to try psychedelic drugs may help.

But what exactly is awe and where does it come from? "It's a subjective feeling rooted in the body," according to psychologist and pioneering awe researcher Dacher Keltner at the University of California, Berkeley. In 2003, he and Jonathan Haidt, now at New York University, published the first scientific definition. They described awe as the feeling we get when confronted with something vast, that transcends our frame of reference and that we struggle to understand. It's an emotion that combines amazement with an edge of fear. Wonder, by contrast, is more intellectual – a cognitive state in which you are trying to understand the mysterious.

You might think that investigating such a profound experience would be a challenge, but Keltner insists it's not so hard. "We can reliably produce awe," he says. "You can get people to go out to a beautiful scene in nature, or put them in a cathedral or in front of a dinosaur skeleton, and they're going to be pretty amazed." Then, all you need is a numerical scale on which people can report how much awe they are feeling. Increasingly, studies are including a physiological measure too, such as the appearance of goosebumps – awe is the emotion most likely to cause them, and second only to cold as a source.

In this way, Keltner and others have found that even mild awe can change our attitudes and behaviour. For example, people who watched a nature video that elicited awe – rather than other positive emotions such as happiness or pride – were subsequently more ethical, more generous and described themselves as feeling more connected to people in general. Gazing up at tall eucalyptus trees left others more likely to help someone who stumbled in front of them. And after standing in front of a *Tyrannosaurus rex* skeleton, people were more likely to describe themselves as part of a group. It might seem counterintuitive that an emotion we often experience alone increases our focus on others. But Keltner thinks it's because awe expands our attention to encompass a bigger picture, so reducing our sense of self.

"The desert is so huge, and the horizons so distant, that they make a person feel small," wrote Paulo Coelho in *The Alchemist*. He was right. In a large study, Keltner found that after inspiring awe in people from the US and China, they signed their names smaller and drew themselves smaller, but with no drop in their sense of status or self-esteem. Similarly, neuroscientist Michiel van Elk at the University of Amsterdam, the Netherlands, ›

found that people who watched awe-inducing videos estimated their bodies to be physically smaller than those who watched funny or neutral videos.

The cause of this effect might lie in the brain. At the annual meeting of the Organization for Human Brain Mapping in Vancouver, Canada, in June, van Elk presented functional MRI scans showing that awe quiets activity in the default mode network, which includes parts of the frontal lobes and cortex, and is thought to relate to the sense of self. "Awe produces a vanishing self," says Keltner. "The voice in your head, self-interest, self-consciousness, disappears. Here's an emotion that knocks out a really important part of our identity." As a result, he says, we feel more connected to bigger collectives and groups.

The notion of transcending the self has traditionally been associated with religious or mystical experiences. "Immenseness, infinitude, indescribability are some of the classical characteristics of mystical experiences that leave a person with a very powerful sense of awe," says neuroscientist Andrew Newberg at the University of Pennsylvania, who studies how religion affects the brain. For Keltner, this is one reason why awe was so little studied until recently. "People felt like awe is really about religion and psychologists were loathe to study religion," he says. But after interviewing thousands of people around the world about their experiences, he believes it's a mistake to see awe as inseparable from God. "Even in really religious countries, people are mainly feeling awe in response to other great people and nature," he says. "People have always felt awe about non-religious things. It's available to atheists in full force." Newberg, who is studying the awe felt by astronauts (see "Out of this world," below), agrees. "You don't have to have any given belief system in order to have these experiences," he says.

Nature is a more powerful source of awe than religion

CHRISTOPHER KIMMEL/AURORA

Instead, Keltner believes that awe predates religion by millions of years. Evolution-related ideas are tough to back up, but he argues that responding to powerful forces in nature and in society through group bonding would have had survival value. Chimps show signs of awe, such as goosebumps, during thunderstorms, he notes. "I think the central idea of awe is to quiet self-interest for a moment and to fold us into the social collective."

It's an instinct that has been co-opted for political ends throughout history, for example in grandiose structures from the pyramids of Egypt to St Peter's Basilica in Vatican City, or even Trump Tower. "Awesome art and architecture have long been part of the apparatus by which people have been controlled, both socially and psychologically, and kept in their place," says Benjamin Smith, an expert in rock art at the University of Western Australia. "The finding that awe diminishes our sense of self fits perfectly with this history."

Despite these darker associations, there's mounting evidence that feeling awe also has personal benefits. First, focusing on the bigger picture rather than our own concerns seems a powerful way to improve health and quality of life. Keltner's team has found that feeling awe makes people happier and less stressed, even weeks later, and that it assists the immune system by cutting the production of cytokines, which promote inflammation. Meanwhile, a team from Arizona State University found that awe activates the parasympathetic nervous system, which works to calm the fight or flight response. Researchers at Stanford University, California, discovered that experiencing awe made people feel as if they had more time –

OUT OF THIS WORLD

When NASA astronaut Chris Hadfield stepped out of the International Space Station for his first spacewalk, it was the culmination of decades of preparation. Yet he was totally unprepared for "the raw, omnipresent beauty" of our home planet. "It was stupefying," he told an audience in London in 2014. "It stops your thought."

Hadfield isn't the only one to have his mind blown by a trip into space. In fact, the phenomenon is so common it has a name: the overview effect. It's a powerful example of awe, according to neuroscientist Andrew Newberg at the University of Pennsylvania. Having collected astronauts' accounts of the effect, he now hopes to work with commercial space flight companies to study what such experiences do to travellers' brains. "We've drawn up ideas," he says. One possibility would be to scan people's brains before and after space flight to see what changes occur. Another would be to figure out a way to scan them while in space.

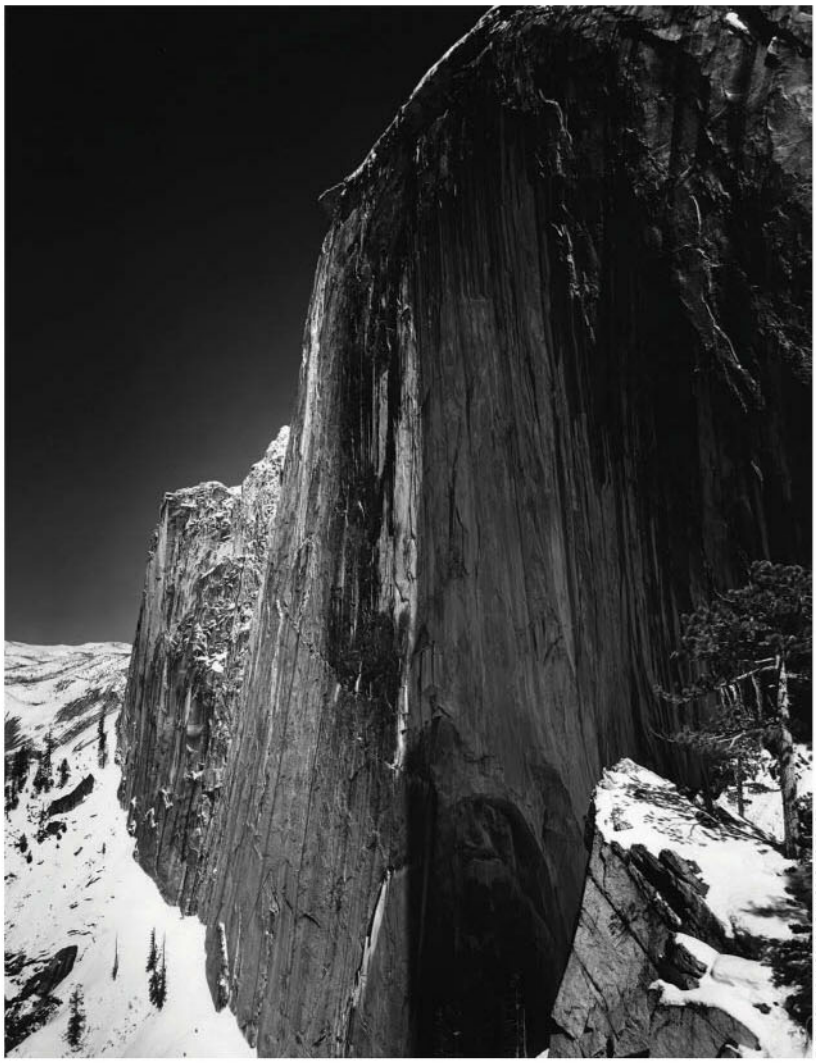
Meanwhile, researchers at the University of Central Florida's Institute for Simulation and Training have been bringing the overview effect down to Earth. They took more than 100 people on a virtual trip to space, and found that they reported similar impacts to real astronauts, including tranquillity, elation, increased altruism and feeling small. Viewing Earth triggered stronger awe than views of deep space. And the less religious they were, the more awe they felt.

There's a growing realisation that awe has all sorts of benefits for individuals and society. Whether through space tourism or virtual reality, Newberg hopes that having more people experience the awesomeness of space might lead to greater compassion and a more collaborative society on Earth. As Hadfield put it: "We're all crew on the same spaceship. As soon as we can start to see ourselves that way, we will advance tremendously."

and made them more willing to give up their time to help others.

Awe also seems to help us break habitual patterns of thinking. The Arizona team discovered that after experiencing awe, people were better able to remember the details of a short story. Usually, our memories are coloured by our expectations and assumptions, but awe reduces this tendency, improving our focus on what's actually happening. Researchers have also reported increases in curiosity and creativity. In one study, after viewing images of Earth, volunteers came up with more original examples in tests, found greater interest in abstract paintings and persisted longer on difficult puzzles, compared with controls.

In the modern world, though, we're more likely to be gazing at our smartphones than at giant redwoods or a starry sky. And Keltner is concerned about the impact of our increasing disconnection from nature, one of the most potent sources of awe. "I'm struck by how awe makes us humble and charitable," he says.



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"Feeling awe makes people happier and less stressed, even weeks later"

"Is that why we have so much incivility and hatred right now in the US? I think we should be asking these questions."

Keltner warns of a lack of opportunities for awe in poor communities as well as education, with its focus on test results rather than exploration. "We are taking that away from our kids and that is a very serious problem."

Kenneth Tupper, a philosopher of education at the University of British Columbia, Canada, agrees. "The institution of modern schooling is very well designed to not evoke experiences of wonder and awe," he says. This can leave teenagers feeling "jaded and disenchanted", without a sense of connection to anything larger than themselves. To counter such alienation, he suggests, self-obsessed Western societies might consider an unconventional way to rekindle awe, taking a lesson from traditional societies. Many of these use plant and fungus-based psychedelic drugs such as ayahuasca, peyote and psilocybin mushrooms to expand the mind and forge a connection to something bigger than the self, he notes. "These kinds of experiences are extremely highly valued." Tupper thinks we could all benefit from similar rituals.

That's not as crazy as it might sound, according to Robin Carhart-Harris at Imperial College London. Through brain scanning, he and others have found that psychedelic drugs such as psilocybin and LSD reduce activity in the default mode network – just as awe does. In addition, boundaries between normally segregated bits of the brain temporarily break down, boosting creativity. Study participants who take psychedelics often describe being struck by vastness, and report an altered sense of self – to the point where it may disappear completely. "My feeling is that it's the same thing," says Carhart-Harris. "Psychedelics are hijacking a natural system and fast-tracking people to these experiences of awe."

There's growing interest in using psychedelics to treat anxiety and depression, but Carhart-Harris argues that if taken in a safe and controlled environment, a dose of psychedelic awe could benefit healthy people too. "You can be more well," he says. "You can just feel calm and content and integrated and connected." This idea gains support from trials of more than 100 healthy volunteers. Roland Griffiths and his colleagues at Johns Hopkins University in Baltimore, Maryland, found that those who took a single dose of psilocybin rather than a placebo reported feeling happier and more altruistic afterwards. They still had higher well-being and life satisfaction more than a year later.

Keltner says this is important work. "Psilocybin should not be stigmatised," he says. It's a potent source of awe, but there are plenty of other ways you can increase your awe quotient, he adds. First, you should raise your expectations. Put aside the myth that awe is rare, says Keltner. His surveys reveal that people feel low-level awe on average a couple of times a week. Then, think about what you find awe-inspiring. Everyone is different, but whatever does it for you, try to make it part of your everyday experience: when you're choosing which route to walk to work, which book to read or what movie to see. "Don't think it takes big bang conversions to get five minutes of awe," he says. "Find your sources and go get it." ■

Jo Marchant is a consultant for *New Scientist* based in London

BOOM OR BUST

Making bigger explosions means harnessing some unconventional chemical powers, says **David Hambling**

SIMON ROBERTS/GALLERY STOCK

BLEARY-EYED, you acknowledge the coffee machine announcing the arrival of the morning brew. You apologise to the fridge door as you fumble for the milk. Narrowly avoiding the salt, you locate the sugar on the counter. Energy required. One spoonful or two?

BOOM! The whole lot goes up.

It's easy to forget that sugar can be an explosive. In fact, it's four times more powerful weight for weight than TNT. Forgetfulness here can have tragic consequences. In 2008, finely powdered sugar ignited at a refinery in Savannah, Georgia, causing a blast that claimed 14 lives.

Fortunately, under normal circumstances it takes a lot to make sugar explode. Not so nitroglycerin, the explosive favoured by early safe-crackers: it is notoriously unstable, going sky-high at the slightest shock. An ideal explosive – one with power, but that can also be easily controlled – lies somewhere in the middle. It would store a lot of energy in its chemical bonds, releasing it easily, but not too easily. Therein lies a problem. With everyone from miners to the military to missions to Mars seeking more bang for their buck, conventional chemistry has more or less delivered the best explosives it can.

So step forward unconventional chemistry. A few labs across the world are probing a new generation of "disruptive energetic materials" that promise more explosive power than ever before. Some of them might even leave sugar in the dust – and allow us to reach for the stars.

Finding better explosives has always tended to be a rather haphazard process. No one knows who first discovered the explosive properties of potassium nitrate aka saltpetre, the active ingredient of gunpowder. It was being used in China around a millennium ago, but it wasn't until the late 17th century that some of the first experiments dedicated to finding out how it worked were conducted at London's fledgling Royal Society. Only after Alfred Nobel's nitroglycerin factory blew up in 1864, killing his younger brother, did he discover that by combining nitroglycerin with ground rock you could make a drier, slightly less powerful version that was much safer to handle. Dynamite was soon put to work blasting mines, tunnels, railway cuttings and canals, making Nobel a very rich man.

Construction still remains a prime customer for explosives, as does the military. The most destructive explosions, of course, come from ripping apart the atomic nucleus, ›

Molecular ingenuity could give us more spectacular blasts

STEPHANE CORVAJA/ESA

Rockets' payloads are tiny relative to the sheer mass of fuel needed to reach orbit

but nuclear bombs are made not to be used. The difficulty of controlling and containing nuclear reactions, and the hazardous waste they produce, mean they are unlikely ever to find use as peaceable explosives. Military interest in better chemical explosives is led by a desire for more potent versions of conventional weaponry like MOAB, the "mother of all bombs" containing over 8 tonnes of explosive, that the US dropped on jihadists in Afghanistan earlier this year, or to make small drones equipped with mini-bombs as effective as full-sized munitions.

For the better part of a century, however, those seeking more explosive power have had another, loftier ambition: space exploration. Escaping Earth's gravity requires a lot of thrust. In 1903, the Russian scientist Konstantin Tsiolkovsky derived the rocket equations that have ever since governed our efforts to do that. The essence of rocket science consists of ejecting hot, explosively expanding gas downwards, generating a reactive force that propels the rocket upwards.

There's a big sting in the rocket tail, however. The more thrust you want to generate, the more fuel you need; but the more fuel you carry, the more thrust you need to get airborne. This catch-22 means gunpowder cannot generate enough impulse to get into space, however much you use. State-of-the-art rockets use a mix of liquid hydrogen and liquid oxygen, which has a much higher energy density. Even so, a mere 2 per cent of the launch weight is payload and more than 80 per cent is propellant, and a rocket can still only reach orbit by ditching weight as it goes. That's why we need multistage rockets that shed empty fuel tanks as they climb.

With better fuels you might get 10 or 15 times the payload for the same size of rocket, says consultant Ian Johnston of Rocket Workshops in Droitwich, UK. That would make satellite launches far more economical, opening up new possibilities for bulky projects like crewed Mars exploration and lunar bases. "With better fuel, you could have single-stage-to-orbit spacecraft," says Johnston. " 'Game changer' is too small an expression for it."

Diamonds and popcorn

A good way to change a game is to change its rules. One line of research to do just that builds on a curiosity that was exercising the Royal Society back in the 1660s just when gunpowder was: Prince Rupert's drops. These tadpole-shaped trinkets are formed by molten glass cooling rapidly, and are named after Prince Rupert of the Rhine, a cousin of King Charles II who first brought them to England. The way the drops form leaves them under tremendous internal strain. A hammer will bounce off the drop's body and not break it, but if you snap the tail the strain is suddenly released, sending a wave through the drop, shattering it into powder.

This explosivity is based on the release of not chemical energy, but mechanical strain. At the US Army Research Laboratory (ARL) in Maryland, Jennifer Ciezak-Jenkins and her colleagues have been experimenting with the same principle using nanoscopic diamonds. Diamond forms only at high temperatures and pressures, such as those found deep in Earth's mantle, and is a "metastable" form of carbon. It is stable in ambient conditions, only crumbling over cosmic timescales back to graphite.

The energy release comes more easily if the diamonds are very small. Medical researchers have already made nanodiamonds cling to tumours and then irradiated them with ultraviolet light, causing them to expand rapidly, killing the cancer cells.

The ARL experiments keep nanodiamonds under huge strain by surrounding them with a cage of hexagonally bound carbon rather like a buckyball. Burst the ball and the strain is released explosively. "The nanodiamonds pop like popcorn," says Ciezak-Jenkins. Simulations suggest that this could be done by smashing the nanodiamonds together, producing a burst of high-speed, high-temperature carbon particles. These would burn rapidly in atmospheric oxygen, making them ideal candidates for a rocket propellant.

In practice, it isn't that easy. Getting the particles to accelerate is tricky, and high-power lasers are needed to trigger an explosive reaction. We'd need an impractically huge laser if it is to work on a large scale.

Munawar Chaudhri, a materials scientist at the University of Cambridge who has worked extensively with Prince Rupert's drops, is sceptical whether using materials under strain will add much to their explosive capabilities. He points out that the strain energy stored in Prince Rupert's drops is only about a thousandth of the chemical energy in the same weight of explosive, and something similar is likely to be true of nanodiamonds, too. "I do not think that releasing a large amount of stored energy during the collision of nanodiamonds is feasible," says Chaudhri.

If the nanodiamonds fail to make waves, it might be back to chemistry – just not as we know it. Almost all industrial explosives, from gunpowder through dynamite to the ammonium nitrate-based explosives that dominate the market today, have a hefty pinch of nitrogen in them. In molecular nitrogen, two atoms are connected by a triple bond that releases a load of energy when broken. Polynitrogen takes that idea to its logical

extreme. Take a load of nitrogen atoms, connect them together in one mega-molecule, then break their bonds and… boom! "Polynitrogens are excellent candidates for disruptive energetic materials," says chemist Karl Christe of the University of Southern California at Los Angeles. Theory suggests, in fact, that they should be five times as powerful as TNT.

Flash in the pan

The practical challenges start with the fact that polynitrogens don't obviously exist. Theory suggests they form like diamonds under extreme conditions of temperature or pressure, but nature seems not to have tried this experiment, at least not in our immediate neighbourhood. Gaseous nitrogen becomes solid at a pressure of about 60,000 atmospheres; models suggest it takes almost two million atmospheres to make polynitrogen. And there's no guarantee that polynitrogen will be a metastable state like diamond once the pressure is reduced again.

Christe led a research campaign at the US Defense Advanced Research Projects Agency in the 1990s to make polynitrogen compounds, and successfully isolated pentanitrogen, an ion with five nitrogen atoms, in 2002. But they could never synthesise it in large quantities – and pure, electrically neutral polynitrogen molecules will be even harder. "It is a long shot because of probable low thermal stability, high sensitivity and great difficulty of preparation," says Christe.

Earlier this year, however, researchers at the Nanjing University of Science and Technology in China reported developing large quantities of ring-shaped, negatively charged pentanitrogen ions within a larger stable molecule – a first step towards useful polynitrogen chemistry. Meanwhile, Ciezak-Jenkins and her colleagues have gone for the direct approach. Following work on the polymerisation of nitrogen at the Max Planck Institute for Chemistry in Mainz, Germany, they have developed a technique for making neutral polynitrogen in a diamond anvil cell, which produces huge pressures. The result is a blue liquid with a density three times that of water and about 50 times as dense as liquid hydrogen, allowing more energy to be packed into a small volume – in theory.

In practice, the liquid is unstable at room temperature and reacts explosively on contact with air, for reasons the researchers don't yet understand. Ciezak-Jenkins jokes that she is sitting on the "world stockpile" of polynitrogen – a total of 3 grams stored at a cryogenic 77 kelvin. At least 10 grams will be needed to test its explosive power, and that test will need to be repeated several times. There's still a good chance it might just be a modern nitroglycerin – powerful, but too prone to blowing up in your face to be useful.

Perhaps polynitrogen is not the final word anyway. As long ago as 1935, hydrogen was predicted to have a metallic phase that, like diamond and polynitrogen, forms only under tremendous temperatures and pressures. It might occur naturally at the heart of gas giants like Jupiter. It might even be metastable, remaining metallic once formed, even at room temperature and pressure. Above all, it is predicted to store a huge amount of energy – about 50 times as much per gram as TNT.

That might make it even more unruly than polynitrogen. Earlier this year, a team led by Isaac Silvera at Harvard University apparently produced a speck of the stuff using a powerful diamond anvil cell to compress solid hydrogen. Unfortunately, the cell failed just after they had made it, and the tiny sample, 15 micrometres across and a few micrometres thick, vanished.

Other researchers have been sceptical about the claim, and will continue to be until the team can repeat the experiment. Until we can measure the material's properties, we don't even know if it is solid or liquid, let alone whether it is metastable and able to release its stored energy rapidly. "You may be able to form it at 5 million atmospheres," says Eugene Gregoryanz, a condensed matter physicist at the University of Edinburgh, UK, "but we just don't know whether it will be unstable or metastable at one atmosphere." He also doubts whether it can be produced in the quantities necessary to make it useful. "That metallic hydrogen exists is beyond reasonable doubt," he says. "But it's a bit far-fetched as rocket fuel."

"Metallic hydrogen could store 50 times as much energy per gram as TNT, but can we make enough of it?"

Ciezak-Jenkins still thinks it is worth a punt. She says her team is carrying out experiments in collaboration with several groups, believing metallic hydrogen might well trump polynitrogen. Silvera points out that if metallic hydrogen turns out to be metastable, you might not need large quantities initially, either: it should be possible to grow a small sample by allowing a gas of hydrogen atoms to condense on its surface. "If a sample exists at room temperature, you have a seed of metallic hydrogen, and you just spray atomic hydrogen gas on it," says Silvera.

There's another reason to favour the new materials as rocket fuels: they are potentially cleaner. Common rocket fuels such as ammonium perchlorate produce toxic and corrosive hydrochloric acid as a by-product, so the area around a launch pad has to be decontaminated after every launch. Nanodiamonds burn to carbon dioxide, which although a greenhouse gas is non-toxic; polynitrogen turns into nitrogen gas and metallic hydrogen produces only steam.

So Mars, here we come? Perhaps. With conventional chemistry at a dead end, if we want to aim high with space exploration then unconventional chemistry seems like our best bet. Assuming, of course, people aren't too busy on Earth blowing each other up with the new explosives – or that the sugar doesn't get us, one way or another. ■

MORTON/AP/REX/SHUTTERSTOCK

The 2008 Savannah refinery blast was lethal proof of sugar's explosive power

David Hambling is a freelance writer based in London

The fragility of you

Your sense of self is a ghost in the physical world, says **V. S. Ramachandran**. But there are still ways to probe consciousness, he tells Catherine de Lange

PROFILE
V. S. Ramachandran is director of the Center for Brain and Cognition at the University of California, San Diego, and an adjunct professor at the Salk Institute

Mirrors can help unravel the nature of consciousness

IT'S the end of a long day of talks, and a gaggle of people are jostling around one of the final speakers. Everyone seems to have a question for V. S. Ramachandran, who is as close to a celebrity as a neuroscientist can get. Most want to know more about the curious brain conditions he has been discussing, but one woman has a more personal interest. Listening to his talk, she came to suspect that she has a very unusual brain.

Ramachandran has built a career on studying people with strange brains, and working out what they can tell us about what it means to be human. Perhaps his most famous work is on phantom limb syndrome – the sensation some people have that their missing limb is still present – but he has also studied synaesthesia, autistic savants and bizarre conditions like Cotard syndrome, in which people believe they are dead.

Today he has been talking about calendar synaesthesia, one of the most striking examples he has seen of how the body and brain interact to shape our minds. When most people think about what they plan to do in November, say, they have a hazy concept of the months ahead. But people with calendar synaesthesia can actually see a calendar in front of them, often in a strange formation – a hula hoop that touches them in the centre of their chest, for instance.

He suspects this hints at the way our brains cope with the non-intuitive concept of months. "The brain didn't have time in evolution for creating the representation of time – it's too abstract. What evolution often does is take pre-existing hardware and re-tool it." We did develop tools for conceptualising our surroundings. "So you take a spatial map, map time onto space, and you get a calendar." For synaesthetes, that calendar seems to be visible in space.

Answering questions from his fans, Rama (as everyone knows him) is sparkly eyed and fun. But when Dorian tells him she thinks she has calendar synaesthesia, his demeanour changes. Leaning in, he quizzes her about her experiences. How does she see the world? Could she draw him a picture? He pulls out a piece of paper and she searches for a pen. Eager to see what she is going to draw, several onlookers offer their own. We all want a glimpse of the inner workings of her mind. She draws a loop to show how the calendar looks to her, with months coming off. Then she says she feels herself to be "sort of hovering above it".

It's not uncommon for Ramachandran to meet the people he studies through this sort of chance encounter, he later tells me. And occasionally they shine a light onto one of the hardest questions about what it means to be human: the nature of consciousness.

The reason this is so hard to study is because it is inherently subjective. "The first person singular does not exist in the physical world,"

Photographed for New Scientist by Robert Benson

he says. "It's a ghost." He calls this the "vantage point problem". But, he says, it doesn't make consciousness impossible to study. You just have to find ways of showing that the subjective experience someone is telling you about is real – which is what Ramachandran specialises in. "You take the sense of self and say, OK, what can I say empirically?" he says.

Case studies can also help in revealing the blurry boundary between the self and the outside world. One of Ramachandran's most unusual cases is a man called David, who has Capgras syndrome. This is usually characterised by the belief that a loved one has been replaced by an impostor. David, though, believes himself to be the impostor.

"He looks at his reflection and says 'mom, that's the real David. If he comes back, are you going to disown me?'," says Ramachandran. When pressed for an explanation, David said the only logical one was that he had a long-lost twin and they were separated at birth. "It's an ingenious solution to the dilemma that he's in, and it sends a chill down your spine. It takes you into questions about what the self is."

Our sense of self is also affected by those around us. For instance, when people with mirror-touch synaesthesia see someone else being touched it feels as though they are being touched in the same way. One of Ramachandran's students has this: "If she sees someone else being tickled she feels a tickle in her armpit or her belly and she starts giggling. She feels the rhythmic motion first and then the mirth catches up."

People who experience such dramatic differences in perception may be rare, but we are all capable of distorting our sense of self. A simple experiment can show how. Try looking at yourself in a double-reflecting mirror – two mirrors facing each other such that the second reflects the image in the first. Then raise your right arm. The first reflection is a normal mirror image, but the second is inversed, which we are not used to seeing. "So when you raise your right hand, it raises its right hand. It's a doppelgänger, miming your behaviour," Ramachandran says. Keep looking and something odd can happen to your sense of self. "You start experiencing that you are out there."

"Consciousness is inherently subjective, it does not exist in the physical world"

What's more, if you watch your arm moving in the second mirror, you may see a slight delay. As Ramachandran puts it, it's slowed down as if your hand is moving through treacle. Exactly why this happens is something he and his team are working on, but we know that neurons in your brain telling your hand to move fire milliseconds before you consciously decide to move it. To avoid the sensation of being a puppet, your brain smoothes things out so that everything feels simultaneous. Ramachandran suspects that when you see this doppelgänger in the mirror, your brain doesn't compute it as you – so the correction isn't applied. In essence, you are seeing the unconscious machinery of the brain laid bare.

These insights build a picture of our consciousness as something very flimsy. When I put this to Ramachandran, he agrees: "It's very tenuous, ephemeral." He also concedes there is a limit to how much of consciousness we can unravel with his approach. "You can figure out the circuitry and all that, but it still leaves the qualia, or experiences – whether it's an orgasm or the colour of red or the flavour of marmite or curry or whatever. That problem will remain with us until we find a new way to do science. Maybe it'll be a permanent dual view of the world. The inside view and the outside view." ■

Learning to be fair

Changing the way we approach inequality may mean re-exploring our forager past, finds **Ben Collyer**

After Piketty: The agenda for economics and inequality edited by Heather Boushey, J. Bradford DeLong and Marshall Steinbaum, Harvard University Press
The Great Leveler: Violence and the history of inequality from the Stone Age to the twenty-first century by Walter Scheidel, Princeton University Press
Toxic Inequality: How America's wealth gap destroys mobility, deepens the racial divide, and threatens our future by Thomas Shapiro, Basic Books

SLACK-JAWED publishers watched in amazement as *Capital in the Twenty-First Century* by Thomas Piketty sold 2.2 million copies in the two years after its publication in 2014. Unknown outside a small circle of scholars studying old tax returns, Piketty found himself feted by top policy-makers and excited students alike, while pundits claimed a turning point.

The Piketty effect is spawning a shoal of books, all aiming to recast global economics or avert more inequality. These books are complemented by research in social, cognitive and biological sciences, documenting poverty's cost to people and communities.

Now the instigator of this flurry of activity, Harvard University Press, has entered the fray again. *After Piketty* collects papers by 24 commentators, ranging from those sympathetic to Piketty to the more critical. Piketty himself writes the final chapter.

All the contributors agree that his ideas can be boiled down to two fundamental assertions. First, his tax data confirmed earlier findings that income inequality fell after the world wars, and is now rising alarmingly. Second, and more controversially, he detected an underlying signal in the data: inequality rises as the share of national income derived from capital investment increases and the share going to wages falls.

Behind this signal lies something deeper, Piketty argues: a steadily falling rate of economic growth. Investors demand a fixed rate of return even when growth stutters, and workers pay the price. On current trends, we may soon be rerunning the grim inequities of the late 19th century.

His reviewers detect a central contradiction, however. While Piketty seems at times to argue that a trend to rising inequality is an inevitable economic "law" of peacetime, he advocates policy solutions – in particular, a tax on capital. Nor does he address the causes of lagging growth, which if reversed would undermine his predictions.

"Scheidel believes in four horsemen of equalisation: war, disease, revolution and state collapse"

So what do the contributors think? Some question whether Piketty counted the right things, others suggest his assumptions don't tally with other data. For example, shouldn't slaves be included on the capital side? Are companies incapable of raising productivity? Still others propose different factors driving inequality – the rise of corporate lobbyists, outsourcing, the use of tax havens, racial and gender inequalities, and the global drive for cheap labour. While lack of debate about production is a weakness, the authors unite in rejecting the idea of a natural law of inequality.

A more troubling strand of post-Pikettyism comes in the shape of *The Great Leveler*, which extends the study of inequality back 10,000 years. Historian Walter Scheidel argues that historical efforts to reduce inequality have mostly failed or been reversed. In fact, nearly all periods of peace seem to widen inequality. The only serious historical forces closing the income gap are war, disease, revolution and state collapse: his four horsemen of equalisation.

Scheidel's excellent survey has the merit of drawing evidence from the smallest scrap – height in burial sites, records of wages or rations, differences in house sizes over time, for example.

The causal links are revealing. For example, it was the Black Death, and subsequent labour

ALEX WEBB/MAGNUM

Is modern inequality fuelled by the global drive for cheap labour?

MATT BLACK/MAGNUM

Not barely managing: the smallest setback can push you over the edge

shortage, that allowed the rise in pay that followed. As populations recovered, wages fell again. More usually, income gaps close from the top down. After war, assets held by the rich become worthless as workshops, homes and roads to market are destroyed. Revolution and civil war are even more poisonous. Worse still, most revolts fail, and mass uprisings reap only merciless revenge. Something unique must happen, says Scheidel, if we are to reduce inequality by peaceful means.

But one of the problems with just looking at income or markers for income is the loss of social context. This means it is probably a mistake to draw sweeping conclusions about the failure of popular struggles in the past. For the participants, gains in legal and social rights were often more important than pay rises. Struggles against slavery, or for religious freedom or workplace organisation, come to mind.

That income data alone can give only the barest glimpse of the lived experience of inequality is clear from sociologist Thomas Shapiro's *Toxic Inequality*. He defines this as the especially harmful intersection of income and racial inequality in the US. For over a decade, he and colleagues at Brandeis University in Massachusetts, and elsewhere across the US, gathered personal stories about inequality from 200 families from different ethnic and income backgrounds in selected US cities. One child in the research group was murdered during the study period, by a stray bullet in a run-down area. Others inherited wealth, bought big houses in safe areas and sent their children to private schools.

The figures and interviews show black and Hispanic families fare worse both financially and in their life histories. Nevertheless, poor families emerge heroically. Often they are penniless because they have helped relatives, lack work benefits despite their long hours, or have become entangled in a web of arcane welfare legislation.

The most dangerous trap is the lack of anything put by for a rainy day. An emergency can plunge a family into long-term debt for want of a few hundred dollars. Inequalities are real, life-changing, stressful and often sudden in impact. *Toxic Inequality* reads like a dispatch from the front lines: Shapiro insists on exposing inequality's intimate miseries, but he also identifies the most urgent policy changes.

Here we see a glimmer of light: social vigilance is the one proven curb on unfairness. Curiously, Scheidel also recognises the role of social vigilance in a brief reference to hunter-gatherers. Inequalities in forager societies, especially over food supply, are resisted by what anthropologists often call a "fierce egalitarianism". Scheidel himself talks of "active equalisation", "distinctive moral economy", and the rejection of dominance that keeps inequality at bay. He cites the influential anthropologist Christopher Boehm, author of *Moral Origins*, to acknowledge the universality of these beliefs among foragers.

It is puzzling why he doesn't return to this, and temper his conclusions. He recognises that the failure to share is taboo for hunter-gatherers, and that it is countered by pestering, gossip, ridicule and ostracism.

Research elsewhere shows concessions apply for the sick, young and elderly. Personal autonomy and experience are also generally highly respected,

"For hunter-gatherers, failure to share is taboo, countered by pestering, gossip, ridicule, ostracism"

and typically, foragers all have equal rights to make group proposals, and aren't coerced into collective decisions as long as others aren't disadvantaged.

This social order only collapses under extreme resource shortage. It is possible this powerful moral outlook has been a central feature of human prehistory. There is little in the archaeological record to suggest social hierarchies in everyday life over the hundreds of thousands of years preceding the first attempts at agriculture.

An even deeper trend, where canine teeth get smaller and body sizes more equal between the sexes, points to a human social order that steadily turned its back on the dominance likely with our ape ancestors.

There is little dispute in any of these books that humans ever had much truck with unfairness. So might the struggle for human rights, combined with modern communications and technology, open a peaceful route beyond Scheidel's horsemen?

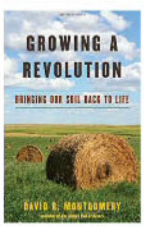
We already have a globalisation of gossip and ridicule of elites. But if a forager world outlook is any guide, then improving production and sharing more equally needs a society with more participation in decision-making. Is this a new direction for post-Pikettyism? ■

Ben Collyer is a writer based in Essex, UK

Don't desert the earth

Soil science may yet avert an agricultural catastrophe, finds **Gary Paul Nabhan**

Growing a Revolution: Bringing our soil back to life by David Montgomery (W. W. Norton)



THIS author is down to earth in every sense. David Montgomery, a research geologist at the University of Washington, is one of our most eloquent and precise earth science communicators. In his latest book, he takes on one of the toughest problems contributing to climate change and resource depletion: the impoverishment of the soil. On top of being a catastrophe in itself, the collapse of the soil microbiome also impairs its capacity to sequester carbon and retain moisture.

Montgomery visits farmers, range managers and others who set out to show that improving the diversity and resilience of the soil microbiome can be economically viable and have a lasting ecological impact. This point has been made before, in Courtney White's *Grass, Soil, Hope* and by Eric Toensmeier in his practical guide *The Carbon Farming Solution*. Montgomery's meticulous scientific research deepens the discussion, reviewing the recent technical literature to explain and evaluate farmers' claims.

Montgomery is one of the most prolific science writers in the US, and sometimes that industriousness takes its toll. For my money, the best book ever written on the fungi, nitrogen-fixing bacteria and insects that run the world from beneath our feet is *The Hidden Half of Nature*, which Montgomery co-wrote with his wife. In contrast, these latest journalistic accounts of visiting "carbon farmers" and "carbon cowboys" around the world feel a little thin.

NOAH BERGER/THE NEW YORK TIMES/EYEVINE

Disturbed earth: soil microbiomes are in decline across the planet

Much of value remains. Montgomery steers clear of the suggestion that there is a single biotechnological fix to soil ecology – a one-size-fits-all approach like Allan Savory's managed grazing or Wes Jackson's "natural systems agriculture". He looks instead for a mix of tactics, which will be applied in different proportions to fit different landscapes.

"We can restore beneficial microbes to our skin, might we really perform the same feat for the soil?"

If there is any flaw in Montgomery's scientific assessments, it may lie in his optimism. He has high hopes for annual crops, though many ecologists think they are ecologically quite damaging. It is hard to imagine that any annual herbaceous crop could sequester much carbon, compared with longer-lived perennial crops in the same settings. "Food forests" of fruit and nut trees, or even deep-rooted grasses and other herbaceous crops do far less damage to the soil because they require less tillage.

The effort that farmers of annual crops expend to make their operations more sustainable are noble. But I'm wary of any hype, never mind whether it comes from the biotech industry or the biodynamic farm movement, suggesting that annual crops can be as ecologically sound and mitigate climate change as effectively as orchards and perennials.

If Montgomery is indeed "growing a revolution" then his next steps are clear, and it will be fascinating to know whether some of the suggestions he floats before us will bear fruit. Might future agricultural systems be able to apply lessons drawn from elsewhere in biology to solve our current agricultural crisis? Montgomery explains how microbial ecologists working in hospital operating rooms are learning to reverse the devastation caused by antibiotics, and restore beneficial microbes to our skin and gastrointestinal tracts; might we really perform the same feat for the soil?

Montgomery has a knack for opening our minds to large, critically important questions. Plausible answers to those questions can be slow in coming, and this can be frustrating. But that, to my mind, is why we need more risk-takers like Montgomery in our midst. ■

Gary Paul Nabhan is an agroecologist and author of *Ethnobiology for the Future* (University of Arizona Press)

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PREVIEW

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British Media Awards 2017 SHOW OF THE YEAR

AEO WINNER BEST CONSUMER SHOW LAUNCH

A WILD LIFE EXPOSED

Thursday 28 September

Life is never dull for naturalist and impassioned campaigner **Chris Packham**. His travails at the far frozen poles, and the sticky forests and searing deserts in between, have brought him eye to eye with nature's most astonishing creatures and landscapes. He shares his story and theirs in this entertaining, family-friendly show, and asks: what of their future?

SCIENCE, FICTION AND THE FUTURE

Sunday 1 October

Margaret Atwood's books, like *The Handmaid's Tale* and many others, don't contain aliens and spaceships but often concern the future. She takes ideas that are current in science and speculates what they will mean for our society in the near future. Find out how science has influenced her life and her writing, and why her fiction is often labelled dystopian.

SOLVING INTELLIGENCE: THE FUTURE OF AI

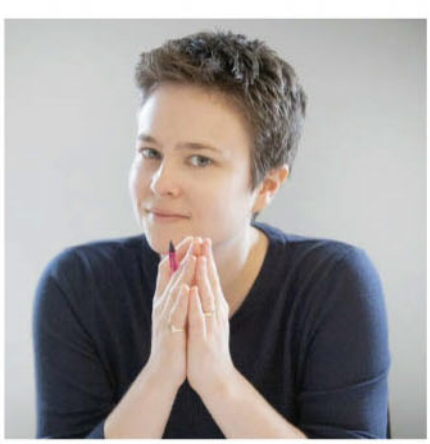
Friday 29 September

Demis Hassabis has worked as an artificial intelligence researcher, neuroscientist and video game designer. He is founder and CEO of DeepMind, a company that is building software more powerful than the human brain to solve the world's most complex problems. Find out how machine learning is on the way to solving the greatest of them all – understanding human intelligence.

THE MUSIC OF PROOF

Thursday 28 September

Composer **Emily Howard** and mathematician **Marcus du Sautoy** introduce the world premiere of a musical work inspired by maths. Hear it performed by the Piatti String Quartet and learn what connects sounds and numbers.



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VILLAGE FETE OF THE FUTURE

Thursday to Sunday

Roll up, roll up! The science village fete is back with new games for all the family. Classic fairground attractions are reinvented to explore how the world will change: examine future shortages with our fast and funny game show *Higher or Lower*, pit your might against robots in *Test Your Strength*, and try to keep your planet orbiting in *Two Body Problem*.

"Seeing our daughter's face as she talked the whole journey home was priceless"
2016 visitor

TUDOR TREASURES

Thursday to Sunday

The Mary Rose was Henry VIII's flagship until it sank in 1545 near Portsmouth. Nearly 440 years later the world watched as it rose from its watery resting place. Now is your chance to get your hands on its precious artefacts. Explore Tudor materials using the latest techniques, and discover how science is saving the Mary Rose for future generations.

ENGINEERING INSPIRED BY STAR WARS

Thursday to Sunday

Feel the force and discover the droids with the Royal Academy of Engineering. Explore the latest advancesin robotics, haptics, and more, all inspired by Star Wars™

EXTREME LANGUAGE

Thursday 28 September

How did humans evolve complex spoken language? Geneticist **Simon Fisher** teams up with beatbox champion **Jack "Hobbit" Hobbs** to explain the role that critical genes such as *FOXP2* play. Discover how we can even go beyond speech and push the human vocal system to the very limits.

MEET AN ASTRONAUT

Tim Peake made history as the first British astronaut on the International Space Station, and will be joined by the legendary Apollo 15 pilot **Al Worden**, one of only 24 people to have flown to the moon.

LIFE ON THE OCEAN FLOOR

Saturday 30 September

Marine ecologist **Alan Jamieson** explores the deepest spots of the ocean floor. Find out what it's like 8 kilometres beneath the waves and about the sea creatures overturning our understanding of extreme ocean environments.

MUCH MORE TO EXPLORE

Each day you'll find over 25 talks to choose from, plus a wealth of things to see, hear, touch, play with and learn. To see the full programme, plan your visit and book your tickets go to **newscientistlive.com**

THEATRE HIGHLIGHTS

MAIN STAGE

THURSDAY A WILD LIFE EXPOSED Chris Packham
FRIDAY TEN SPECIES THAT CHANGED OUR WORLD Alice Roberts
SATURDAY WHAT HAPPENED AT THE BIG BANG? Sean Carroll
SUNDAY THE BORDER BETWEEN LIFE AND DEATH Adrian Owen

HUMANS

THURSDAY IS THERE A CURE FOR AGEING? Linda Partridge
FRIDAY TURNING OUR GENES INTO MEDICINE Adrian Thrasher
SATURDAY THE MICROBIOME AND YOUR ROUTE TO BETTER HEALTH Kevin Whelan
SUNDAY THINKING HARD ABOUT MEDITATION Miguel Farias

ENGINEERING

BAE SYSTEMS
INSPIRED WORK

THURSDAY WELCOME TO HYPERLOOP ONE Alan James
FRIDAY CROSSRAIL, CITIES AND THE FUTURE Laurie Winkless
SATURDAY THING EXPLAINER: COMPLICATED STUFF IN SIMPLE WORDS Randall Munroe
SUNDAY SYNTHETIC BIOLOGY: DESIGNING THE FUTURE Paul Freemont

COSMOS

esa Discovery

THURSDAY GRAVITATIONAL WAVES: A NEW ERA OF ASTRONOMY Sheila Rowan
FRIDAY THE TWO GREATEST MYSTERIES IN PHYSICS David Tong
SATURDAY WHO OWNS THE MOON? Jill Stuart
SUNDAY CASSINI'S GRAND FINALE Michele Dougherty

EARTH

THURSDAY CLIMATE CHANGE: WINNERS AND LOSERS Jane Hill
FRIDAY IS LIFE QUANTUM MECHANICAL? Jim Al-Khalili
SATURDAY FEEDING THE WORLD, HEALTHILY AND SUSTAINABLY Charles Godfray
SUNDAY WHY IS THERE ONLY ONE SPECIES OF HUMAN? Chris Stringer

TECHNOLOGY

BT

THURSDAY WHEN COMPUTERS GET ACCESS TO YOUR EMOTIONS Rosalind Picard
FRIDAY BUILDING ROBOTS: COMPLEXITY, CYBERNETICS, COCKROACHES Ravi Vaidyanathan
SATURDAY WHEN BAD STATS MAKE FAKE NEWS David Spiegelhalter
SUNDAY IS TRYING TO PROTECT YOUR PRIVACY FUTILE? Angela Sasse

To see the programme in full and
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Programme subject to change

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For more information, please visit www.radcliffe.harvard.edu or email sciencefellowships@radcliffe.harvard.edu.

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Candidates must have a strong doctoral record and have completed their Ph.D. Candidates should have demonstrated a promise of excellence in both research and teaching. Teaching duties will include offerings at both undergraduate and graduate levels.

Please submit a cover letter, curriculum vitae, research and teaching statements, up to three representative reprints, and names and contact information of three to five references (three letters of recommendation are required, and the application is complete only when all three letters have been submitted) to

http://academicpositions.harvard.edu/postings/7663

Questions regarding this position can be addressed to **alvarez@wjh.harvard.edu**. The committee will consider completed applications starting immediately on a rolling basis through October 1. Interviews will be conducted in late September and continue in October.

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Fellowships

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- **Geology & Geophysics**
- **Marine Chemistry & Geochemistry**
- **Physical Oceanography**

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Further information about the Scholarships and application forms as well as links to the individual Departments and Institutes and their research themes may be obtained through the Academic Programs section of the WHOI web pages at:

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EDITOR'S PICK

Plants, too, have their own low cunning

From Anthony Trewavas, Edinburgh, UK

Erica Tennenhouse describes snails, starfish and slime moulds learning without brains (15 July, p 32). But any judgement that this is surprising is coloured by our limited animal perspective. We equate behaviour with visible movement and elevate nerve cells in reasonable numbers as the only means of learning, remembering and delivering intelligence.

A simple definition of intelligence as behaviour that profits from experience during the life cycle fits immune systems perfectly. In the single-celled *Physarum* slime mould, intelligent behaviour arises from sophisticated and complex networks of tens of thousands of proteins and thousands of protein-modifying enzymes.

Higher plants, Earth's dominant life form, continue to develop in the face of a variable and usually unpredictable environment. They learn and profit from experience by adjusting their characteristics . It is easy to demonstrate that plants remember former parts of their experience over many months and even years. That, too, is intelligent behaviour.

Climate change needs a collective response

From Andrea Needham, Hastings, East Sussex, UK

Bob Holmes suggests ways in which you can make a difference to climate change: reducing air travel, eating less meat and so on (24 June, p 35). He mentions only individual consumer behaviour.

Surely getting actively engaged in social movements, such as 350.org's Fossil Free campaign, should also be considered?

This aims to get institutions such as universities and pension funds to ditch investments in the oil, coal and gas industries, to break the hold they have on our economy and governments.

In five years, it has persuaded more than 740 institutions in more than 75 countries, managing assets worth over $5.4 trillion, to make some form of divestment commitment. I am sure such local campaign groups would welcome new, scientifically minded members.

From Guy Cox, St Albans, New South Wales, Australia

In your feature on climate change, you mention schemes that would take up large tracts of otherwise useful land, but not culturing and harvesting microalgae. The Centre for Solar Biotechnology at the University of Queensland, founded and directed by my colleague Ben Hankamer, is working on large-scale culturing of microalgae. This can provide biofuels and remove carbon from the atmosphere using a tiny fraction of the land area needed to do these things in open paddocks.

The editor writes:

■ We have reported on this idea in the past (20 February 2016, p 30).

"Artificial intelligence learns 'noise' unless partnered with human oversight"

Bonny McClain is sceptical about artificial intelligence outperforming human doctors (15 July, p 36).

The changing market for fossil fuels

From Bob Cory, Altrincham, Cheshire, UK
Oil companies being "doomed" is old news to the market (8 July, p 20). BP and Shell are yielding 7 per cent, double the market average – another way of saying that their share prices are half what they would be if the firms' futures weren't so depressing.

All this is an action replay of tobacco, which has been "doomed" for decades, but still refuses to die. So really smart investors are probably buying oil shares not selling them, as markets invariably overreact.

From Kathryn Nelson, Reading, Berkshire, UK
In your leader on the risks of failing to recognise the economic restructuring that dealing with climate change will produce, you assert that oil and gas reserves will become "worthless, stranded assets" (8 July, p 3). But fuel is not their only use. They are raw materials for many other products, such as plastics, pharmaceuticals and lubricants. These are already a better use of a limited resource than burning.

Of course, since the majority of production is currently used as fuel, there will need to be significant structural change in the oil and gas industries when demand drops.

Fetuses following faces from inside the womb

From Anne Barnfield, London, Ontario, Canada
Babies may "look for faces as soon as they are born" – or even in the womb (17 June, p 12). But we should be wary of over-interpreting this: looking does not necessarily imply recognition.

Others argue that newborn babies don't necessarily have a predisposition to look at faces: it may be that they simply attend to moderately complex, high-contrast visual stimuli.

From Neil Doherty, Barnsley, South Yorkshire, UK
Experimenters looking at fetuses spotting face-like patterns shone three dots of light into the womb, configured to resemble two eyes above a mouth (17 June, p 12). As a control, they inverted the three dots, with one dot sitting above two. Does this suggest that fetuses already understand "up" and "down", which would be immediately handy at their birth?

The editor writes:
■ The orientation of the three dots was arranged relative to the position of the baby's head at the time, not to gravity.

Some already impose population controls

From Moira Macdonald, Exeter, Devon, UK
Daniel Cossins asks whether "we" should impose population controls (8 July, p 34). But it has been obvious since effective contraception and safe abortion became available that it is men worldwide who are at the controls.

Evidence exists that, given affordable access to the means of regulating their fertility, women do their best to avoid having more babies than they anticipate being able to raise successfully. That there are so many of us on the planet is because men maintain social structures in which safe abortion is restricted, banned or unavailable and where access to ›

contraception costs too much, is forbidden or is still unavailable – China excepted.

Birth control is indeed a massive human rights issue – the problem is the denial of women's human rights. The solution is not to start, but to stop imposing the current controls. Free each woman to be the sole decision-maker over her own body. Give her access to safe, affordable means to regulate her fertility, to get an abortion if and as soon as she needs one. Then watch the global birth rate plummet.

Philanthropists should look at where they got it

From George Kasabov, Liston, Suffolk, UK

David Auerbach suggests how Jeff Bezos, the founder of Amazon, should act as a philanthropist (1 July, p 24). He assumes that it is good and natural that Bezos should use the money he has gained from his company to fund philanthropic work outside the ambit of Amazon.

But shouldn't charity begin at home? What about using his wealth inside Amazon? Wouldn't it be better to ensure that his employees and suppliers are treated fairly, for instance, through better working conditions? The social inequality produced by his platform needs to be ameliorated. Shouldn't Bezos create an equitable company first and foremost, rather than extract vast monopolistic profits for himself and his major investors, and then flaunt them in public philanthropy?

Credit for illumination where credit's due

From Sam Edge, Ringwood, Hampshire, UK

Please don't perpetuate the myth that Thomas Edison invented the incandescent light bulb (17 June, p 44). Heinrich Goebel demonstrated a practical prototype in 1854. Edison rejected an offer from Goebel to sell his patent, claiming it had no merit – but eagerly snapped it up at a bargain price from Goebel's impoverished widow.

Joseph Swan completely defeated Edison's attempts to overturn his patents for the technology. Edison first formed a joint company then bought him out. The existence of so much "prior art" should have prevented Edison from ever being granted a US patent – but, as with Alexander Graham Bell and the telephone, the US patent office was notoriously partisan, if not downright corrupt.

Another gourmet bacon sandwich in space

From Simon Cains, High Wycombe, Buckinghamshire, UK

Sandrine Ceurstemont says "the first and last people to enjoy bread in space were the two astronauts on NASA's 1965 Gemini 3 mission" (17 June, p 14). But Britain's liquid-nitrogen-loving chef Heston Blumenthal made this possible for compatriot Tim Peake in 2015. Major Tim selected seven meals he would like to eat in space, including, of course, the great British bacon sandwich. After two years of testing, Blumenthal came up with a sandwich that would still be edible after the NASA sterilisation process: heating for 2 hours in a can at 140°C. The brown bread was described as dense and sticky, this being to avoid the crumb problem. The whole meal of seven small dishes was sampled by Tim Peake in 20 minutes and is reported to have cost $2.6 million.

What is it that gives some eggs a pointy end?

From Simon Carter, Bromsgrove, Worcestershire, UK

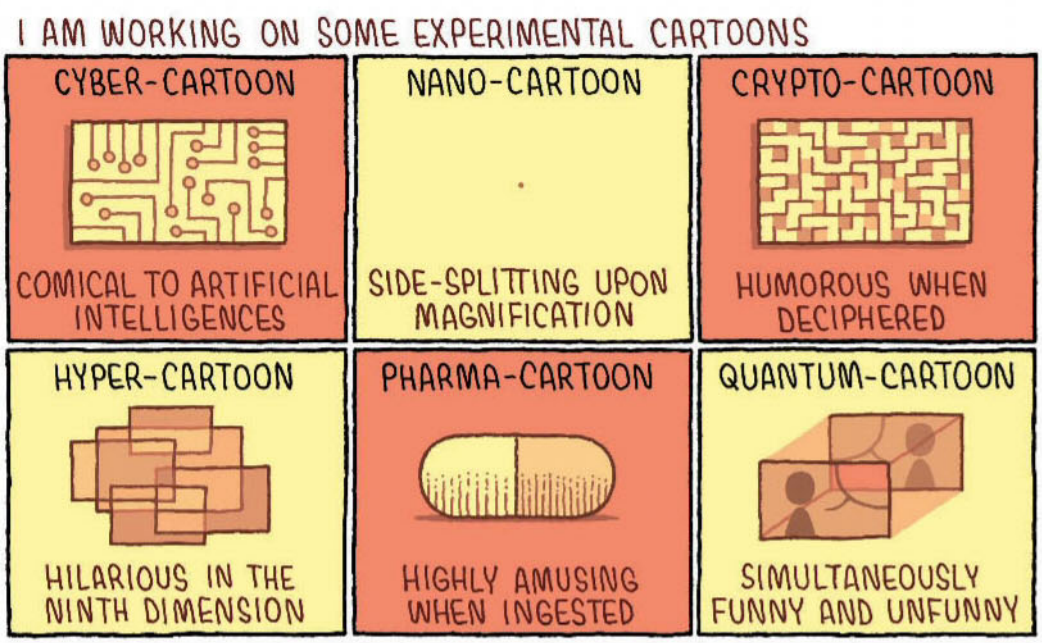
I was fascinated by the shape of bird eggs being related to flying style (1 July, p 16). Maybe birds that are better at flying have more precarious nests, and eggs that aren't spherical and so don't roll out? Could it be the nature of the nest and the shape of the eggs that are related, with the birds' flying style directing the nest type?

Theories of mind at work in the laboratory

From John Downing, Oslo, Norway

You report evidence that some animals have a theory of mind (8 April, p 10) and Bryn Glover asks who is studying whom (Letters, 13 May). First laboratory rat to second rat: "I've really got that fellow in the white coat well trained. Every time I press this lever he gives me a raisin."

TOM GAULD



For the record

- **The final illustration of our report of investigations of flow was in fact of copper rods (1 July, p 32).**
- **The musician and author we quoted on birds with swing is David Rothenberg (15 July, p 11).**

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SIGNAL BOOST

Offering your projects a helping hand

From quake to marathon

THE Kailash Children's Home in Kathmandu is home to 100 orphaned or impoverished children from remote areas of Nepal. The children receive healthcare and are educated in local schools, and live as one family in a secure environment. In 2015, the children decided to run the Tenzing Hillary Everest Marathon to raise money for improvements to their home. It was to be their first fundraising effort.

The iconic Everest Marathon is the world's highest and most spectacular race. The air is thin and the terrain is tough. The marathon is difficult and downright treacherous and attracts professional runners from around the world.

The Kailash children trained hard for months and 16 of them passed the intense training assessment required to compete. Their aim was to trek for four days up to the starting point near Everest base camp before racing down the 42-kilometre trail in a single day. But then tragedy struck. A major earthquake hit Nepal, killing more than 9000 people and destroying the homes of hundreds of thousands. The children's home in Kathmandu was severely damaged, and as aftershocks continued to shake the area they spent many weeks living in tents until a programme of emergency repairs could be put in place. The 2015 race was, of course, cancelled, but in 2017 it was reinstated, and five of the original 16 Kailash runners were able to successfully complete the marathon on 29 May.

The children are fundraising to repair their damaged home. While their accommodation is adequate, they have very limited space for study, learning and social activities. They are supporting an international effort to raise funds for new buildings which, of course, need to conform to new earthquake-proof standards.

Peggy Sellers, Trustee, Himalayan Youth Foundation

To find out more about these intrepid runners or make a donation, please visit the UK charity that supports the Kailash Children's Home: **www.hyf-uk.org**

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PAUL MCDEVITT

STOP the presses: Richard Woods writes in to correct Paul Allen's claim that typesetters used "mutt" and "nut" as seemingly useless guard words when discussing "em" or "en" sized lengths (15 July). "The need to standardise typefaces and sizes in hot metal printing led to a union between the American and British points systems. Thus a Pica Em (mutton, not mutt) was 12 points (one-sixth of an inch) and an en (nut) six points."

He says that while a shout of "you need a couple of nuts in there, John" might seem funny, getting it wrong meant that when the frame was tightened, the type would burst out into a horrendous alphabet soup, otherwise known as printers' pie.

Richard recounts a day in 1972 when the White Paper on the UK's European Economic Community membership was published and London's *Evening Standard* rushed it into print. The last of 21 pages was done at haste, tightened and "burst up and out and down".

He says "I spent the next 40 minutes with a compositor, a galley proof and more patience than you can imagine, reassembling the lines in correct order, under the evil eye of an impatient editor."

"NO, NO, no!" writes Glyn Hughes, "the J. P. Joule pub in Manchester isn't named after James Prescott Joule the physicist, it is named after James Prescott Joule the brewer, who happened to do a bit of physics in his spare time to reduce heating costs in the beer-making process" (15 July).

Long may we toast these scientists who work for beer money, though – where would we be without the Student's t-test, developed by statistician William Sealy Gosset to monitor the quality of Guinness?

"Prestwich has the delightfully named 'Railway and Naturalist'," adds Glyn, "named after the pioneer of natural selection and sometime railway surveyor, Alfred Russel Wallace."

Possibly on a one-way road, Howard Bobry reports a road sign in Nehalem, Oregon, "directing drivers to the 'recycle centre and cemetery'." Turn left at the Soylent Green factory?

JOINING us at the table, Martin Chandler reports the existence of "The John Wallis" in Ashford, UK, named after the mathematician and sometime resident.

The inventor of the infinity symbol would no doubt appreciate the timeless pursuit of drinking in pubs. Meanwhile the ghost of Sir Isaac Newton still lingers in the Cambridge pub that bears his name (suggested by Alec Cawley), which undoubtedly stills plays host to regular lofty conjectures.

ALSO chipping in to this round is Klaus Æ. Mogensen, who notes the existence of the Ørsted Ølbar (Ørsted Beer Bar) in Copenhagen.

"It is named for Hans Christian Ørsted, the Danish physicist who discovered electromagnetism." Or perhaps it comes from the park across the road, says Klaus, which is likewise named after Ørsted.

AND Keith Waldon tells us of the font of ingenuity around his home in Gloucestershire. There is the Whittle Inn, "named after Frank Whittle, the inventor of the jet engine," while nearby is the Wheatstone Inn, named after inventor Charles Wheatstone, who developed "the Wheatstone Bridge, the electric telegraph and the English concertina". Perhaps there's something in the water?

PREVIOUSLY, Steve Ingamells suggested that "Infinite Buildings Solutions Ltd" might be a suitable client to construct the Hilbert Hotel (15 July).

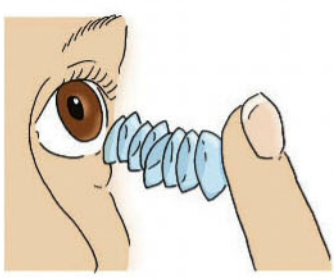
"This makes me wonder if this was the company responsible for a new housing development near Royston a few years ago, that was marketed as 'Infinity', part of the trend for fancy non-descriptive names given to new housing developments," says Rupert Featherstone. "This had the pleasing side effect of road signs in the local area directing you to Infinity, which you could in fact reach."

A few years later, work started on another development next to Infinity, "which I really hoped would be marketed as 'And beyond', but sadly they settled for 'Affinity' instead".

ANOTHER entry into accidental foreign language retronyms: John Farnhill reports that Toyota may struggle to sell its MR2 model in France. Spoken aloud, "it sounds like *merdeux*," that's French for, uh, "not very good".

Feedback is reminded of the 1962 Chevy Nova's supposed poor performance in Mexico, based on the idea that *no va* translates in Spanish as "won't go". Despite being wholly apocryphal, this cautionary tale still runs regularly in columns and on websites, proving that fanciful stories can get better mileage than a mid-sized family saloon.

THE *BMJ* reports that doctors at Solihull Hospital, UK, discovered no fewer than 27 contact lenses in the eye of a 67-year-old woman undergoing routine cataract



surgery. Surprisingly, the patient had not reported any discomfort.

The medics note the woman had "deep set eyes, which might have contributed to the unusually large number of retained foreign bodies."

"SURELY the scentless perfume from Josie Maran (3 June) is the perfect gift for a female homeopath," writes Dave Hulme. We're sure there are versions pour femme and pour homme, Dave. But how to tell which is which?

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

Feel the heat

On a beautifully sunny, windless day last summer, I sat in my back garden and felt very warm indeed. The air temperature was 16°C, but there is no doubt that it felt more like a day when the thermometer read 25°C. Why the discrepancy?

■ A number of factors besides ambient air temperature affect heat loss from our bodies, and your correspondent hints at several explanations for their surprising warmth at 16°C – windlessness, for example. Moving air removes heat much more efficiently from our skin than a still layer of air at the same temperature, hence the familiar wind-chill factor. And if your correspondent had dressed warmly based on the air temperature, then their clothing would have trapped an insulating layer of air.

Our bodies also radiate heat, and if objects radiating at us are colder than our skin then we experience a net heat loss. On a sunny day, the sun is a major source of radiant heat, reducing our net heat loss.

If you are in a car, then to be comfortable you may need to set its air conditioning's temperature several degrees lower on a day with sunshine streaming through the windows, compared with a sunless day. This is because the sun's radiation is directly heating your body, regardless of the air temperature.

Also, I wonder if your correspondent happened to be standing beside a sun-drenched wall. If so, it would be an additional source of radiant heat.

Lastly, the day in question was described as "beautiful". Perhaps taking pleasure in the weather also contributed to a sensation of warmth.

Tim McCulloch
Sydney, Australia

■ Thermal comfort depends to a large degree on your skin temperature, which in turn depends on heat exchange.

The human body exchanges heat with the surroundings by four routes: conduction (that is, between objects in contact), convection (to a surrounding liquid or gas), radiation (by the absorption and emission of electromagnetic radiation) and evaporation (the phase change of water from liquid to gas). Exchange by each of these routes depends on different characteristics of the environment, which is why it is fiendishly difficult to develop a single index of thermal comfort.

"An air temperature of 20°C can feel quite warm on a still, sunny day, but cold on a clear, windy night"

Your correspondent identifies the important role that radiation plays in heat balance and thermal comfort. In the absence of a strong radiation source (like the sun), heat exchange at 16°C will be dominated by convectional loss, and you will feel cold. But with a strong source (and especially in the absence of wind), radiation exchange will dominate – in this case, radiant heat input from the sun to the skin.

My third-year students collect data on skin temperature and thermal comfort in a range of environments, and are amazed to discover that an air temperature of 20°C can feel quite warm on a still, sunny day, but unbearably cold on a clear, windy night.

Shane Maloney
School of human sciences
University of Western Australia
Crawley, Western Australia

■ Meteorological stations place most of their instruments inside a special box to avoid direct sunlight. They cannot be in the shade or lee of a tree or a building because they must also measure wind speed and direction, so the "Stevenson screen" was devised: a white-painted, well-vented box that has a double roof with an air space between to avoid the effects of direct solar heating.

Incidentally, the primitive 1960 Land Rover I once owned in Kenya had a similarly constructed "tropical" roof, which was extremely effective at keeping the vehicle's interior cool under the equatorial sun.

For the same reason, an outdoor thermometer should be in a shady location and shielded from the rain, but at 16°C, you would definitely want to sit in the sun. Depending on the latitude and time of day, you could easily experience temperatures 10°C warmer than a shade thermometer would indicate. Don't forget to apply your sunscreen.

Peter Bursztyn
Barrie, Ontario, Canada

Salvaging Hubble

The illustrious Hubble Space Telescope will eventually re-enter Earth's atmosphere and be destroyed – or so I understand. Could it be returned to Earth safely and put in a museum? If so, what would be the cheapest way to do it? (Continued)

Our apologies to Sam Palasciano whose earlier submission to this question on 3 June contained an error introduced by us – Ed

■ Hubble's primary mirror weighs roughly 1800 pounds or 800 kilograms, not 450 as the article stated. This could be significant if someone wanted to seriously pursue this question.

However, I would much rather someone came up with a way of extending the life of the Hubble telescope in orbit. The replacement Webb Telescope, as I understand it, operates at different wavelengths. Hubble was designed to have a more useful operating window, including both ultraviolet and infrared, an advantage that will be lost when it is closed down.

Sam Palasciano
Oceanside, California, US

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