New Scientist

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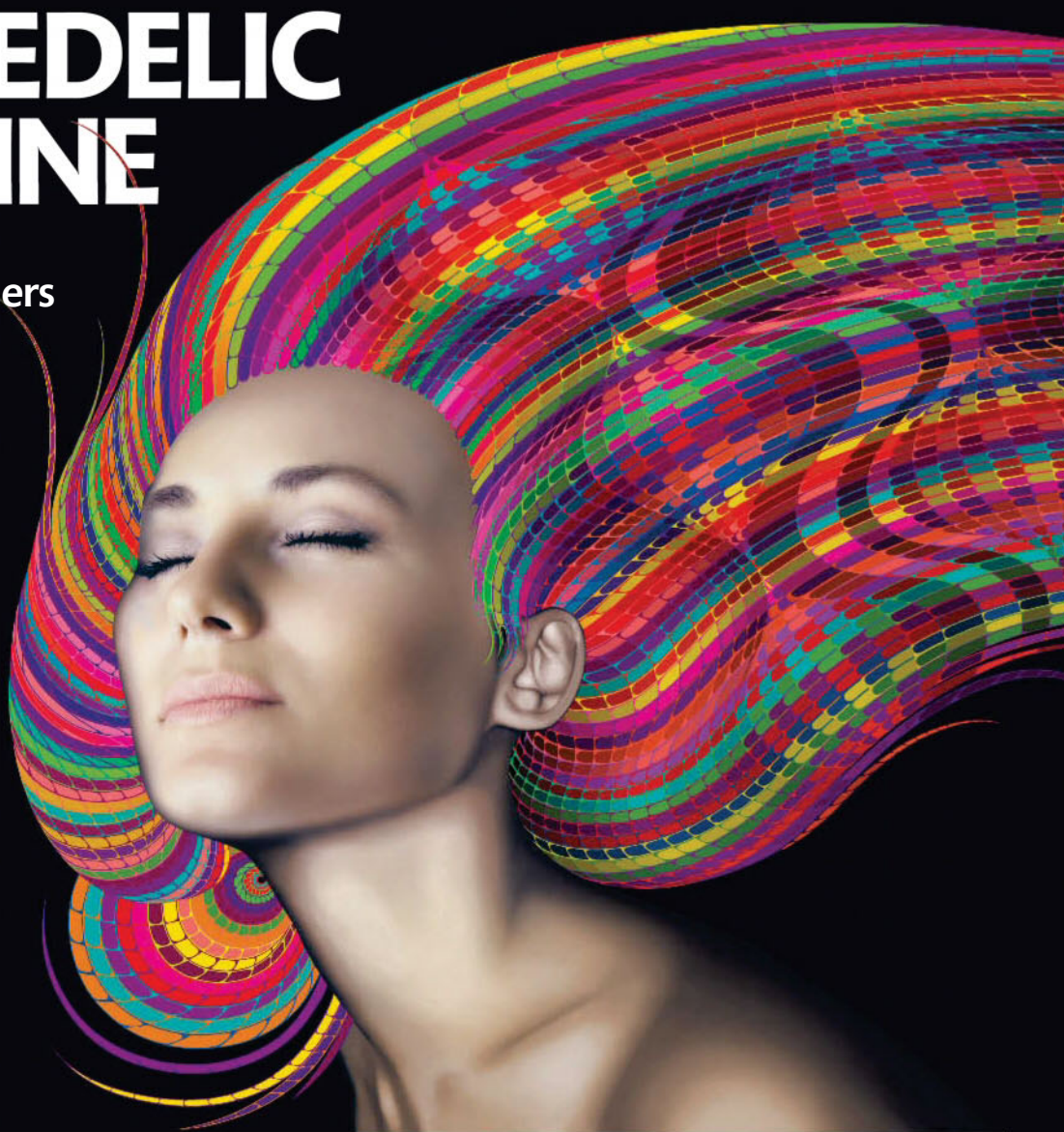

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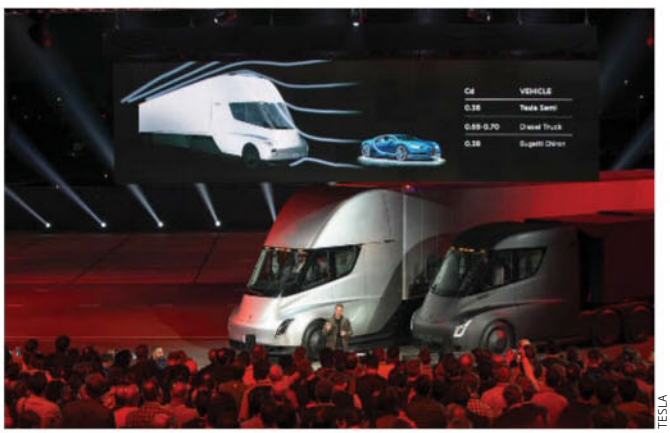

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The long trip to the clinic

Science, not politics, must decide the future of psychedelics

THERE'S an old joke in renewable energy circles: nuclear fusion is 30 years away, and always will be. This is slightly unfair, but it carries a whiff of truth. The breakthrough always seems tantalisingly close, yet never arrives.

If biomedicine has a nuclear fusion of its own, it has to be psychedelic medicine. Every few years, there is a surge in scientific interest followed by breathless proclamations of the long-awaited psychedelic renaissance. The story always follows the same arc: psychedelic therapy showed huge promise in the 1950s, was crushed by the establishment in the late 1960s and is now being revived by a group of fearless visionaries. In five years, 10 at the most, doctors will be routinely prescribing LSD, psilocybin, MDMA and other psychedelic drugs for a range of conditions.

New Scientist has not been immune to the hype cycle. In 2005, we ran a feature-length article about the imminent revival of psychedelic therapy. At the time, there were promising early results for a range of conditions including PTSD, obsessive-compulsive disorder and end-of-life anxiety. "It may not be long before doctors are prescribing hallucinogens," we said.

How long is long? Nearly 13 years on, none of these early trials has delivered on its promise.

The research goes on, however, and on the back of encouraging results from clinical trials and brain scans, scientists are again confidently asserting that psychedelics are on the verge of medical approval (see page 28).

So is it really different this time? We cannot know the future, but there are a number of reasons to believe that psychedelic medicine really can break out of its ghetto and into the mainstream.

"Scientists are again making confident assertions that psychedelics are on the verge of medical approval"

One is that the grey-suited establishment is more receptive than it was a decade ago. Back then, psychedelic research operated under a cloud, always scratching around for money and constantly butting up against onerous drug laws. But the times they are a-changin', with money flowing from mainstream sources and noises emanating from the US Food and Drug Administration and others about loosening the regulatory straitjacket. Can it be a coincidence that the people now occupying positions of power lived through the acid, ecstasy and shroom-fuelled youth culture of the late 80s and early 90s?

More still needs to be done. The law remains excessively tight: psychedelics are still schedule 1 drugs, which means they have no acknowledged uses in medicine. The onus is on scientists to show conclusively that they do.

Some of the scientists also need to embrace the system rather than pushing against it. Talk to many a psychedelics researcher and it doesn't take long to hear complaints of risk-averse funders and regulators. Enough. The outlaw-maverick pose was once an asset in this field; it is increasingly becoming a liability.

It may transpire that, as with so many drugs, the early promise melts away under the glare of full-scale clinical trials. Such is life in pharma research. What must not be allowed to happen is for these promising and much-needed drugs to fail for anything other than the purest of scientific reasons. ■

TRAN VU QUANG DUY/GETTY

Spreading like wildfire

Light pollution to double

ARTIFICIAL lighting is spreading fast. The area of the planet that is lit up grew by 9 per cent in four years. If that trend continues, the total illuminated area will double from its 2012 level well before 2050.

The light disrupts natural day-night cycles, harming our health and nocturnal animals, and further obscures our view of the night sky.

"Dark areas are being lost in places where nocturnal animals, insects and plants have adapted to darkness over billions of years," says Franz Hölker at the Leibniz-Institute of Freshwater Ecology and Inland Fisheries in Berlin.

Hölker, Christopher Kyba of the GFZ German Research Centre for Geosciences and their colleagues used satellite data to track changes in artificial lighting. From 2012 to 2016, the area illuminated and global brightness both rose by 2.2 per cent a year (*Science Advances*, DOI: 10.1126/sciadv.1701528). At that rate, "Earth's lit area could double in 32 years from 2012", says Kyba.

The brightening was fastest in rapidly industrialising countries in Asia, Africa and South America. Light pollution was more static in some heavily lit rich countries, such as the US. It only fell in war zones like Syria.

"The numbers are truly shocking," says Thomas Davies at the University of Exeter, UK.

Among the culprits are energy-efficient LED lights, brought in to cut greenhouse gas emissions. Because they are so cheap, installation of this lighting is more affordable and it is used even where not strictly needed.

Austerity deaths

DOES austerity kill? A landmark study of austerity policies found that 120,000 more people died in England between 2010 and 2017, following funding cuts to the National Health Service, than would have been expected if trends in death rates before the cuts had been maintained.

"If this effect continues, the team predicts a further 75,000 excess deaths could occur by 2020"

If this effect continues, the researchers predict that a further 75,000 excess deaths could occur by 2020 (*BMJ Open*, doi.org/cght).

After the financial crisis of 2008, annual funding increases for the NHS fell from 4 per cent a year to below inflation, even as a growing and ageing population increased demand for healthcare.

Jonathan Watkins of King's College London and colleagues found that after controlling for other economic changes, death rates rose after the cuts, especially among the over 65s.

The two events were statistically associated in time, which doesn't formally prove cause and effect, the team notes. But excess deaths correlated most closely with a lack of nurses in care homes and cuts to community nursing.

This is alarming given that a bad flu season is expected to strike the UK soon, and people over 65 are the most likely to die from flu. Cuts to nurses visiting people outside hospitals mean more people remain hospitalised longer, causing a shortage of hospital beds, which could make this flu season especially tough.

Radiation cloud

RUSSIAN authorities have confirmed reports of a spike in radioactivity in the air over the Ural mountains.

The Russian Meteorological Service said it recorded the release of ruthenium-106 in the southern Urals in late September and classified it as "extremely high contamination". France's nuclear safety agency earlier this month said that it recorded radioactivity in the area between the Volga river and the Ural mountains from a suspected accident involving nuclear fuel or the production of radioactive material.

At the time, Russia's state-controlled Rosatom corporation said there had been no radiation leak from its facilities. The Russian meteorological office's report, however, noted high levels of radiation in the villages adjacent to Rosatom's Mayak plant for spent nuclear fuel.

Mayak has denied being the source. Greenpeace said it would petition the Russian prosecutor general's office to investigate "a possible concealment of a radiation accident".

DRONEBASE/AP/REX/SHUTTERSTOCK

Oil leak

Keystone oil spill

NEBRASKA has given the OK for the controversial Keystone XL oil pipeline to run through the state – even though the existing pipeline sprang a leak last week.

On 16 November, the Keystone pipe spilled 5000 barrels of oil – nearly 800,000 litres – in South Dakota. Despite concerns, water supplies seem unaffected.

The Keystone pipeline is owned by TransCanada. It transports oil from Canada's tar

sands region to refineries on the Texas Gulf Coast, where the oil is turned into petrol and diesel.

The South Dakota spill came days before the decision on the controversial proposed extension to the pipeline, called Keystone XL. But it didn't affect the outcome. The Nebraska Public Service Commission chose on Monday to approve a route for the pipeline through their state.

A 2014 report found Keystone XL would boost global emissions of carbon dioxide by up to 110 million tonnes per year, by enabling crude oil to get to market that otherwise might not.

Saying no to coal

THE latest meeting to discuss action on climate change made modest progress, despite the US stating earlier this year that it will ditch the Paris agreement.

"It showed that the rest of the world is steadfast in its support for the Paris agreement, despite the backwards steps being taken by the federal government in the United States," said Nicholas Stern of the London School of Economics.

At the COP23 meeting in Bonn, Germany, last week, more than 20 governments called for a rapid phase-out of coal. The Powering Past Coal Alliance was led by the UK and Canada, which aim to phase out coal by 2025 and 2030 respectively. Other countries have not committed to a specific date.

Coal is one of the dirtiest fuels, in terms of carbon dioxide and other pollutants. However, CO_2 emissions from coal are falling: it is losing out to other energy types.

At the only official event held by the US, there were calls for "cleaner fossil fuels". This was widely condemned. "Promoting coal at a climate summit is like promoting tobacco at a cancer summit," said New York mayor Michael Bloomberg.

Enceladus mission

RUSSIAN billionaire Yuri Milner has set his sights on Saturn's moon Enceladus.

Milner founded the $100 million Breakthrough Starshot project, an attempt to send small probes to Alpha Centauri. Now, he has announced plans to explore funding a mission to Enceladus.

The icy moon is thought to be a prime location in the search for alien life thanks to the global ocean under its surface. Geysers spray its water into space, making it easier to sample for signs of life.

In 2015, NASA's Cassini spacecraft found molecular hydrogen in the plumes – a sign that there may be hydrothermal vents in Enceladus's ocean. On Earth, microorganisms cluster around such vents.

"Can we design a low-cost, privately funded mission to Enceladus which can be launched relatively soon, and that can look more thoroughly at those plumes, try to see what's going on there?" Milner asked the New Space Age conference in Seattle this week.

He says the mission would be a precursor to a costlier NASA mission that would take longer to get off the ground. NASA wouldn't reach Enceladus for at least another decade even if it is selected as a future target.

Hunting a missing submarine

A MASSIVE search-and-rescue operation is under way off the coast of Argentina. On 15 November, the ARA San Juan, an Argentinian military submarine, vanished with 44 crew on board. There is a good chance they are trapped but still alive. Teams from Argentina, Brazil, the US, the UK and France, among others, have now united to find them.

The search area could be thousands of square kilometres. But we do know some things. First, the sub is unlikely to be floating on the ocean surface: planes surveying the area with highly sensitive radar would probably have found the vessel by now if it were. Instead, it is most likely to be resting upright on the ocean floor. To stop subs rolling over, they are carefully ballasted with heavy equipment in their lower halves, says Jonty Powis, former programme manager of the NATO Submarine Rescue System project.

Rescue teams will use side-scan sonar to detect the San Juan, says David Shea of Kraken Robotics. This can produce detailed images of the ocean floor. "The advantage you have in that case is the submarine is a very large thing in comparison with other things on the seabed," he says.

The crew may only have until the end of this week. Their emergency water and oxygen supplies would normally last just a week. But by minimising their activity and movements, they could stretch these to 10 days.

REUTERS/MARCOS BRINDICCI

We are running out of time

60 SECONDS

A hole lot of crashes

The Laser Interferometer Gravitational-Wave Observatory has detected another pair of black holes colliding, and they're the lightest LIGO has seen yet. This pair smashed together about a billion light years away. At just 7 and 12 times the mass of the sun, the two merged, creating a black hole 18 times the mass of our sun.

Medicines go Dutch

Europe's medical gatekeepers are heading from London to Amsterdam as a result of Brexit. Nineteen countries vied to be the European Medicines Agency's new home. The agency now has until March 2019 to complete the move, and has said that a "large majority" of its 900 staff will happily relocate.

Do animals feel pain?

EU law recognises that animals feel pain and emotion. But UK law soon won't. The UK parliament voted against a clause in the EU Withdrawal Bill that would incorporate that recognition into UK laws after Brexit.

Ivory ban off and on

It is still illegal to import elephant trophies into the US. Donald Trump announced he was ending a ban on the imports of trophies – including ivory – from Zimbabwe and Zambia, which was enacted in 2014 by the Obama administration to combat poaching. Then Trump changed his mind and decided to keep the ban in place while he, belatedly, reviewed the facts.

Get in the mood

How emotional are you after a tipple? A survey of 30,000 drinkers from 21 countries found that 30 per of spirit drinkers felt their drinks made them more aggressive, versus 2.5 per cent of red wine drinkers. Only 20 per cent of spirit drinkers reported feeling chilled, versus half of those who drank red wine or beer (*BMJ Open*, doi.org/cghb).

You can defeat Alzheimer's

Clare Wilson discovers why some people can ward off dementia

RESISTANCE isn't futile, especially when it comes to Alzheimer's. Some people's brains can withstand the ravages of the disease by elongating the connections between brain cells – a process that seems to counter mental decline.

Now we need to understand why some brains can respond to the disease in this way and to see if the effect can be enhanced with medicines or lifestyle changes.

Alzheimer's disease, which causes memory loss and confusion, is the most common form of dementia. The condition is characterised by a build-up of a protein called beta-amyloid, which forms plaques between brain cells, and tangles of another protein called tau inside the cells.

A long-standing mystery is why some people have plaques and tangles in their brain at autopsy, yet were mentally sharp when they were alive. This resistance to Alzheimer's, seen in about a third of people who die without cognitive problems, is more common in those who stayed longer in education and had mentally demanding jobs. One idea is that intellectual stimulation builds a "cognitive reserve" – but it is unclear what physical form this takes.

"It's possible that the spines are reaching out to maintain the synaptic connections"

To investigate further, Jeremy Herskowitz at the University of Alabama at Birmingham and his colleagues studied brain samples from 41 people. They had either beta-amyloid plaques but no symptoms, plaques and symptoms, or no plaques or symptoms.

MADELINE GRAY/THE PALM BEACH POST/ZUMAPRESS.COM/ALAMY

Mental acuity plays a part

The team took close-up pictures of the samples, then used software to trace the physical shape of the brain cells and their connections, or synapses.

This technique allowed the team to visualise the first neuron of a pair that make up a synapse. This neuron sends out small buds known as spines, which connect with projections from other neurons – each synapse exists where a spine links to a projection. The spines of people who were Alzheimer's-resistant were longer than those from the other groups (*Annals of Neurology*, doi.org/cgfx).

Synapses are where signals pass from one neuron to another. The longer spines might make the synapse more effective in this role, says Herskowitz. Or new spines might be growing outwards to generate more synapses to replace those destroyed by plaques and tangles. "It's possible that the spines are reaching out to maintain the synaptic connections. They are putting themselves out there to catch a new one," says Herskowitz.

While striking, the finding may not be the only explanation, says Michael Valenzuela at the University of Sydney. Brain-imaging studies suggest that people who are resistant to Alzheimer's may compensate for damage by using different parts of their brain.

Nor, by itself, does it tell us whether there is anything we can do to reduce our risk. "What this work does not address is whether the unique properties of those who evaded dementia are genetically endowed, determined early in life, or malleable throughout life," says Valenzuela.

Animal research, on the other hand, hints that lifetime experiences can indeed ward off dementia. For instance, in mice genetically altered to develop a version of Alzheimer's, mental deterioration is delayed if they are kept in more interesting cages, with play tubes and boxes.

For now, standard advice to reduce dementia risk is to do things like talking with friends, learning a second language – or even just doing crosswords, as well as staying in good physical shape. ■

KEEP HEALTHY WITH A MENTAL WORKOUT

Could a brain-training game help prevent dementia?

Researchers at the University of South Florida gave 2800 people 10 training sessions across six weeks. Some people were taught memory tricks, others practised reasoning skills or received processing-speed training. A final group weren't given any intervention.

Of the 1200 participants assessed up to a decade later, those who did the processing-speed training were 29 per cent less likely to have dementia than those in the control group. The other kinds of training made no difference to dementia risk.

The jury is still out, however, since the correlation was judged as statistically very weak.

Robotic pump helps hearts keep beating

IT'S a pump that could bring your heart back to life. A lack of donated hearts often means people with heart failure die waiting for a replacement. But now a robotic device has been designed to help out with pumping duties to keep diseased hearts beating for longer. Nikolay Vasilyev at Boston Children's Hospital, one of the creators of the device, hopes it may even allow a full heart recovery, rendering a transplant unnecessary.

The device consists of an implanted semi-circular brace that hugs the diseased chamber, surrounding it with an inflatable sleeve. To keep it in place, it is anchored to the interventricular septum – a sturdy wall that separates the heart's two main chambers. When the sleeve inflates, it squeezes the diseased chamber to give it an extra boost while it pumps (*Science Robotics*, DOI: 10.1126/scirobotics.aan6736).

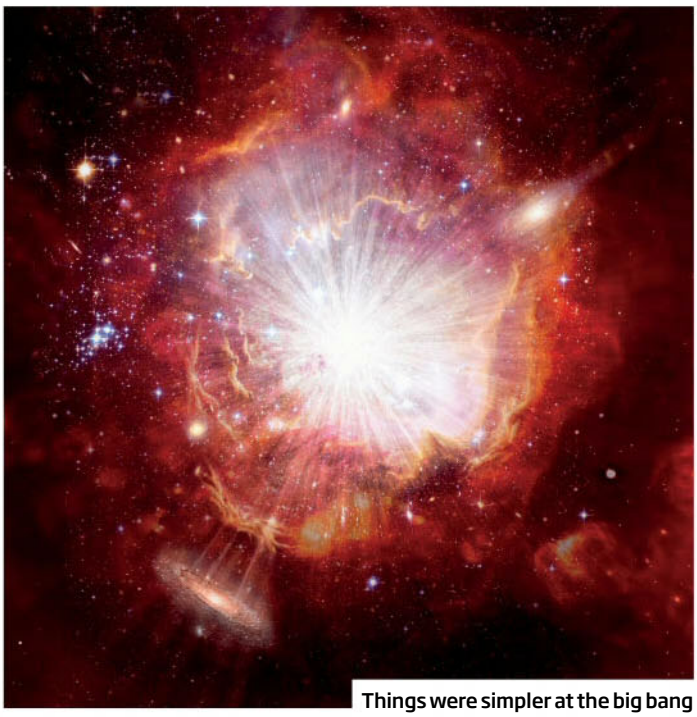
Other devices tend to bypass the damaged heart, and because they typically need to have blood flowing through them, anticoagulants are necessary to prevent the blood clotting. "With anticoagulant therapy, it's very hard to reach the balance between too much and not enough," says Vasilyev. Getting the balance wrong can lead to bleeding or clotting.

So rather than bypassing the heart, Vasilyev's robotic device utilises it. "Conceptually, it's a very straightforward and elegant idea: use the heart but simply give it an extra squeeze," says Peter Friend at the University of Oxford.

This forced exercise might do more than just keep the heart going. "We believe that this additional help will be enough for the heart to become healthy again in some circumstances," says Vasilyev.

"Heart failure is a huge health problem, but there is some evidence that it is a reversible condition," says Friend. Giving the ticker a hand during ticking just might be key to recovery.

Timothy Revell ■



HENNING DALHOFF/SCIENCE PHOTO LIBRARY

Things were simpler at the big bang

Three of the forces in the universe get reunited

JUST after the big bang, there was one force. As the universe cooled, it split into the four forces of today's universe: gravity, the weak and strong nuclear forces and electromagnetism.

To explain that, physicists have long been searching for a grand unified theory that combines everything except gravity into one force. Now, a new idea does just that, but without predictions that had jinxed earlier attempts.

Particle colliders have shown that electromagnetism and the weak nuclear force become one "electroweak" force at energies of about 100 gigaelectronvolts (GeV). This takes us to about a trillionth of a second after the big bang.

"But the question is 'what happened after one trillionth of a trillionth of a trillionth of a second after the big bang?'" says Bartosz Fornal at the University of California, San Diego. Would the strong nuclear and electroweak forces still have been united?

Fornal and Benjamín Grinstein, also at UCSD, have now built on an earlier idea called SU(5), but with a crucial tweak.

Proposed in 1974 by Howard Georgi and Sheldon Glashow, SU(5) says at the high energies of grand unification, all particles are represented by mathematical structures that can be thought of as pentagons and decagons. Each

"The question is what happened a trillionth of a trillionth of a trillionth of a second after the big bang"

side of a pentagon represents a fundamental particle such as a quark or a lepton. Mathematically, the pentagon's sides are identical, so there is no way to tell apart these particles. It is only when the universe cools that this symmetry breaks, shattering the metaphorical pentagon into pieces, each of which is either a quark or a lepton.

One side effect of SU(5) is that it predicts an extra interaction between quarks and leptons. This makes protons liable to decay.

But experiments that look for the radiation released by decaying protons have seen nothing. They put the lifetime of a proton at more than 10^{34} years, orders of magnitude more than what is predicted by SU(5).

To get round this, grand unified theories can incorporate supersymmetry, which doubles the number of known particles and can extend the lifetime of protons. But the Large Hadron Collider at CERN has seen no evidence of supersymmetry.

Now Fornal and Grinstein have added two structures to SU(5), one with 40 sides and another with 50 (arxiv.org/abs/1706.08535). These structures represent heavy fields, which help unify the electroweak and strong nuclear forces, and also prevent the proton from decaying. And it does it without resorting to supersymmetry.

Ilja Doršner at the University of Split in Croatia is impressed. But he says the theory can be refuted if proton decay is observed.

The next step is to see if the theory can explain why the mass of the Higgs boson is less than expected. Instead of doing the usual nip and tuck to make the Higgs's size fit their theory, Fornal says, there might be a way to do it by adding extra fields to the theory.

Such tweaks are sometimes needed to make the observed universe add up mathematically. The Higgs field itself was added to solve just such a problem – the origin of mass for all particles – and that turned out to be correct.

The pair also want to incorporate a candidate particle for dark matter into the theory, which would require a more general unified group of dark matter plus all the forces and particles we know. In that case, when the symmetry broke as the universe cooled, dark matter would have fallen out as a particle.

Anil Ananthaswamy ■

The blockchain to fix all blockchains

Amalia Illgner

THE blockchain revolution is struggling. The much-vaunted technology behind bitcoin promises to enable trusted transactions without intermediaries, so why have the overwhelming majority of new blockchain projects failed? One problem is that there is no longer a single blockchain: the past few years have seen an explosion of different proprietary versions.

Now a London start-up is adding yet another to the pile – but unlike its predecessors, this one is meant to connect them all. The creators of this meta-blockchain think it could restart the blockchain revolution.

Over the past few years, groups from governments to supermarkets have tried to make good on the promise of the blockchain. A real estate start-up recently completed the first home purchase on the blockchain and US supermarket Walmart is beginning to use it to verify the provenance of its groceries.

However, the different blockchains are not necessarily compatible. Walmart has heavily invested in its proprietary type – but its suppliers may migrate to any of a dozen others, all incompatible. This could be one reason why 92 per cent of 26,000 blockchain projects launched in 2016 are now defunct, as a recent analysis by consultancy Deloitte revealed. "The overall value of the blockchain system is limited if two parties can't transact or transfer assets," says blockchain specialist Tyler Welmans at Deloitte.

What is needed is some connecting technology that allows the movement of incompatible data across different blockchains – much the way TCP/IP made it possible for different systems to use the internet, enabling it to thrive.

Quant Network believes it has created the equivalent technology for blockchain, says Gilbert Verdian, co-founder of the company, which is filing a patent next week for what it calls the Overledger. He says this allows the same transmission and ordering of data over all current and future blockchains. "We can match data across any ledgers," says Verdian.

A version of this already exists for cryptocurrencies. Known as an atomic swap, it allows people to swap incompatible cryptocurrencies by assigning an exchange value. "The overledger seems to be a straightforward extension of the original atomic swap idea," says Emin Gun Sirer at Cornell University in Ithaca, New York. But instead of only supporting currencies as atomic swaps do, this works for any data that can be put on the blockchain.

Interoperability could come with its own problems, says Mark Staples at Australia's CSIRO. "Governance is particularly tricky, because two connecting worlds will likely operate under different policies," he says. Not everyone wants their blockchains to be open. A government might legitimately want to put a fence around its own information.

However, no one will be forced to sign up and for those who do, this is the first credible solution to a problem that has been called the holy grail of blockchain. ■

DAVE TACON/POLARIS/EYEVINE

It's like the tower of Babel in here

Brain zap changes your love of music

CAN'T stand the new Taylor Swift track? A quick jolt to the brain might change your mind.

Robert Zatorre of McGill University, Canada, and colleagues asked people to listen to pieces of music – some chosen by the 17 volunteers, others picked by the researchers – and rate how much pleasure each gave them. Participants also had the chance to buy the songs with their own money.

On two occasions, they made these decisions while having part of their brain targeted with transcranial magnetic stimulation (TMS). In the third trial, participants received a sham treatment in which the brain wasn't stimulated.

Using different forms of TMS, the researchers could excite or inhibit the dorsolateral prefrontal cortex. When it was excited, the participants liked the music more and were willing to spend about 10 per cent more to buy songs they hadn't chosen themselves, compared with during the sham session. When the region was inhibited, they liked the music less and parted with 15 per cent less cash (*Nature Human Behaviour*, doi.org/cgg9).

Previous studies have shown that applying TMS to the dorsolateral prefrontal cortex can modulate the release of the neurotransmitter dopamine in the striatum, a deeper part of the brain involved in reward processing. The striatum is active when we anticipate pleasure from music and during the peak experience of this listening pleasure.

"We could modulate the reward system so that it's more responsive to pleasurable stimuli"

Understanding how to manipulate these brain circuits could aid therapies for disorders that involve the reward system, says Zatorre. Apathy is a common symptom of depression and Parkinson's disease, leaving people unmoved by previously enjoyable experiences. "Part of therapy could be to enhance their well-being by modulating the reward system so that it's more responsive to pleasurable stimuli," he says. Sam Wong ■

Black holes eat stars and burp cosmic rays

WHITE dwarf stars shredded by black holes could explain showers of cosmic rays and neutrinos we see on Earth.

Our planet is bombarded by these subatomic particles, but no one knows where they originate. Now a team led by Daniel Biehl at Deutsches Elektronen-Synchrotron in Germany suggests that they could be formed by white dwarfs being torn apart.

"A tidal disruption event is what happens when a star gets too close to a black hole and the strong gravity tears the star apart," says team member Cecilia Lunardini at Arizona State University. "Part of the debris of the destroyed star falls into the black hole, and this causes the black hole to emit energy and accelerate particles."

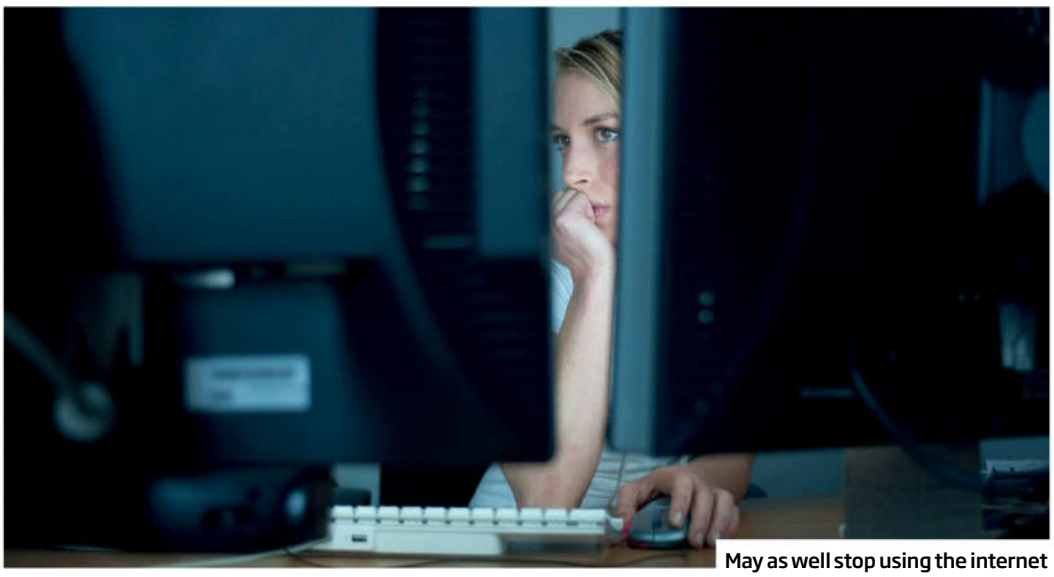
The researchers say both cosmic rays and neutrinos could be produced by the disintegration of nuclei torn from white dwarves and then accelerated in the jets of radiation and particles emitted by black holes (arxiv.org/abs/1711.03555).

Julian Krolik at Johns Hopkins University agrees it is a possibility. But it will take time and luck to observe such an event in a white dwarf, as only a small portion of black holes produce jets and have a white dwarf close enough to be affected.

We have an uncertain grasp of the mechanics behind how cosmic rays reach such high velocities, so it is unclear if black hole jets could be responsible. Although tidal disruption events were theorised decades ago, researchers have confirmed only a few observations. "The rate of these events for a white dwarf is even more uncertain than the rate of events involving ordinary stars," says Krolik.

This idea will only be confirmed if we see simultaneous observations of X-rays, which are indicative of a tidal disruption event, and incoming neutrinos from the same patch of sky, says Lunardini. Even then, other processes may be at work that also produce these high-energy particles.

Mika McKinnon ■



PLAINPICTURE/R. MOHR

May as well stop using the internet

The code that watches every word you type

HAVE YOU ever typed something into a search box on a website and then thought better of it? New research shows 482 sites may be passing on that data anyway.

We have long known that information we provide online can be tracked. Scripts running on websites deposit cookies or track you to other sites.

But these seem tame compared with what Steven Englehardt at Princeton University and his colleagues found after combing through hundreds of websites to examine the scripts they run: the widespread use of a type of script called a session replay, which logs everything you do on a website, including what you type before you hit "enter". It then sends this information to the third party that has placed the script there.

This can bypass traditional privacy measures like https, as while your connection to the site is secure, the third parties have been pre-authorised by the site to watch you there, and how they send the information they glean isn't guaranteed to be private.

The scripts themselves aren't new: they have long been used to show developers how customers react to website updates. As companies come under pressure to monetise their websites, the third parties offering such services have grown in number, says Lukasz Olejnik, a cybersecurity and privacy consultant based in London.

"The third party sites have been pre-authorised to watch you there and send the information on"

Scripts have become more widely used and gather more data.

Their ability to take any information no matter how private concerns Alan Woodward, a security researcher at the University of Surrey, UK. "Take passwords," he says. "These can be scooped up in the session scripts and sent to third parties."

Englehardt's team found session replay scripts running on 482 websites including US pharmacy Walgreens, which until recently used the third-party firm FullStory. The study was published on Princeton University's website, Freedom to Tinker.

"We take the protection of our customers' data very seriously and are investigating the claims made last week. As we look into the concerns that were raised, and out of an abundance of caution, we have stopped sharing data with FullStory," a Walgreens spokesperson told *New Scientist*. FullStory had not responded to a request for comment as *New Scientist* went to press.

While FullStory is explicit on its website that it doesn't sell data gathered in this way, others don't make such a clear guarantee. This kind of data has huge potential for targeted advertising and marketing, for example.

There are ways to protect yourself from sharing this kind of information, for example, only using sites you trust, and reading their privacy policies. However, reading all privacy notices on every site you interact with in a year would take 76 working days.

The only way to control the third-party firms is by regulation, says Olejnik. Third-party data-collection sites might need to change their practices after May 2018, when the EU General Data Protection Regulation enters into force and begins to clamp down on "disproportionate misuse of data without user consent".

Abigail Beall ■

Using bombs to bomb-proof cars

Paul Marks

WHEN an improvised explosive device (IED) detonates under a military vehicle, it is often not the blast that kills people inside – it is the extreme acceleration. But a new vehicle design in which rocket motors fitted to the roof exert a counterforce could save lives.

The idea isn't as mad as it may seem. The upward force of an IED blast can instantly catapult a vehicle many metres into the air. Although vehicle floors are strengthened to prevent debris hitting occupants, people often sustain serious or fatal internal injuries from the jarring acceleration, which causes damage to vital organs.

But what if you exerted an equal and opposite downward force at the moment of detonation? The possibility was always there – it is just a creative application of Newton's laws – but received military wisdom has held that an IED blast happens too fast to allow for countermeasures.

Yet when Roger Sloman was analysing ultra-high-speed video of a test detonation beneath an old Russian scout vehicle, he noticed something unexpected. Sloman, managing director of UK-based countermeasures company Advanced Blast and Ballistic Systems, realised that after the blast, the vehicle remained in place for a full 10 milliseconds before it began to move upwards.

Sloman set to work figuring out how to counteract the acceleration effects within that narrow time frame.

The system he developed instantly detects a blast using crush sensors in the vehicle's floor, then fires rockets on the roof that provide a downward force. He worked with Daniel Jubb at rocket maker Falcon Project in Buckinghamshire, UK, to develop and patent a wholly new kind of solid rocket motor that can fire within 3 milliseconds.

In tests in July, observed by the UK Ministry of Defence, an IED blew a Snatch Land Rover without the technology more than 5 metres into the air. But when a similar vehicle was fitted with two linear rocket motors (LRMs), the vehicle stayed on the ground.

"The peak thrust from all those rocket nozzles is insane," Jubb says – the two LRMs in the test made the vehicle momentarily weigh around 120 tonnes.

ABBS

Rocket-protected car

The research was presented last week at a conference on armoured vehicle protection in London.

Although IED incidents worldwide are declining, they are still increasing in Afghanistan, so US forces may see a need for the rocket motors. "This technology looks like it is going to be exceptionally useful," says Gregory Chambers, a former US Marine Corps armour specialist.

The LRMs could find other applications, too: downward-facing rockets fitted on helicopter skids could be used to cushion crash landings, Sloman says. This could be useful for some of the "flying car" projects being backed by Google and Uber. ■

New message to ET could get a quick reply

ARE you there, aliens? Earth, here. A radio message is winging its way to a neighbouring star system that could contain a potentially habitable planet. So close is the star that a reply is even possible within 25 years.

"I think that's an unlikely outcome, but it would be a welcome outcome," says Douglas Vakoch at Messaging Extraterrestrial Intelligence (METI) International, an offshoot of the more familiar Search for Extraterrestrial Intelligence. The target is Luyten's star, a red dwarf 12 light years away. In March, two planets were found there. One of them, GJ 273b, orbits within the star's habitable zone and could harbour liquid water, and perhaps life.

The message was sent on the anniversary of the Arecibo message, a radio transmission beamed towards a distant star cluster in 1974. That message held information on the planets of our solar system, the structure of DNA and a cartoon-like picture of a human being. The new message – beamed from Norway over a three-day period in October – is simpler and may be more readily understood, Vakoch says. It includes information about maths, details on the radio waves that carry the message and a tutorial on clocks and timekeeping, to see if any potential inhabitants of GJ 273b understand time as we do.

"It's like shouting in a forest before you know if there are tigers or lions or other dangerous animals there"

Intentionally sending messages to space is a controversial idea, even within the SETI community. First, it is far from clear who should speak for humankind. Another concern is the potential danger of reaching out.

"Ninety-eight per cent of astronomers and SETI researchers, including myself, think that METI is potentially dangerous, and not a good idea," says Dan Werthimer at the University of California, Berkeley. "It's like shouting in a forest before you know if there are tigers, lions and bears or other dangerous animals there." Dan Falk ■

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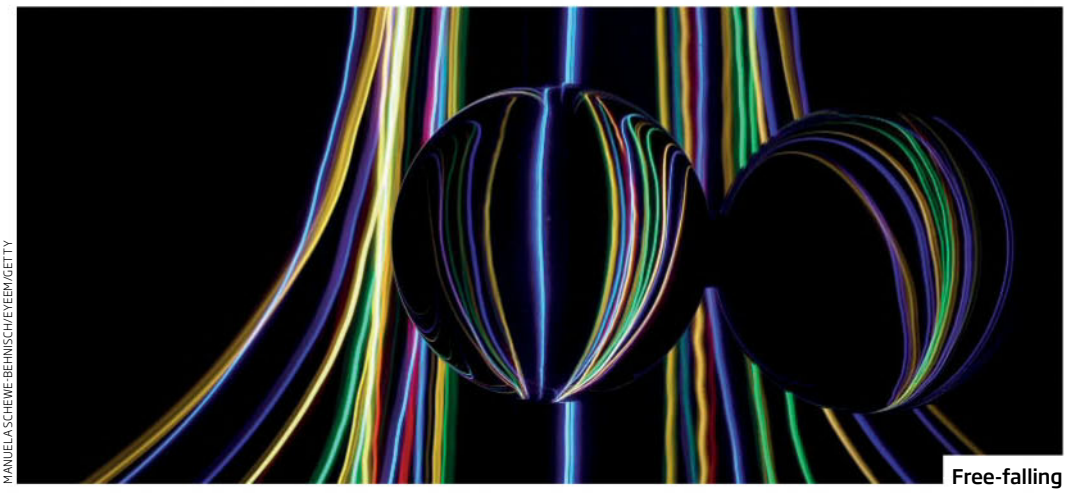

MANUELA SCHEWE-BEHNISCH/EYEEM/GETTY

Free-falling

Testing gravity's quantum nature

Anil Ananthaswamy

DESPITE decades of effort, a theory of quantum gravity is still out of our grasp. Now physicists have proposed an experiment to test whether gravity is quantum or not, thereby settling questions about the force's true nature.

At present, general relativity, which describes what we perceive as gravity, and quantum mechanics are both needed to explain what takes place inside black holes and happened at the big bang. But the theories have proved incompatible, leading to apparent paradoxes and things like singularities, where the theories break down.

If gravity is a quantum mechanical force, adjacent free-falling masses could get entangled by it. So, measuring the properties of one would instantly influence the other. To test this, Sougato Bose of University College London and his colleagues propose an experiment.

It starts with a neutral mass of about 10^{-14} kilograms containing material with a property called spin, which can be up or down. This mass falls through a continuously varying magnetic field that affects its path. It is like the mass encounters a fork in the road, taking one path if its spin is up and another if it is down. As the mass falls, it is in a superposition of states, being on both paths.

Next, a series of microwave pulses alter the spin of the mass – and thus its path – at various stages of descent. At the bottom, the paths reunite and the mass returns to its original state.

To test the quantum nature of gravity, two masses would be dropped. Each has two possible paths, so there are four possible states for the masses combined. One state represents the paths where the masses are closest. These should be at least 200 micrometres apart to avoid other interactions that can dominate gravity.

"The biggest hurdle to doing it for real would be putting such relatively large masses in a superposition"

Once the masses are back to their original state, a test to see if their spin components are entangled should tell us if gravity is indeed a quantum force (arxiv.org/abs/1707.06050). The assumption, of course, is that the experiment ensures there are no other ways the masses can get entangled – such as via electromagnetic interactions.

Even if entanglement isn't found, that wouldn't prove that gravity is classical, unless all other interactions that can destroy entanglement, such as collisions with stray photons or molecules, are definitively ruled out.

Antoine Tilloy at the Max Planck Institute of Quantum Optics in Germany is impressed with the mooted experiment, but says that a positive result would only eliminate some classes of theories of classical gravity.

A null result would be the most surprising outcome as it would mean gravity lacks quantum roots, says Maaneli Derakhshani of Utrecht University in the Netherlands. "This would then raise tough but interesting questions about how and when exactly gravity 'turns on' in the quantum-classical transition for ordinary matter," he says.

The biggest hurdle to doing the experiment for real would be putting such relatively large masses in a superposition. The most massive objects observed to be in two places at once are orders of magnitude smaller than what would be required. But efforts to go higher continue. ■

Clay sucks water into Earth's depths

WE MIGHT finally know how ocean-sized deposits of water hundreds of kilometres below Earth's surface are getting there. A form of clay, called kaolinite, might be soaking up water like a sponge and then carrying it deep underground.

Kaolinite accounts for 5 to 60 per cent of ocean sediments depending on the location. Now it seems it can act as an irrigation system for the upper mantle, the hot rock layer that extends from 10 kilometres beneath our feet to more than 400 kilometres. The kaolinite gets sucked down when an oceanic plate collides with continental crust and nosedives beneath it, a process called subduction.

Yongjae Lee of Yonsei University in Seoul, Korea, and his colleagues simulated the increasing pressure and heat the kaolinite encounters during the descent. They found that it can absorb huge amounts of water from the surrounding chunk of crust.

In kaolinite's "super-hydrated" form, water accounts for 29 per cent of its weight. This is the maximum it can carry, and happens at depths of around 75 kilometres, where the clay meets temperatures of 200°C and pressures of 2.7 gigapascals, more than 25,000 times that at sea level (*Nature Geoscience*, DOI: 10.1038/s41561-017-0008-1).

The huge water content is roughly twice the 14 per cent found in serpentines, previously the most water-rich minerals widely subducted into the mantle, says Jon Blundy of the University of Bristol, UK, who was not part of the research team.

Halfway through the upper mantle, about 200 kilometres down, where the temperatures top 500°C and pressures exceed 5 gigapascal, the clay starts to lose its water. It continues doing so until it reaches the bottom of the upper mantle.

"The researchers may have opened up a whole new potential water recycling route on Earth," says Blundy.

Andy Coghlan ■

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Endometriosis affects the brain

Jessica Hamzelou

ENDOMETRIOSIS may reprogram the brain to cause anxiety and depression, according to research in mice.

Endometriosis is caused by cells from the uterus lining, also known as the endometrium, moving elsewhere in the body. It affects 176 million women and can cause severe pain as well as infertility. But despite affecting 1 in 10 women of reproductive age, we know very little about it.

The pain probably partly explains why women with endometriosis are also at risk of depression and anxiety. But Hugh Taylor at Yale University and his team have been investigating whether some women develop mood disorders directly as a result of uterus cell migration.

Mice don't menstruate like people, so to mimic endometriosis, the team removed some of the mice's endometrial cells and implanted them into their abdominal cavities. A separate group of mice had a sham surgery, in which they were operated on but didn't have any endometrium moved.

When the team assessed the mice 12 weeks later, they found characteristic endometriosis cysts – balls of tissue filled with blood – in the abdominal cavities of the mice whose endometrial cells had been moved.

They then gave the mice a series of tests to examine their mental health. A standard test for mouse depression, for example, is to hold a mouse up by the tail. A healthy animal will squirm while a depressed one will flop. Another test involves putting a mouse in an enclosure with a wide open space – healthy mice will explore, while anxious animals will retreat to the darkest corners.

Across all of the tests, the mice with endometriosis cysts behaved differently to those that had sham surgery. "They had more anxiety and they were more depressed," says Taylor. "This was caused by the endometriosis."

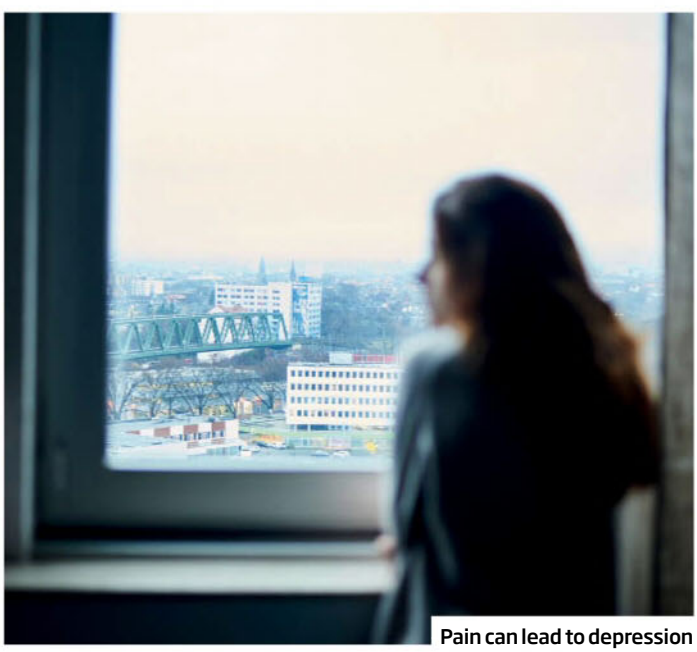
When the team compared the brains of the two sets of mice, they found that in those with endometriosis cysts, the activity of genes linked to anxiety and pain was different in regions known to be involved in pain and mood.

"We are showing that endometriosis reprograms the brain," says Taylor, who presented his findings at the American Society for Reproductive Medicine annual meeting in Texas last month. It isn't known yet how endometriosis might be having these effects.

Erin Greaves at the University of Edinburgh, UK, isn't convinced. She says the depression and anxiety experienced by women with endometriosis probably has more to do with the pain and infertility they experience.

But she agrees that endometriosis affects the whole body, not just reproductive organs. Her team has found that the condition causes changes in the brains and spinal cords of mice that make them more sensitive to pain.

Greaves hopes the work will encourage researchers to focus on pain. "Research in endometriosis has been significantly held up because the people who work [on it] are gynaecologists or scientists who work in reproductive health," she says. "Now, from our work and Taylor's work, we know there are changes in the central nervous system." ■



PLAINPICTURE/MIELEKT

Pain can lead to depression

Dark matter may be sending us positrons

A BAFFLING number of antimatter particles stream past Earth, and their origin has been a mystery for years. Now a team has killed off one of the leading hypotheses for their origin, increasing the likelihood that the explanation relies on dark matter, the mysterious stuff making up 27 per cent of the cosmos.

The favourite of the two main explanations was that the positron excess could come from fast-spinning stellar remnants known as pulsars. Their powerful magnetic field lines accelerate electrons to high speeds, causing them to collide with photons, which split into pairs of electrons and positrons. Two nearby pulsars, called Geminga and PSR B0565+14, were identified as possible sources.

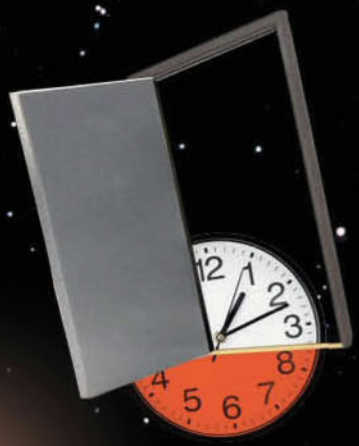
The second, more exotic hypothesis was that the excess is a by-product of the annihilation of dark matter particles. That's an exciting prospect given that we have yet to directly detect dark matter and therefore remain unclear on what it actually is.

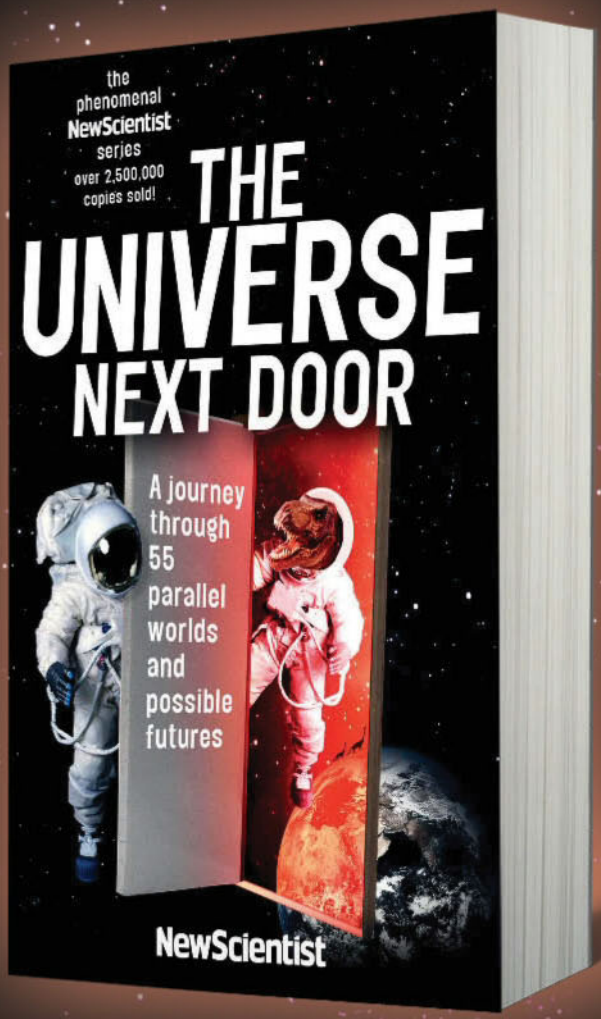
Now, after nearly a decade, an international team using the High-Altitude Water Cherenkov Gamma-ray Observatory in Mexico has measured the positrons emanating from those two nearby pulsars and found they couldn't account for the surplus reaching Earth (*Science*, 10.1126/science.aan4880). "It's a breakthrough," says Joseph Silk at Johns Hopkins University in Maryland. He says the work nudges the answer towards dark matter, which had fallen out of favour recently. "The dark matter community has more directions to explore – that's the upshot," he says.

"Pulsars may not make the antimatter streaming past Earth. We now have more of a mystery than before"

It could still be that other undetected pulsars explain the positron excess. And there are other astrophysical sources, like supernova remnants, that might also produce the positron excess, says Hao Zhou at Los Alamos National Laboratory in New Mexico. Regardless, "we now have more of a mystery than we had before", says Silk. Shannon Hall ■

WHAT IF **TIME** STARTED FLOWING BACKWARDS?





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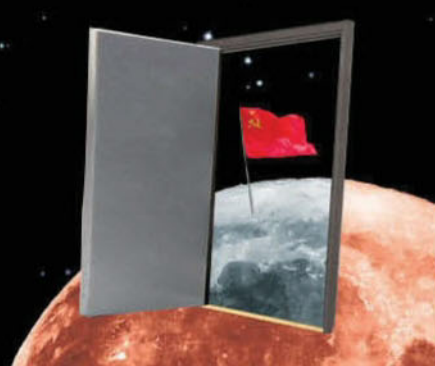

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Amish gene can make them live 10 years longer

A GENE variant seems to be enough to make people live 10 years longer, and protect them from diabetes.

The gene is called *SERPINE1*, and is known to code for a protein that promotes ageing. But a faulty variant of this gene arose six generations ago in an Amish group, causing the people who carry one copy of the variant to produce half as much of the protein.

Douglas Vaughan of Northwestern University, Chicago, and his team have now studied the gene in 177 members of the Old Order Amish community in Berne, Indiana. Of these, 43 people carried at least one copy of the variant.

The team analysed their DNA, as well as other signs of ageing, such as insulin resistance. They also worked out which of 221 dead relatives would have carried the gene variant, and analysed how long each of them lived.

They found that people who carried at least one copy of the gene variant lived, on average, 10 years longer, dying at the median age of 85 (*Science Advances*, doi.org/cgch).

People with the gene variant also had 30 per cent lower levels of insulin when fasting – a sign of slower ageing. None of the carriers of the variant developed diabetes, while 7 per cent of those without the variant did. "The carriers appear to be completely protected from diabetes," says Vaughan.

Drugs that target the protein are already being developed, including one that might alleviate baldness.

A female fly can ruin your drink

A SINGLE fly in your glass of wine may be enough to spoil it.

Female fruit flies produce a pheromone to attract males. When Peter Witzgall and Paul Becher at the Swedish University of Agricultural Sciences in Uppsala isolated this pheromone, they wondered if it explained an anecdote about a fly changing the taste of wine just by landing in it.

The team enlisted a panel of eight wine tasters and asked them to examine glasses of wine. Some glasses had previously contained a female fly for 5 minutes, some had held a male and others had no contact with flies. The tasters all rated wines in the glasses that had contained female flies as having a stronger and more intense smell.

And in glasses of Pinot Blanc that had been tainted by female fruit flies or trace amounts of pheromone, the tasters found the taste "somewhat unpleasant" when as little as 1 nanogram of the pheromone was present (doi.org/10.1101/206375).

This suggests that even if you quickly remove a fly, it may already have spoiled your wine.

"The compound is not only detectable in tiny amounts, it's also hard to wash off, which means that the smell might even stick to glass after dishwashing," says Becher.

An AI scarecrow to scare elephants

A HUNGRY elephant is normally too big, tough and smart to deter, so can devastate crops and even end up being killed by humans. But a new AI scarecrow could help.

It can detect and identify pests, before responding intelligently with the right combination of sound or light. Each of these "sentinels" has a library of startling and scary noises: predator sounds, animal alarm calls, irritating tones and self-generated noises. Teams of the devices can protect large areas.

In tests earlier this year in Gabon, the scarecrow worked. "Elephants usually turn and escape as quickly as possible back the way they entered," says Ashley Tews of Australia's national research organisation CSIRO, which developed the system.

The team now plans to try it in Australia to tackle other clever agricultural pests, including wallabies and dingoes.

Pluto's haze keeps it so very cold

PLUTO is around 30°C colder than expected, thanks in part to the shielding effects of a sooty haze around the dwarf planet.

On Pluto, ultraviolet light from the sun breaks apart gas molecules like nitrogen and methane to create reactive ions. These recombine to create monomeric hydrocarbon molecules, which then stick together to form soot.

Xi Zhang at the University of California at Santa Cruz and his team calculated that the particles can absorb about 1 to 5 per cent of incoming solar energy, with the rest reflected back by Pluto's surface (*Nature*, doi.org/cgbz). This could be confirmed by the James Webb Space Telescope, which launches in 2019.

Blue tits dump late mates

BLUE tits ditch their partners if they turn up late to the breeding season.

Like about 85 per cent of birds, blue tits are socially monogamous, meaning they form couples and share the workload of raising their young. But they often break up.

To find out why, Carol Gilsenan at the Max Planck Institute for Ornithology in Munich, Germany, and her colleagues studied over 100 breeding pairs for eight years. The birds were microchipped to identify when they visited 277 nest boxes.

There were advantages to sticking together: couples that mated in consecutive years laid eggs a day earlier, had 0.5 more eggs and produced 0.7 more fledglings on average. Yet only 20 to 50 per cent of couples stayed together from one year to the next.

Unlike other birds, this didn't seem to be linked to their previous breeding success or other suitors.

Instead, most splits seemed to be caused by a partner arriving later than the other. If a bird had to wait more than three days for its partner, it was five times more likely to find a new one (*Animal Behaviour*, doi.org/cgft).

"For a species with high mortality like the blue tit, it makes sense to pair with a new mate rather than waiting around," says Anne Peters at Monash University in Melbourne, Australia.

BLICKWINKEL / ALAMY STOCK PHOTO

Spiders have evolved wildly out-of-sync body clocks

SOME species of spider have such short biological clocks it is as if they are jet-lagged by more than 5 hours every morning. Yet they seem to feel no ill effects.

Orb-weaver spiders build webs to catch prey. They are active at night, building a fresh web during the pre-dawn hours. To study their rhythms, Darrell Moore of East Tennessee State University and his team recorded the activity patterns of different orb-weaver species. The spiders were placed in glass tubes in darkness and monitored by infrared sensors.

Three species had biological clocks averaging just 17.4, 18.5 and 19 hours. Two had slow clocks, averaging 28.2 and 28.5 hours, and one had no internal clock at all.

"We've never seen a circadian clock remotely like this," says team member Natalia Toporikova of Washington and Lee University in Virginia.

The team then tried advancing or delaying daylight by 6 hours. The spiders adjusted within 24 hours. Other animals would be out of sync for about a week.

The pressures that maintain 24-hour circadian rhythms in most species have loosened in these spiders, says Moore. Their shorter rhythms may help them weave webs before dawn, avoiding being eaten by birds. The findings were presented at the Society for Neuroscience meeting in Washington DC last week.

"Shorter periods are great for getting up earlier for early food sources," says Sigrid Veasey at the University of Pennsylvania. "If food comes out right at dawn, it is likely important to get up early enough to build a fantastic web."

Nearby exoplanet could host life

A NEWLY discovered planet orbiting a nearby star could be the closest habitable world to us. The Earth-sized planet, named Ross 128b, is just 11 light years away. It is thought to have a relatively mild climate, with temperatures from an icy -60°C to a balmy 20°C. That could mean it has oceans or lakes in which life may have evolved.

The planet orbits close to a cool and dim red dwarf. Such stars are usually prone to deadly eruptions of ultraviolet radiation and X-rays, so nearby planets are likely to be severely irradiated, casting doubt on whether life could survive there. But Ross 128b's star is much less volatile than typical red dwarfs. Even though the planet orbits quite near its star, its surface probably receives only about 1.4 times more radiation than Earth.

It is still unclear where Ross 128b lies in relation to its star's habitable zone. Since the planet doesn't pass between its star and Earth, it is difficult for us to study it in more detail and find out. It could be an oasis for life. Or it could be a sweltering hellscape more like Venus, or a frozen wasteland like Neptune, with no liquid water.

NASA

Why is Jupiter's Great Spot red?

WE MIGHT know what gives Jupiter's Great Red Spot its colour. The hue may be formed by radiation from space splitting molecules in the planet's clouds, which then combine to form red compounds.

Mark Loeffler at Northern Arizona University irradiated ammonium hydrosulphide, commonly found in Jupiter's atmosphere, with high-energy protons that mimic radiation coming from the sun.

This produced particles that were green when the sample was held at -113°C and reddish when cooled to between -123°C and -223°C, looking redder as they got colder (*Icarus*, doi.org/cgb3). Clouds on Jupiter are about -145°C.

Last year, Robert Carlson at the Jet Propulsion Laboratory in California produced reddish material, which he says more closely matches the red spot, by irradiating ammonia and acetylene with ultraviolet light. When blended with white clouds, it matches shades of red seen across Jupiter's surface.

The final ingredient may be reddish organic molecules called tholins, found on Pluto and other cold or icy bodies in the solar system.

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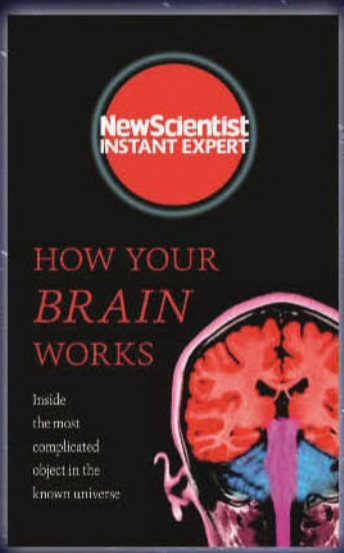

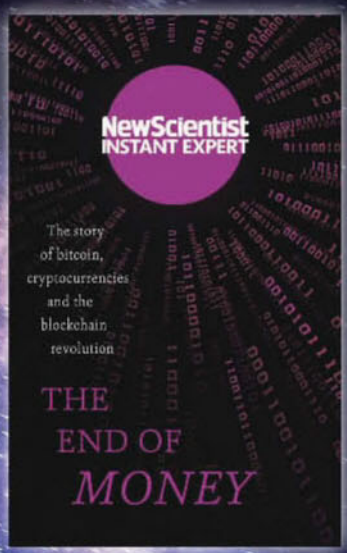

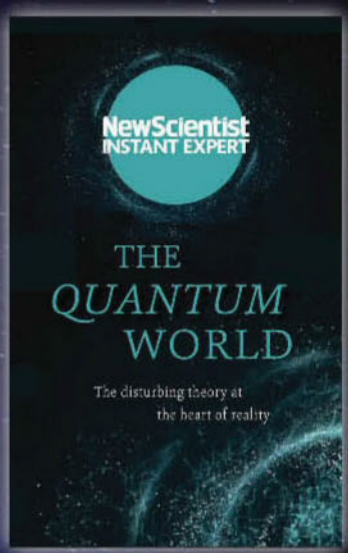

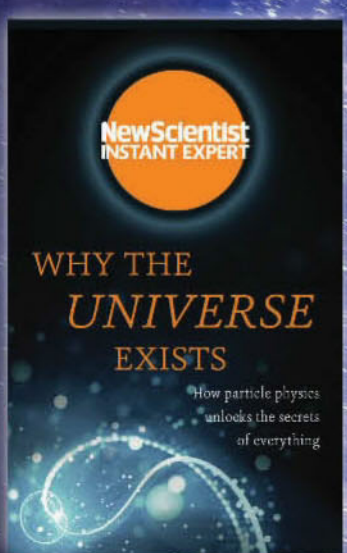

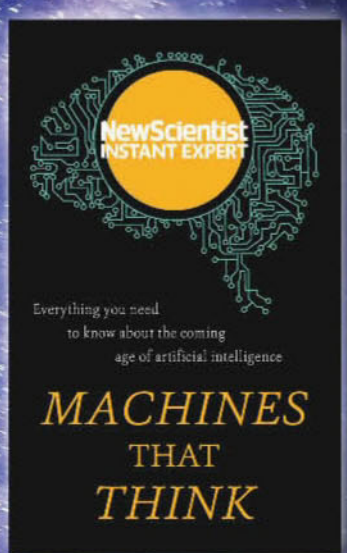

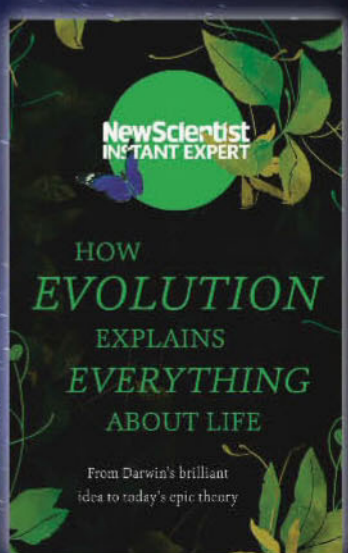

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Death of the gas guzzler

Tesla's electric trucks will speed the transition from fossil fuels, but we must curb road freight too, says **Michael Le Page**

ELECTRIC cars used to be a joke – the ugly, expensive option for wealthy tree-huggers. But thanks to companies like Tesla, they are now sleek, desirable and increasingly affordable.

With the car revolution already under way, Tesla and other manufacturers are turning to heavier vehicles. Last week, Tesla CEO Elon Musk unveiled his all-electric truck, the Tesla Semi.

Just a few years ago it seemed unlikely that diesel's dominance in heavy vehicles could ever be challenged. Now the question is how long the transition away from diesel will take – and whether it will deliver the massive and rapid reductions in emissions we so desperately need to limit global warming to 2°C above pre-industrial levels.

Road transport produces around 4 gigatonnes of carbon dioxide a year, about a sixth of annual greenhouse gas emissions, and this could triple by 2050.

There is wide agreement that it is time to start phasing out cars with internal combustion engines. A few countries even intend to ban the sale of petrol and diesel vehicles – Norway plans to do it as early as 2025.

"Road transport produces around 4 gigatonnes of carbon dioxide a year, and this could triple by 2050"

Cars are the easy part, however. Around 40 per cent of road transport emissions come from freight. To reduce these, we need electric trucks to really take off.

But there is a fundamental problem. The further you want to go in an electric vehicle, the more batteries you need. These are big and heavy, so the more your truck has, the less cargo you can haul.

Large trailer-pulling trucks – known as big-rigs or semi-trucks – can carry a load of 20 tonnes for around 1400 kilometres on a single tank of diesel. To travel that far, an electric truck would need a 25-tonne battery pack and could haul only 4 tonnes, calculates battery researcher Venkat Viswanathan at Carnegie Mellon University in Pennsylvania.

This makes the practical range much shorter. A prototype heavy-duty electric truck unveiled by engine maker Cummins earlier this year can haul a 22-tonne trailer, but has a range of just 160 kilometres unless a diesel generator is added on. Tesla claims the Semi, pictured right, can haul 36 tonnes – including the weight of the truck – up to 800 kilometres.

Tesla didn't announce a price for the Semi, but it is likely to be eye-watering. A diesel semi-truck costs $120,000. For an electric truck with a 500-kilometre range, the battery pack alone would cost $200,000, says Viswanathan.

This is why many are expecting the industry to stick with diesel in the short term. "We don't see yet how big changes can happen there," says Zita Marko Daatland, head of energy market analysis at Norwegian energy company Statoil.

But maybe oil companies should be worried. For starters, not all heavy vehicles need a long range. Daimler – the world's biggest commercial vehicle manufacturer – began delivering its new all-electric light truck

ERIC RAPTOSH PHOTOGRAPHY/PLAINPICTURE

Big polluters

this year, with a 3-tonne payload and 100-kilometre range. Parcel delivery company UPS was the first customer. "Short-haul trucks are already taking off," says Viswanathan. "This space will explode very soon."

Partly-electric garbage trucks also hit the streets of Sonoma County, California, last year. The trucks have an electric engine, made by Wrightspeed, along with batteries and a generator that can be powered by diesel or gas to extend the range of the trucks.

Wrightspeed claims the savings are so great that no one will buy a diesel-engine garbage truck after 2021. That may be marketing hype but there are big advantages to going electric. The most compelling is that it is much cheaper per kilometre – less than half the cost of diesel in the US.

Maintenance is also cheaper as there are fewer moving parts in electric engines to go wrong. The downside is that batteries are still very expensive and may have to be replaced after a few years, depending on usage.

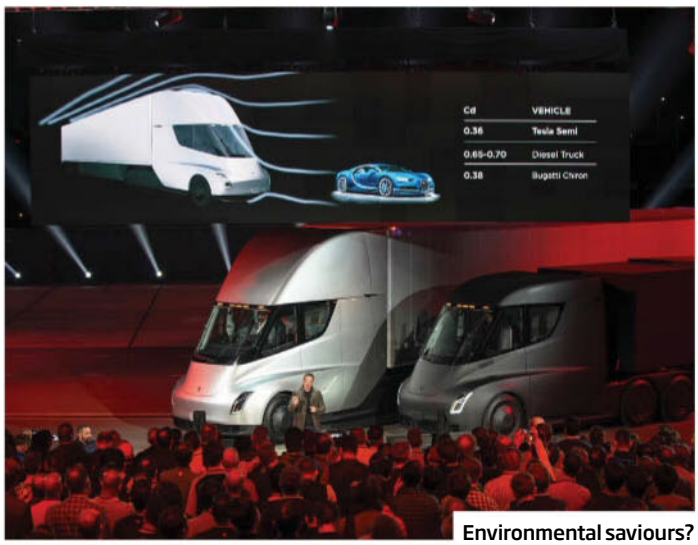
"The maintenance cost of electric is negligible," says Viswanathan. "The upfront costs are prohibitive."

Get trucking

Nikola Motor Company in Utah thinks it can solve both the range and price problem. It plans to produce electric semi-trucks powered mainly by hydrogen fuel cells rather than batteries, to give a range of 1200 kilometres.

But it isn't going to sell these hybrid trucks outright. Instead, from 2021 it will lease the trucks to customers, charging them per mile of use. Nikola will build the trucks, the hydrogen stations and even make the hydrogen on-site from grid electricity. The company has already signed contracts worth $6.5 billion, says CEO Trevor Milton. "We are booked out for 10 years."

Milton doesn't think purely electric trucks can compete in the long-haul business for the foreseeable future. He says the energy-to-weight ratio of batteries needs to increase by a factor of 10 or 20 to make them competitive.



TESLA

Environmental saviours?

The hydrogen fuel cell approach could work where trucks ply the same routes over and over again, says Viswanathan. But building hydrogen stations is far costlier and more difficult than building charging stations, so he doesn't think it will take off widely.

The good news is that advances in batteries could make all-electric long-haul trucks competitive with diesel far faster than generally thought, says Viswanathan. The energy-to-weight ratio of batteries only needs to double, he thinks. At the current rate of progress, that could happen in a decade.

Tesla is also relying on automation to help make all-electric trucks competitive sooner than this. The Semi will be capable of platooning – travelling nose-to-tail in convoys to reduce drag, with the following trucks driving themselves. Viswanathan calculates that platooning could produce energy savings of up to 15 per cent, allowing trucks to carry more cargo or travel further on the same batteries.

The Semi is only semi-autonomous – it can stay in lane by itself, for instance – but fully self-driving trucks could cut costs even further by eliminating drivers, travelling a little slower and by recharging when electricity is cheapest – which is likely to be when the wind blows or on a cloud-free day. "I think these technologies will be enormously important for improving range and battery life," says Viswanathan.

"The maintenance cost of electric trucks is negligible, but the upfront costs are prohibitive"

It's tough to predict what will happen, says Jason Roycht of engine maker Robert Bosch. His firm has a lot invested in diesel, he says, but will also be making the electric engines for Nikola. As economies of scale kick in, the price of electric vehicles could fall sharply.

Even with all these innovations, it seems unlikely that the switch will deliver big reductions in greenhouse gas emissions anytime soon. Take Norway, for example. It is leading the way when it comes to switching to electric cars, but it will still fail to meet its 2030 targets for cutting transport emissions, says Hans Jakob Walnum of the Western Norway Research Institute. "In the short term it's going to be nearly impossible to meet those targets."

One reason is that road freight has been increasing strongly. And because road freight is still very closely linked to economic growth, neither Norway nor the European Union plan to limit its overall growth. That leaves improvements in efficiency as the main way to reduce emissions.

The flaw with this approach, says Walnum, is the "rebound effect": improvements in energy efficiency may deliver big savings at first but encourage increased usage that then swallows up some of the gains. When the cost per kilometre of carrying freight falls, for instance, the end result is that more freight gets hauled further. "You get these very long supply chains," he says.

Going electric won't entirely solve this problem, at least not in the short term. For starters, even if electric trucks are a success, it is still likely to be several decades before most diesel juggernauts go the way of the dinosaurs. Electric cars have a big head start but will still only make up a third of the global fleet by 2040, Bloomberg New Energy Finance estimated earlier this year.

And while electric vehicles are often described as zero-emission, they are really only low-emission: there are emissions from their manufacture, and from the fossil fuels used to generate much of the electricity that powers them. If overall road freight keeps growing – perhaps boosted by technologies such as autonomous driving – that growth could offset some or even all of the savings made from going electric. Electric vehicles produce some air pollution, too.

This matters, as to have any chance of limiting warming to near 2°C, we need to be cutting emissions by more than 5 per cent per year. If governments are serious about limiting climate change, they need to find ways to limit road freight growth in the short term, such as a high carbon tax or more support for rail freight. Hoping Elon Musk will solve all of their problems isn't the answer. ■

A welcome measure

Scotland's policy to see off cut-price alcohol can finally take force. It's a victory for the nation's health, say **John Holmes** and **Petra Meier**

SCOTLAND will become the first country to introduce minimum unit pricing for alcohol after its government won a legal battle last week. The aim is to cut the deaths and disease associated with heavy drinking, and the huge pressure this puts on public services.

The policy links the price of wine, beer, cider and spirits to alcoholic strength. The 50 pence minimum unit price will mean a beer with two units of alcohol must cost at least £1, and a bottle of wine with nine units £4.50.

More pertinently, the price of a 3-litre bottle of strong white cider, which has 22.5 units and costs just £3.59, would rise to £11.25, bringing into question the survival of these products in Scotland. Alongside low-cost, high-strength lagers and cheap white spirits, these ciders are disproportionately bought by the heaviest drinkers and have helped to fuel alcohol problems

in Scotland and across the UK.

It is a welcome end to a fight that began in 2012 when the Scottish government legislated for a minimum unit price. The alcohol industry, led by the Scotch Whisky Association, launched legal action to block it. Its view that the policy is disproportionate was rejected by the UK Supreme Court.

This will save lives. Our team has long studied alcohol pricing. We estimate that a 50p minimum unit price in Scotland will cut alcohol consumption by 3.5 per cent, leading to 120 fewer deaths, 2000 fewer hospital admissions and 3500 fewer crimes a year. Importantly, those gains are felt most in heavy drinkers of lower socioeconomic status – those most harmed by drinking.

Critics will complain about restricting choice and pricing out poor people. If only it were that simple. People are bad at taking

One comeback too far?

In a Spotify world, why would anyone want to reprise flimsy tape cassettes, asks **Paul Marks**

ONE morning in 1965, Rolling Stones guitarist Keith Richards awoke to find that the night before in a stupor he had created the memorable riff to one of the band's biggest hits.

"I had no idea I'd written it, it's only thank God for the little Philips cassette player," he recalls. "I'd put a new tape in the previous night, and saw it was at the end. I pushed rewind and there was *Satisfaction*." That recollection neatly frames the convenient magic that made the tape cassette a hit: as the first compact, easy-to-use way to record and play back sound, it was a revelation.

That convenience peaked in 1979 with the launch of the Sony Walkman wearable player.

Since then, solid-state and streamed music playback has finished the job of steamrollering tape that CDs started. Yet some feel there is magic left in the cassette. And so, like vinyl, they are hoping to fuel a revival.

Behind this is what's billed as the world's last cassette maker, National Audio Company of Springfield, Missouri. With stock dwindling, and its South Korean supplier no longer making raw

"To many, the word cassette brings back bad memories of precious tapes getting snagged in players"

tape, it had to act, not only to fuel bands like Metallica that still use cassette, but also a growing number of indie bands who want to do likewise. So it bought machines once used to make magnetic strips for credit cards to repurpose for making tape.

To many of us, the very word "cassette" brings back angst-ridden memories of painstakingly made mixtapes getting snagged in players, forcing us to tease out the tangle and wind the tape back up, hoping not to ruin it. Surely it's a welcome goodbye to all that?

Not necessarily. Music on tape has a unique, vital sound and record labels are picking up on

into account potential future consequences when making decisions, particularly when it comes to use of an intoxicating and addictive substance.

What's more, alcohol doesn't only harm drinkers. In England, the National Health Service spends about £3 billion of taxpayers' money each year on treating alcohol-related diseases and injuries, while alcohol-related crime, drunken disorder and work absence affect us all. And then there are less obvious problems including domestic violence, child neglect and family breakdown.

The Scottish victory is symbolic, but the public health community hopes it will open the floodgates. Wales, Northern Ireland and Ireland were awaiting the court decision before advancing their own minimum pricing policies. Meanwhile, in England, the idea is still "under review", probably until evidence emerges of the policy's impact in Scotland.

Ultimately, it is encouraging that a new public health measure has withstood fierce opposition from a powerful industry.

Scotland's policy is a first. We're confident it won't be the last. ■

John Holmes and **Petra Meier** are at the Sheffield Alcohol Research Group, University of Sheffield, UK

that. Encoding audio as varying magnetic fields, as tape does, is bound to give a different quality to other methods. As a former drummer, its vitality was brought home recently when I played a tape of a 1977 rehearsal. It still had astonishing clarity and presence.

One more good thing: saving the cassette could help protect another old invention from the digital juggernaut: the pencil. You see, there's nothing better for winding a tape back into a cassette than the sharp end of a six-sided stick of wood and graphite. ■

Paul Marks is a science and technology writer based in London

INSIGHT Gene drives

BUCKWINKEL/ALAMY STOCK PHOTO

Possums: loved and loathed

We must take great care wiping out pests

Michael Le Page

NEW ZEALAND is considering using genetic "extinction" drives to tackle invaders such as rats, possums and stoats. These gene drives are essentially genetic parasites that can spread and wipe out populations.

But leading gene drive researchers are calling for caution. They argue that no country should tackle invasive species in this way unless these can be certain the drives won't spread beyond that country's borders (*PLOS Biology*, doi.org/cgcb).

Possums, for instance, are protected species in neighbouring Australia, so it would be a disaster if a possum-killing gene drive was deliberately or accidentally introduced there. Instead, conservationists should release only smart gene drives that cannot spread in other countries.

Natural gene drives have been around nearly as long as life itself. There is normally a 1 in 2 chance that a specific piece of DNA inherited from one of our parents is passed on to any one of our children. But gene drives can cheat. They copy and paste themselves from one chromosome to the other, matching chromosome, so all offspring inherit them. In theory, they can spread to every single member of a population.

In 2014, Kevin Esvelt, now at the Massachusetts Institute of Technology, and colleagues outlined how the gene editing technique CRISPR could be adapted to make artificial gene drives. These, they said, could reverse pesticide and herbicide resistance in insects and weeds, and control damaging invasive species, as well as preventing diseases spreading.

Several CRISPR-based gene drives have now been created. A team at Imperial College London is carrying out lab tests of some designed to combat malaria. Other teams are testing gene drives that make all mouse offspring male. This approach could be used to wipe out invasive species like rats.

"Conservationists should not rush to release gene drives until we can be sure they are safe"

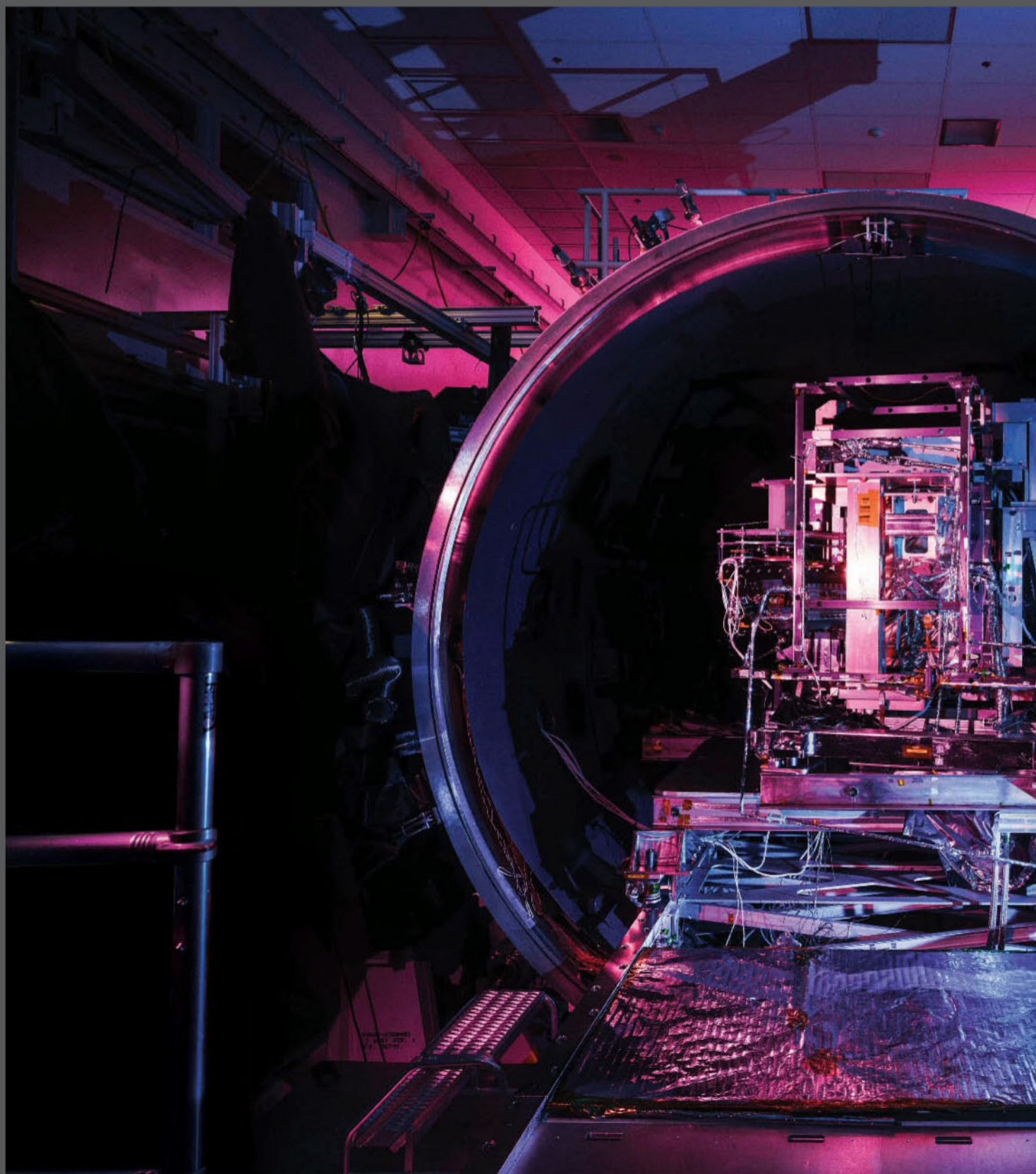
But it was a mistake to talk about what was technically possible without discussing the social and diplomatic barriers, Esvelt now says. "This misled many conservationists, who are desperately in need of hope, to falsely believe that gene drives might be used to humanely remove invasive species without much risk of international spread." He now thinks that gene drives without some inbuilt safety system should only be used with international agreement.

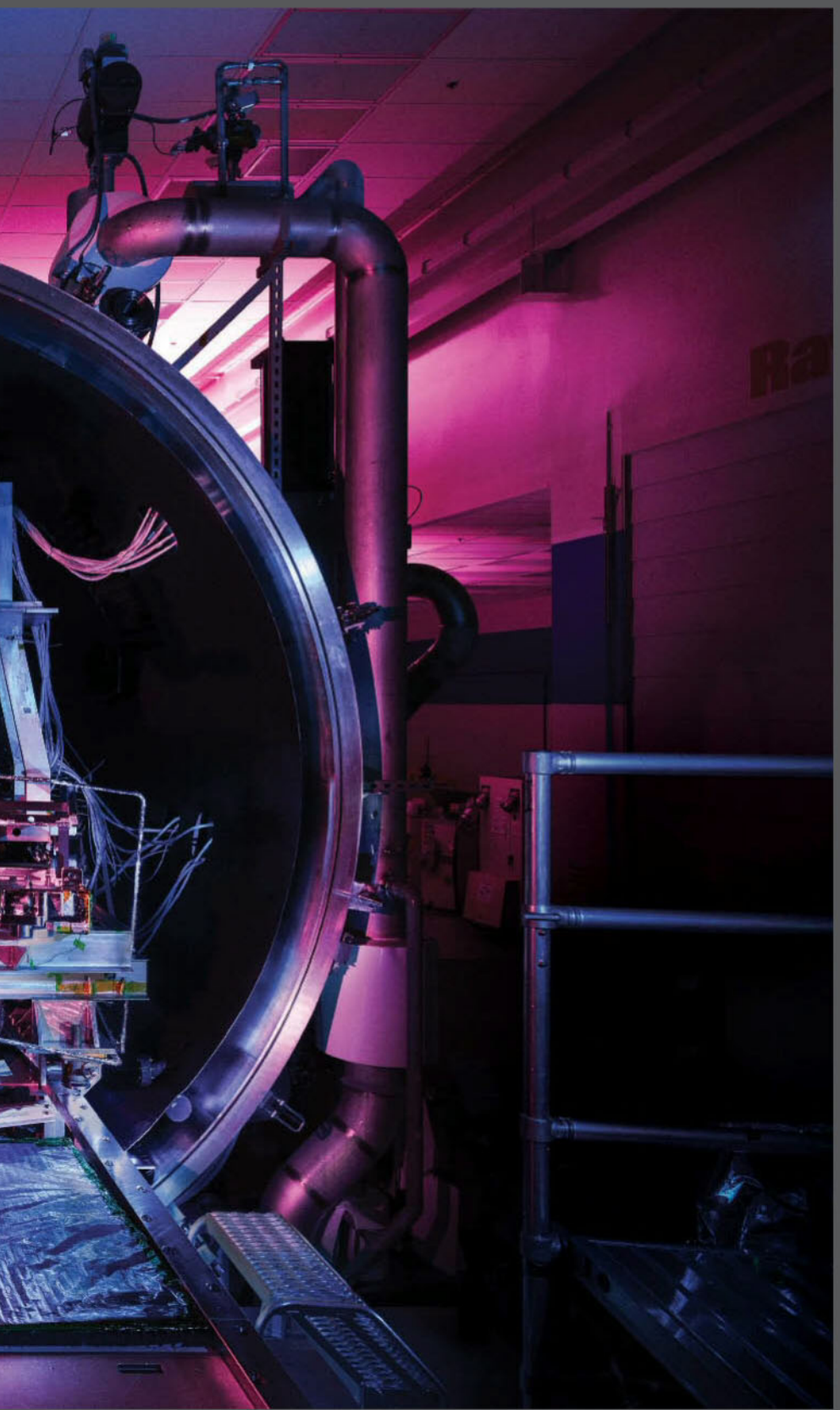
Because worldwide spread could result from the release of just a few individuals, the team say, gene drives should not be developed nor field-tested in areas where the host organism is found – contrary to the recommendations of a recent report by the US National Academies of Science.

There are potential solutions. Last year, Esvelt's team outlined a design for a self-limiting gene drive that vanishes after a few generations. This could be safely tested and used without risking uncontrolled spread.

Another approach would be to look for gene variants specific to invasive populations in particular regions or countries, and design drives that only target these variants.

Conservationists should not rush to release gene drives until we can be sure they are safe, Esvelt says. They have enormous potential for tackling diseases and pests, so it would be a profound tragedy, he says, if an incident with a hastily introduced gene drive led to the entire technology being shelved. ■





Purple rain

ON 18 November, this behemoth of a scientific instrument was launched into orbit so it could look down on Earth to monitor its climate.

Called a Visible Infrared Imaging Radiometer Suite (VIIRS), it takes pictures of our planet in infrared and visible light for a variety of purposes, including to measure the temperatures of the sea and atmosphere, to watch how ice and water move, and to analyse the vegetation level on Earth's surface. In making these measurements, it can help spot forest fires, forecast the weather and even determine how many phytoplankton are in different areas.

It was launched on the JPSS-1 satellite, which also carries four other instruments trained on Earth. The satellite will orbit the planet seven times a day in order to provide two full pictures of the globe every 24 hours.

JPSS-1 is the second of five planned satellites that will make up the Joint Polar Satellite System of orbiting Earth observatories. The last one is scheduled to launch in 2031.

Aside from climate science, the JPSS programme also aims to help those in the maritime and agricultural industries by predicting ocean currents, winds and severe weather events like hurricanes and floods. It will also be used to monitor how much total sunlight is reaching Earth's surface. Leah Crane

Photographer

Reuben Wu
reubenwu.com

Reopen your mind

Psychedelic drugs are transforming the way we think about mental illness, says **Sam Wong**

HE WASN'T the first person to say it, and he probably won't be the last, but Tom Insel's accusation carried extra weight thanks to his job title: director of the US National Institute of Mental Health. Towards the end of his 13-year tenure, Insel began publicly criticising his own organisation, and psychiatry in general, for its failure to help people with mental illness. "There are great examples in other areas of medicine where we've seen innovation really make a difference," says Insel. "Not so much for patients with schizophrenia, post-traumatic stress disorder or depression."

It's hard to argue. Mental illness has reached crisis proportions, yet we still have no clear links between psychiatric diagnoses and what's going on in the brain – and no effective new classes of drugs. There is one group of compounds that shows promise. They seem to be capable of alleviating symptoms for long periods, in some cases with just a single dose. The catch is that these substances, known as psychedelics, have been outlawed for decades.

A psychedelic renaissance has been feted many times, without ever delivering on the high hopes. But this time feels different. Now there is a growing band of respected scientists whose rigorous work is finally bearing fruit – not only in terms of benefits for patients, but also unprecedented insights into how psychedelics reset the brain. If the latest results stand up to closer scrutiny, they will transform the way we understand and treat mental illnesses.

The idea that psychedelic drugs might be used to treat mental illness emerged in the 1950s, a decade or so after Swiss chemist Albert Hofmann first described his experiences of taking LSD. By the mid-1960s, roughly 40,000 people had been given LSD as part of treatments for all manner of mental illnesses, from obsessive compulsive disorder to addiction, depression and schizophrenia.

It looked like we were onto something. Then psychedelics escaped the lab and took off among the counterculture. The backlash meant that by 1970, they had been banned in the US, Canada and Europe. Research ground to a halt.

In the meantime, treatment for depression, the most common mental illness, came to be dominated by drugs called selective serotonin reuptake inhibitors (SSRIs), which boost levels of the neurotransmitter serotonin in synapses by blocking its reabsorption by neurons. Their success in early trials fuelled the idea that depression is caused by a deficiency in serotonin. But recently, this idea has been called into question, as more and more studies suggest SSRIs aren't as effective as we thought.

"The psychedelic revival is finally bearing fruit with a series of startling results"

That comes as no surprise to many psychiatrists. Despite their ubiquity – 8.5 per cent of people in the US take them – SSRIs work for just 1 in 5 people. Even when they do work, there are problems, not least that coming off the drugs brings severe side effects. The picture is no less grim for other mental illnesses: there is a chronic shortage of new treatments and precious few ideas about where fresh options might come from.

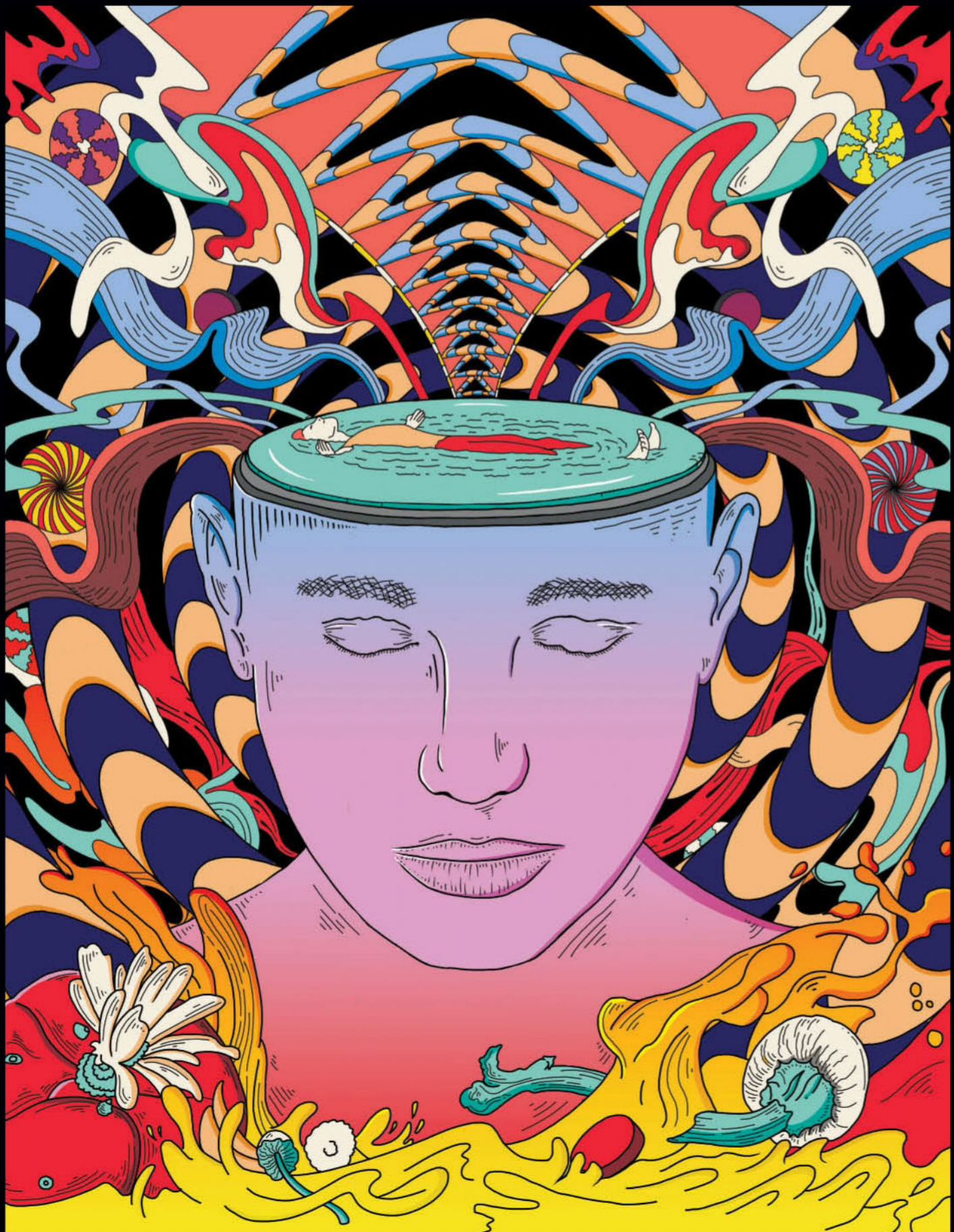
That's part of the reason why a psychedelic revival has always been so tantalising. The first push came in the late 1990s, driven primarily by a US non-profit called the Multidisciplinary Association for Psychedelic Studies (MAPS). After a few individuals were determined enough to go through the arduous process of getting approval to work with psychedelics, the US Food and Drug Administration (FDA) decided to treat psychedelics like other drugs, meaning researchers were not banned from working with them.

Two decades later, those efforts are finally paying off. The psychedelic renaissance is entering a new stage, with a series of startling insights gracing the pages of leading journals and clinical trials making progress.

MDMA, better known as the party drug ecstasy, is the furthest along. Although not a classic psychedelic in that it doesn't induce hallucinations, MDMA works by flooding the brain with serotonin, which makes users feel euphoric. These mood-altering effects are the reason researchers became interested in using it as a tool to assist psychotherapy for people with post-traumatic stress disorder (PTSD).

PTSD will affect roughly 7 per cent of people in the US at some point in their lives. The most effective treatment involves memory reconsolidation. People are asked to recall traumatic events so that their memories of them can be stripped of fearful associations by processing them in a new way. The problem is that recall can sometimes be so terrifying that they have to stop receiving this form of therapy. MDMA appears to help, not only because it extinguishes anxiety and stress, but also because it triggers the release of oxytocin, ›

SHARM MURUGIAH



a pro-social hormone that strengthens feelings of trust towards therapists.

Last year, at the Psychedelic Science 2017 conference in Oakland, California, a group led by Michael Mithoefer at the Medical University of South Carolina presented results from trials in which 107 people with PTSD underwent a psychotherapy while under the influence of MDMA. A year or so after having the therapy, roughly 67 per cent of them no longer had PTSD, according to a measure based on symptoms such as anxiety levels and frequency of nightmares. About 23 per cent of the control group, which had psychotherapy and a placebo drug, got the same benefit.

Healing trip

That convinced the FDA to give the nod for Mithoefer's group to carry out further trials involving more participants, the last hurdle to clear before the drug can be approved. In fact, the FDA was so impressed that it granted MDMA "breakthrough therapy" status, which will accelerate the path towards approval. If all goes well, it could be in use as soon as 2021.

If recent results are anything to go by, however, true psychedelics – those that induce hallucinations – might end up having the biggest impact on mental health. That's because psilocybin, the active ingredient in magic mushrooms, is beginning to look like the real deal: a genuinely effective, long-lasting treatment for depression.

It started in 2006, when Roland Griffiths, a psychiatrist and neuroscientist at Johns Hopkins University in Baltimore, replicated the results of a notorious study from 1962. He showed that a large dose of psilocybin can induce mystical experiences in volunteers without any mental health problems, including feelings of ego dissolution, a sense of revelation, ineffability and transcendence of time and space. Fourteen months after taking the drug at Griffiths's lab, 22 of the 36 participants said the experience improved their well-being or life satisfaction, and rated it as one of the top five most meaningful experiences of their lives.

It was a landmark study. As Solomon Snyder, also at Johns Hopkins, wrote at the time: "The ability of these researchers to conduct a double-blind, well-controlled study tells us that clinical research with psychedelic drugs need not be so risky as to be off-limits to most investigators."

In a double-blind study, neither the researchers nor the participants know who is receiving the experimental treatment. It is tricky to do with drugs like psilocybin because the hallucinations they induce mean volunteers know they aren't taking a placebo. But Griffiths and his colleagues got around the problem by using a placebo that induces a slight stimulating effect to trick recipients into think they got the active drug.

INSOOK GARDINER / ALAMY STOCK PHOTO

Figuring that psychedelic experiences would be particularly valuable to people confronting a terminal illness, Griffiths and others began trials designed to assess the safety and efficacy of psilocybin to treat anxiety in people with advanced cancer. In the largest of those, Griffiths recruited 51 volunteers. Half of them were given a small placebo-like dose during one session, then a high dose five weeks later. For the other half, the sequence was reversed.

"These substances seem to unlock the brain's ability to remodel itself"

The results were published last year. There was a marked reduction in depression and anxiety symptoms compared with placebo after the high-dose session, and for 80 per cent of them those benefits continued to be felt six months later. An associated study at New York University reported similar results.

Meanwhile, Robin Carhart-Harris, a neuroscientist at Imperial College London, has been working with people with depression that has resisted all available treatments. In a trial involving 20 people, participants had two sessions – one on a single low dose of psilocybin (10 milligrams), one on a single high dose (25 mg) – during which they each separately lay listening to specially chosen music, accompanied by therapists.

The findings, also reported last year, were impressive. Those two doses, combined with the psychological support, were sufficient to lift depression in all 20 participants for three weeks, and to keep it at bay for five of them for three months.

That is in stark contrast to the best available antidepressants. "What's weird and so different about these [psychedelics] is that we're talking about a single dose having long-term effects," says Insel, now at a start-up called Mindstrong. "That's a remarkably different approach to what we've been doing, with drugs that people take chronically."

Hints as to why psychedelics work so quickly and so enduringly have come from brain scans. Since 2010, Carhart-Harris has used functional magnetic resonance imaging (fMRI) to scan the brains of people without mental illness while they are experiencing the effects of different psychedelic drugs. He has found that LSD and psilocybin both cause activity in parts of the brain that normally work separately to become more synchronous, meaning the neurons fire at the same time. In addition, connectivity across a collection of brain regions called the "default mode network", which is linked to our sense of self,

AP/REX/SHUTTERSTOCK

Antidepressants (left) don't work for 1 in 5 people. Psychedelic therapy (right) might be more effective

or ego, is drastically reduced. The more this network disintegrates, the more volunteers report a dissolving of the boundaries between themselves and the world around them.

Carhart-Harris thinks psilocybin therapy interrupts the spirals of rumination and negative thoughts that depressed people get caught up in. In that sense, it seemed telling that people in his psilocybin-for-depression trial who experienced aspects of a spiritual or mystical experience saw a bigger decrease in their depression scores than those who didn't.

To see what effect the drug had, however, Carhart-Harris and his colleagues scanned the brains of their participants before and after they received psilocybin-assisted therapy. Contrary to expectations, the integrity of the default mode network, meaning the extent to which neurons across its separate brain regions fire together, had increased one day after therapy. What's more, the magnitude of this effect correlated with the extent to which the volunteers' depression had lifted.

Since the volunteers weren't scanned during the acute drug experience, interpreting this result requires a bit of speculation, but Carhart-Harris sees this as a "reset process". "You take something that's ordered, but pathologically ordered perhaps; you shock it and scramble it and then it returns, but it returns to a healthier mode," he says.

For Carhart-Harris, this trick of unlocking the brain's ability to remodel itself, known as plasticity, is what makes psychedelics so unique and valuable. The effect isn't intrinsically therapeutic, he says, but when combined with psychotherapy it appears to have an unparalleled capacity to alleviate mental illness or behavioural problems.

Back to the future?

And the insights gleaned by peering into the brains of the people who volunteered for his psilocybin trial don't end there. Participants were shown pictures of happy and frightened faces as they lay in the fMRI machine. The amygdala, a part of the brain that deals with emotions, including fear, typically lights up in response to such stimuli. SSRIs dampen those responses. But after the combined psilocybin-psychotherapy session, the amygdala lit up. And again, this effect correlated with how well people did: the greater the response in the amygdala, the more their symptoms improved.

This suggests a profound change in the processing of emotions, which fits with what participants reported in interviews. While SSRIs blunt both positive and negative feelings, it seems psilocybin does the opposite, helping people reconnect with their emotions. Those may not always be positive, but the idea is that connection with emotions is better than numbness.

The usual caveats apply, of course: all of these studies are relatively small and Carhat-Harris's recent trial lacked a control group to directly contrast with those taking psilocybin.

"One needs to be cautious," says Paul Summergrad at Tufts University in Boston, who is a former president of the American Psychiatric Association. "The history of psychiatry and medicine is full of things people get excited about that don't play out."

If larger studies produce similarly compelling outcomes, however, the implications would be profound. "The conversation now with psilocybin and MDMA is very different than what we've had with the development of other antidepressants and anti-anxiety drugs," says Insel. "We're now talking about psilocybin-assisted therapy,

"Some doctors have gone rogue, offering illegal psychedelic treatments"

meaning that it's not just about the chemical but the role the chemical can have in a psychotherapeutic experience," he says.

For Insel, the fact that they are psychedelics is irrelevant. "I'm excited to think that there might be compounds that could be used in a new way to give us something that will make a difference for people who haven't received much assistance from the drugs we have."

So what now? The short answer is more trials. UK firm Compass Pathways plans to conduct a placebo-controlled psilocybin trial in 400 people with depression across eight European countries in the next year. Griffiths is also preparing for a placebo-controlled trial, and Carhart-Harris is planning one to compare psilocybin with a leading SSRI.

One problem is that drug development is an eye-wateringly expensive business. In preparation for MDMA being licensed for PTSD, however, MAPS has set up a public benefit corporation that will market the drug and use the profits to push through other promising psychedelics.

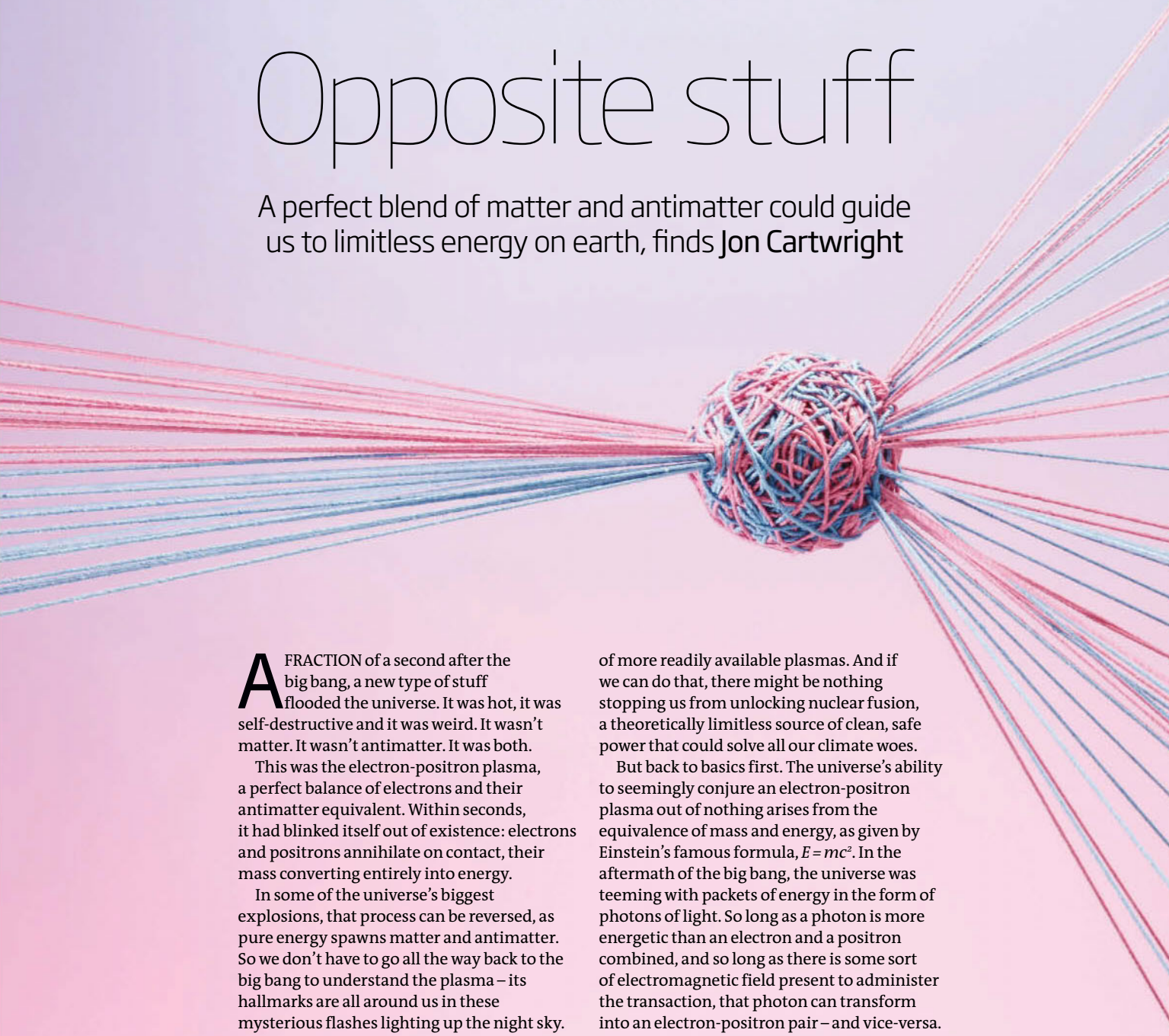
The biggest danger now might be that history repeats itself. The first wave of psychedelics research was to a great extent doomed by excessive enthusiasm. Today, as the revival has gathered steam, some doctors have likewise grown impatient and gone rogue, offering their patients underground psychedelic treatments. Hence the current crop of researchers are at pains to preach patience and rigour.

Insel put it more bluntly at last year's Psychedelic Science conference: "Don't screw this up." ■

Sam Wong is a reporter at *New Scientist*

Opposite stuff

A perfect blend of matter and antimatter could guide us to limitless energy on earth, finds **Jon Cartwright**



A FRACTION of a second after the big bang, a new type of stuff flooded the universe. It was hot, it was self-destructive and it was weird. It wasn't matter. It wasn't antimatter. It was both.

This was the electron-positron plasma, a perfect balance of electrons and their antimatter equivalent. Within seconds, it had blinked itself out of existence: electrons and positrons annihilate on contact, their mass converting entirely into energy.

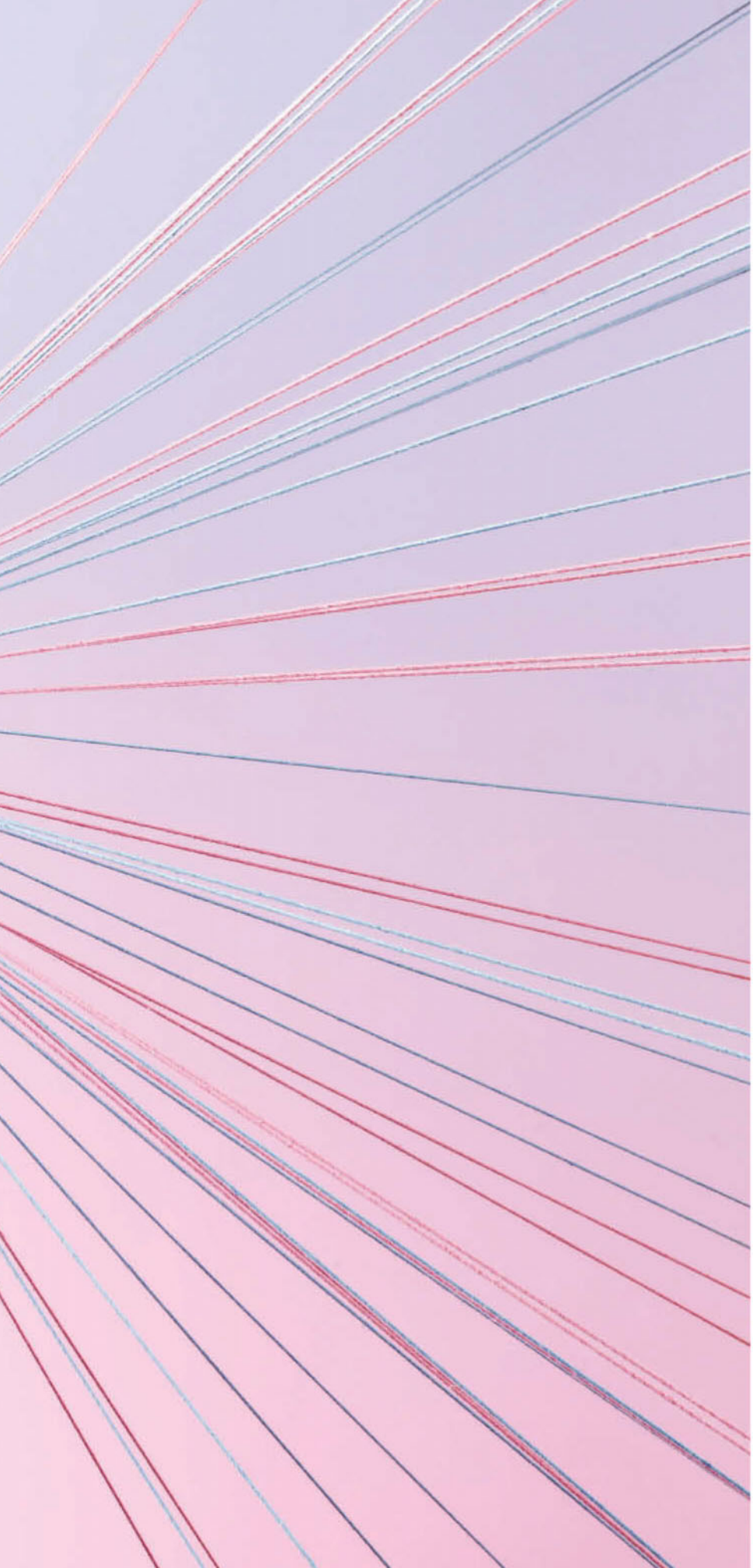
In some of the universe's biggest explosions, that process can be reversed, as pure energy spawns matter and antimatter. So we don't have to go all the way back to the big bang to understand the plasma – its hallmarks are all around us in these mysterious flashes lighting up the night sky.

Just recently, too, we've gone one better, replicating in the lab what normally takes place in an exploding star. That's no trivial undertaking, and raises the question of why we would want to. The reason is that the unique qualities of an electron-positron plasma makes it the ideal test bed for understanding the fundamental workings of more readily available plasmas. And if we can do that, there might be nothing stopping us from unlocking nuclear fusion, a theoretically limitless source of clean, safe power that could solve all our climate woes.

But back to basics first. The universe's ability to seemingly conjure an electron-positron plasma out of nothing arises from the equivalence of mass and energy, as given by Einstein's famous formula, $E = mc^2$. In the aftermath of the big bang, the universe was teeming with packets of energy in the form of photons of light. So long as a photon is more energetic than an electron and a positron combined, and so long as there is some sort of electromagnetic field present to administer the transaction, that photon can transform into an electron-positron pair – and vice-versa.

The electrons and positrons brought into being after the big bang didn't stick around for long. They cooled and then mostly turned back into photons, allowing protons and neutrons to bind into the first atomic nuclei and producing a gigantic flash of light.

What we've become increasingly confident about over the past decade or so is that this



STEPHEN LENTHALL/GALLERY STOCK

plasma-to-energy conversion is still happening today, inside slightly less big bangs taking place in space all around us. Take the events of an otherwise unremarkable Tuesday night in September 2008. In the greatest explosion anyone has ever witnessed, astronomers saw a flash of light amounting to thousands of times more energy than the sun produces in a year – released in a fraction of a second. Fortunately for us, it was more than 12 billion light years away.

Controlled detonation

The event was an example of a gamma-ray burst. Aside from the name, there isn't a lot about gamma-ray bursts that astronomers can tell you for certain. "Almost everything is mysterious," says Julian Osborne at the University of Leicester, UK, and the leader of a satellite mission called Swift, which studies them. There's no shortage of ideas, the leading one being that they rise from a particularly massive star spinning as it explodes into a supernova, channelling the energy of its blast in two diametrically opposite beams. Whatever the truth is, however, electron-positron plasmas are thought to lie at the heart of the mechanism, as electrons and positrons gyrate in magnetic fields or butt up against the interstellar medium, in either case giving off light.

These bursts aren't the only mysterious things that go bang in the night (see "Anniversary fireworks", page 34). Pulsars, which flash periodically like ghostly lighthouses for millions of years, are highly magnetic neutron stars that throw off photons from a tight region around the magnetic poles as they rotate. Fast radio bursts are also powerful, yet are over in less than the blink of an eye. All that is known about them is that they act like turbocharged pulsars, expelling all their photons in a single, ultra-short blast from a region that is 10 times smaller.

Again, we're fingering electron-positron plasma as the culprits. In pulsars and fast radio bursts, the plasmas could even be clustering into antenna-like structures that channel the radio waves into the cosmos. "One can't imagine what else could be involved, if not an electron-positron plasma," says Bing Zhang at the University of Nevada in Las Vegas.

Some want to find out for sure, but that's where our fortune becomes our ›

misfortune – the sources of these bursts are too far away. That's why a few years ago, a group led by Gianluca Sarri at Queen's University Belfast, UK, started work to produce an electron-positron plasma in the laboratory.

With a background in laser physics, Sarri knew that an ultra-short laser pulse could knock the electrons out of a rarefied cloud of atoms and propel them into a beam, at close to the speed of light. If such a beam struck a metal block, it would screech to a halt, projecting its energy in a new, highly energetic beam of photons. Sarri reasoned that here, amid the charged atomic nuclei of the metal, the photons should convert into a beam of electron-positron pairs. If he was right, this could be a way to simulate the universe's wildest events in the safety of the laboratory, and confirm their behaviour.

"Nuclear fusion could be the technology to meet all our energy needs"

In 2012, a first attempt at the laser facility of the University of Michigan got halfway there: a positron beam emerged, but it was drowned out by the metal's other electrons, and no plasma was produced. "We needed a bigger laser," says Sarri. Three years later, his group bagged the Astra Gemini laser system at the Rutherford Appleton Laboratory in the UK. This time, the detectors recorded not only equal numbers of electrons and positrons, but also stringy filamentation of the beam – the hallmark of a plasma's dancing self-interaction.

Such filaments should give rise to the magnetic fields that cause the electrons and positrons to morph into photons. Sarri hopes to reproduce those in a future experiment, but in the meantime he has begun investigating another idea: that a gamma-ray burst's appearance mostly results from its plasma rucking up against the interstellar medium, generating shock waves that fling photons outwards.

In August this year, Sarri and his colleagues sent their electron-positron plasma through a recreation of the interstellar medium and observed hints of unstable behaviour. The results are a tantalising glimpse of how lab experiments could probe high-energy astrophysics. Next, Sarri has set his sights on the forthcoming Extreme Light Infrastructure, a multi-laser facility based at four locations in Europe that he believes will properly simulate the process. "We hope to see shock waves," he says. "For us, this is the holy grail." Sarri believes that in the future, model pulsars and fast radio bursts could also be studied this way.

But there are reasons to covet an understanding of electron-positron plasma closer to home. At its heart, it's just another type of plasma: a gas heated up to such high temperatures that the negative and positive charges separate and float around side by side in a wraith-like fireball. Human-made plasmas are found in neon signs, fluorescent lights, modern television screens and, importantly, the gigantic experimental facilities hoping to crack nuclear fusion.

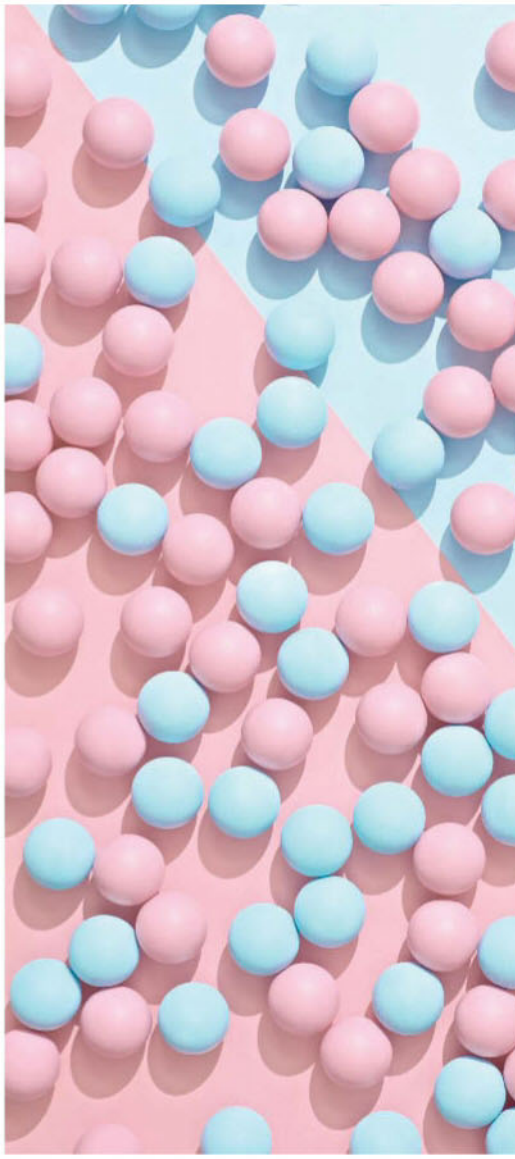
Clean, safe and running on abundantly available fuels such as hydrogen, nuclear fusion has been billed since the 1950s as the technology that will meet all humanity's energy needs. It requires a plasma made of electrons and the atomic nuclei, or ions, from which they have been stripped. When the plasma is sufficiently hot, the ions fuse, releasing huge amounts of nuclear energy. Yet progress has been painfully slow. The Joint European Torus (JET) in Culham, UK, can generate only 70 per cent of the power it requires to operate. ITER, the €15 billion next-generation fusion experiment under construction in the south of France, hopes to generate more power than it consumes by sometime in the late 2030s. It will take another reactor beyond that for commercially viable fusion.

Underlying this waiting game is the theory of plasma physics in fusion reactors, which is highly complex, thanks to the thousand-fold mismatch between electron and ion masses. This poses a challenge for theorists, says Thomas Sunn Pedersen of the Max Planck Institute for Plasma Physics in Germany: it can be impossible to know whether a prediction has failed because their simulation didn't

ANNIVERSARY FIREWORKS

Two of the universe's biggest types of explosion were first observed 50 years ago, and nearly mistaken for something else entirely. A gamma-ray burst was first detected in 1967 by the Vela satellites, which were put into orbit by the US to detect radiation from illicit nuclear weapons tests. Had the operators not noticed that the signals lacked the gradual fading of nuclear-weapon emission, the US and the Soviet Union may have found themselves in a diplomatic crisis. As it was, the operators filed the records away for nearly six years until they could be sure what they were dealing with.

The first observation of pulsars later that year was no less peculiar. When the UK astronomer Jocelyn Bell Burnell identified the oddly regular spikes of radio waves coming from the heavens, she naturally considered "little green men" as a possibility. "We did not really believe that we had picked up signals from another civilisation, but obviously the idea had crossed our minds," she recalled.



STEPHEN LENTHALL/GALLERY STOCK

LOVE-HATE RELATIONSHIPS

An electron-positron plasma isn't the only form of matter that relies on seemingly impossible pairings (see main story). In fact, electrons and positrons can get together in individual pairs to make "positronium", orbiting atom-style around their combined centre of mass and perhaps shedding light on the reason the universe seems to have more matter than antimatter.

Quarks – which make up the protons and neutrons inside atomic nuclei – can also unite with their opposite equivalents. Such is the case with heavy and surprisingly long-lived quark–antiquark pairs of "quarkonia". Since their discovery in the 1970s, quarkonia have given insights into features of the strong nuclear force, which binds quarks together.

Meanwhile, hypothetical Majorana particles could be their own antiparticles, capable of annihilating themselves under the right conditions. Although fundamental Majorana particles are yet to be observed, this year Kang Wang at the University of California, Los Angeles, and others claimed to observe Majorana-like behaviour in the collective motions of multiple particles inside specially layered materials. The strange properties of the Majorana quasiparticles could one day be exploited for quantum computing.

work to enough decimal places, or whether there is some genuinely important physics that has been overlooked.

Enter the electron-positron plasma. If a regular electron-ion plasma is often called the fourth state of matter, after solids, liquids and gases, an electron-positron plasma is distinct enough to be a fifth. Bar having opposite electrical charge, positrons are identical to electrons in all respects, including their mass. Unlike lurching ions, then, positrons dance with electrons in perfect harmony: their plasma is inherently balanced. And that makes their behaviour much simpler to model.

Pedersen likens an electron-positron plasma to the hydrogen atom, whose unrivalled simplicity allowed physicists in the early 20th century to test their theories of quantum mechanics, without fear of any complicating factors. Today, largely based on these efforts, quantum mechanics is a supremely successful theory on which much of modern technology is based. Could electron-positron plasmas be a similar testing ground for plasma physics? "If you make a prediction about an electron-positron plasma, it must be right," says Pedersen. "If it isn't we'll say, 'Ah ha! There's something else here we really need to revisit.'"

"I think he's right," says Steve Cowley, a plasma physicist at the University of Oxford and former chief executive of the UK Atomic Energy Authority. "Electron-positron plasmas won't probe everything, but if you want to compute a plasma in a basic sense, they would be much simpler."

For decades now, Pedersen has been trying to build a plasma reservoir capable of keeping a cloud of electrons and positrons alive. To build it, he has borrowed the same basic technique found in traditional electron-ion plasma research: magnetic confinement. If you design the magnetic fields in the right way, the charged particles can be kept levitating far away from the walls of a container, where they would be swiftly annihilated.

Taming a monster

That all sounds simple enough, but there's a problem: getting the electrons and positrons inside. Electrons are easy to come by, but Pedersen is sourcing the positrons from a nuclear reactor at the Technical University of Munich, and these take a while to accumulate. Unfortunately, the magnetic field used to sustain the nascent plasma also prevents new particles from entering the trap. "We need to open a door, shove the particles in, and shut the door again," says Pedersen.

Problems like this are not easy to solve, but a sizeable grant from the European Research Council this year has given him confidence that a perfect plasma is within reach. In their latest experiments, he and his colleagues have found that by applying a steady voltage across the trap, new electrons and positrons can be encouraged to drift inside without disturbing the magnetic field that contains the others. "We could have the first plasma in two years," he says optimistically.

Pedersen expects his electron-positron plasma to live long enough to betray its rich inner life. One of the key questions he hopes to answer is how long it will take the plasma to escape its confinement and perish on the trap's walls. Everything we know about plasmas so far tells us that it should last several minutes. If the electron-positron plasma turns out to be more volatile than our theories predict, however, it would mean some fundamental physics has been missing all along. Account for that, and it's possible that the more complicated plasmas required for fusion could suddenly make sense too. Despite the decades he's invested into making this hypothetical state of matter a reality, Pedersen is hoping it doesn't stick around too long. "Predictions say that the plasma will be stable," he says. "But that would be boring." ■

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WRITE
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Every time we write,we shed huge amounts of information about who we are. Michael Erard reveals the stylistic giveaways in our digital fingerprints ..
and how to make them vanish
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GENIUS, billionaire, camera-shy: there are a few things we can say about Satoshi Nakamoto, the founder of bitcoin – but we still don't know who he, she or it actually is. Nakamoto has shaken up the financial world, but has not been heard from since 2011, and no one has definitively identified the person behind the name – though many have tried. Now come fresh claims that the world's most elusive billionaire has been unmasked. All thanks to their writing style.

In 2014, a group of students at Aston University, UK, led by forensic linguist Jack Grieve, analysed Nakamoto's academic paper about bitcoin, published in 2008. They found clues to the writer's identity in the frequency of innocuous words like "still" and "only", and in punctuation patterns such as the use of commas before "and" and "but". These matched the writing style of cryptocurrency polymath Nick Szabo.

And earlier this year, American entrepreneur and political pundit Alexander Muse claimed that the US National Security Agency used similar techniques to identify Nakamoto, although whether the analysis also pointed to Szabo is not public knowledge.

These efforts to chase down Nakamoto raise interesting questions about how we reveal our identities every time we write something. How much can be discerned about an author from the way they write? As digital communication proliferates, what are the clues hidden in our tweets, emails and messages that might give us away? And with the rise of software that can analyse masses of data and look for patterns, is there any way to hide?

Every time we speak or write, we shed huge amounts of information about who we are, what we do and where we come from. Detectives have used the written word to solve crime for centuries, but in the last few decades, computers have taken on some of the heavy lifting, analysing patterns in the swathes of digital information we now churn out.

This stylometric analysis is standard fare in undergraduate computer science classes – and is at the heart of plagiarism policing software used every day by universities and publishers, as well as by experts trying to identify criminals from their written traces online.

Most often, the aim is either to figure out precisely who wrote some text or to identify traits of the unknown author: their age, gender, education level or native language. The analysis usually begins with a line-up of possible authors and samples of their writing, from which experts or software extract highly salient features. The mystery text is compared with these, and the match, whatever it might be, is stated as a probability, not a definite yes or no. Those results are then considered along with other pieces of evidence that make up the case, such as alibis. "If all of these point in the same direction, then you can make a strong determination of who the author is," says Shlomo Argamon, a computational linguist at the Illinois Institute of Technology.

MAGICTORCH

Devil strip detail

What counts as a salient linguistic feature can vary from case to case. A famous example involved a ransom note demanding that the money be left on the "devil strip". Asked by police to help out, linguist Roger Shuy at Georgetown University in Washington DC happened to know that "devil strip" was an extremely rare name for the grassy area between the pavement and the street – so rare, in fact, that only people in Akron, Ohio, use it. When Shuy asked the police if they had a suspect from Akron, their jaws dropped. They did, and the subject eventually confessed.

If you don't want your words to unmask you, simply avoiding regionalisms or other kinds of special vocabulary won't do. This is because the giveaway clues are usually commonly overlooked text features that we don't consciously control: which words are capitalised, how many spaces we use after punctuation marks, whether paragraphs are indented. "You almost never get a devil strip," Argamon says. "That was a really lucky break."

Even more telling than text features are the relative frequencies of the so-called function words that glue together sentences. "These don't carry meaning on their own and serve grammatical functions, words like prepositions, conjunctions and personal pronouns," says Argamon. One reason they are so rewarding to analyse, at least in English, is their sheer number: altogether, they make up more than half the words we write (see "Literary secrets laid bare", above).

These seemingly meaningless bits of language could point to someone's personality type, health outcomes and even future acts such as suicide, according to work by James Pennebaker at the University of Texas at Austin.

Others are exploiting telltale linguistic quirks in an effort to infiltrate criminal networks online. Tim Grant, also at Aston University, trains undercover police officers to assume the online identities of arrested paedophiles, in order to catch others or pose as potential victims. Grant creates portraits of their writing style to train officers to monitor their own mimicry. "These are low-trust environments and people are very alert to the wrong language," he says. "If you get the vocabulary choices or communication behaviours wrong, the interaction can get uncomfortable."

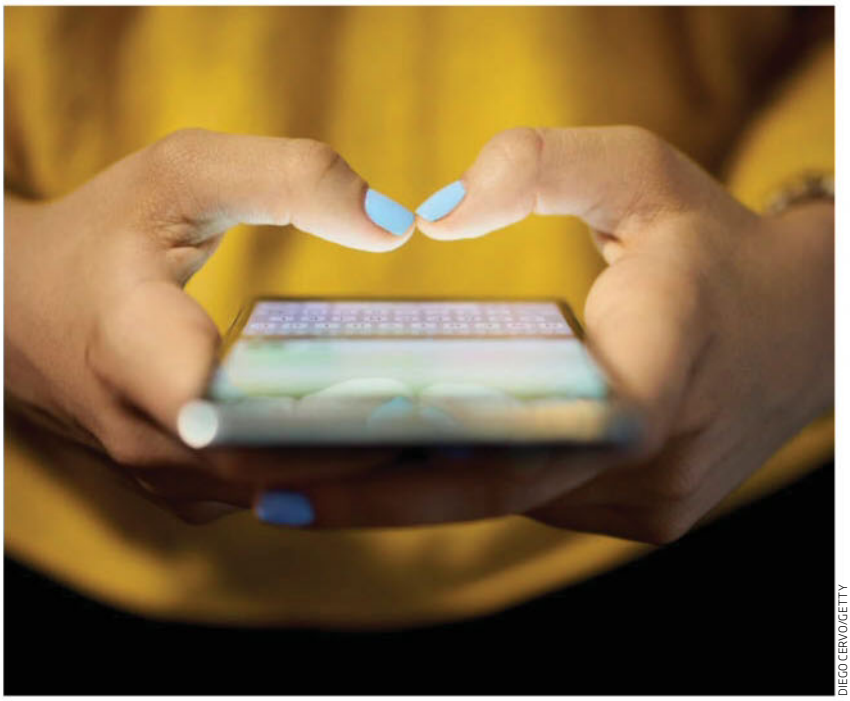
These salient patterns, whether in word choices, sentence structures or unconscious frequencies of function words, point to the remarkable flexibility of language. Linguists used to believe that we all learn a single uniform grammar of a language, then begin to deviate from it to express our personalities. More prevalent now is the idea that we each possess a mental model of our own language, one that differs in slight but important ways from those of others, due to the social and ›

LITERARY SECRETS LAID BARE

Revealing an author by analysing seemingly meaningless bits of language such as so-called function words has history. The technique came to prominence in 2013 when Patrick Juola at Duquesne University in Pennsylvania used similar methods to unmask J. K. Rowling as the author of the novel *The Cuckoo's Calling*.

When the author is dead, it becomes harder to convince everyone, however. Take the 19th-century poem *Twas the Night Before Christmas*, historically attributed to Clement Clark Moore. In 2016, New Zealand literary scholar Macdonald Jackson published an exhaustive analysis that used words like "that" and "the" and pairs of phonemes to settle on Henry Livingston as the author.

This didn't sit well with everyone, however. Scott Norsworthy, a specialist in the works of Herman Melville, derided Jackson's (and his computer's) use of "meaningless bits, inconsequential and perhaps random in their distribution".



DIEGO CERVO/GETTY

CODE WITHIN CODE

It might look as functional as can be, but computer source code can give much away about the person – or group of people – who wrote it. Coders possess a "code print", just as writers have a "writeprint" (see main story), because there are many ways to create a program.

"Depending on people's comfort level and coding skill level, they choose different ways to do things," says Sadia Afroz at the International Computer Science Institute in Berkeley, California.

The code print can involve seemingly minor choices, such as indenting lines using the space bar rather than the tab key, each of which leaves a distinct digital trail. Even the most basic instructions to computers contain variations depending on who wrote them.

In 2015, a team of computer scientists at Drexel University in Pennsylvania used software to analyse the coding style of 1600 participants in the annual Google Code Jam. By looking at keywords and other aspects including the syntax of the code, the software successfully matched code to its author with nearly 93 per cent accuracy.

Analysing contributions over time, the team also found that coders' styles hold steady over a span of several years. The stability of this code print could be important if the only available samples of a known author's code date from some time before.

Why would programmers want to remain anonymous, anyway? We tend to think of the insidious case of the malware writer, but there are legitimate reasons for wanting to hide your tracks. For example, someone may not want to be known as a contributor to open source software if that software is illegal where they live. And activists who produce tools to circumvent censorship may not want to leave traces that would allow governments to identify them.

emotional context in which we learned it.

This leads to individual ways of writing, according to Hsinchun Chen, a computer scientist at the University of Arizona, who first articulated the notion of a "writeprint". The linguistic equivalent of a fingerprint, a writeprint is made up of subtle differences in our writing style, such as vocabulary, sentence length, layout of paragraphs and so on, Chen says.

Disappearing in style

So how can you evade those trying to take your linguistic fingerprint? In one sense, it's easy, Argamon says. Imagine there are 100 authors, who have each submitted a text, and that you don't want anyone to be able to tell which one you wrote. "All you have to do is make your text look like one of the other 99 authors," he says.

This works well in some cases. In one study, Sadia Afroz, now at the International Computer Science Institute in Berkeley, California, and her colleagues at Drexel University in Pennsylvania asked people to write about their morning as if they were the US writer Cormac McCarthy. A stylometric program that had already been trained on McCarthy's writing was fooled: it thought they were the real thing.

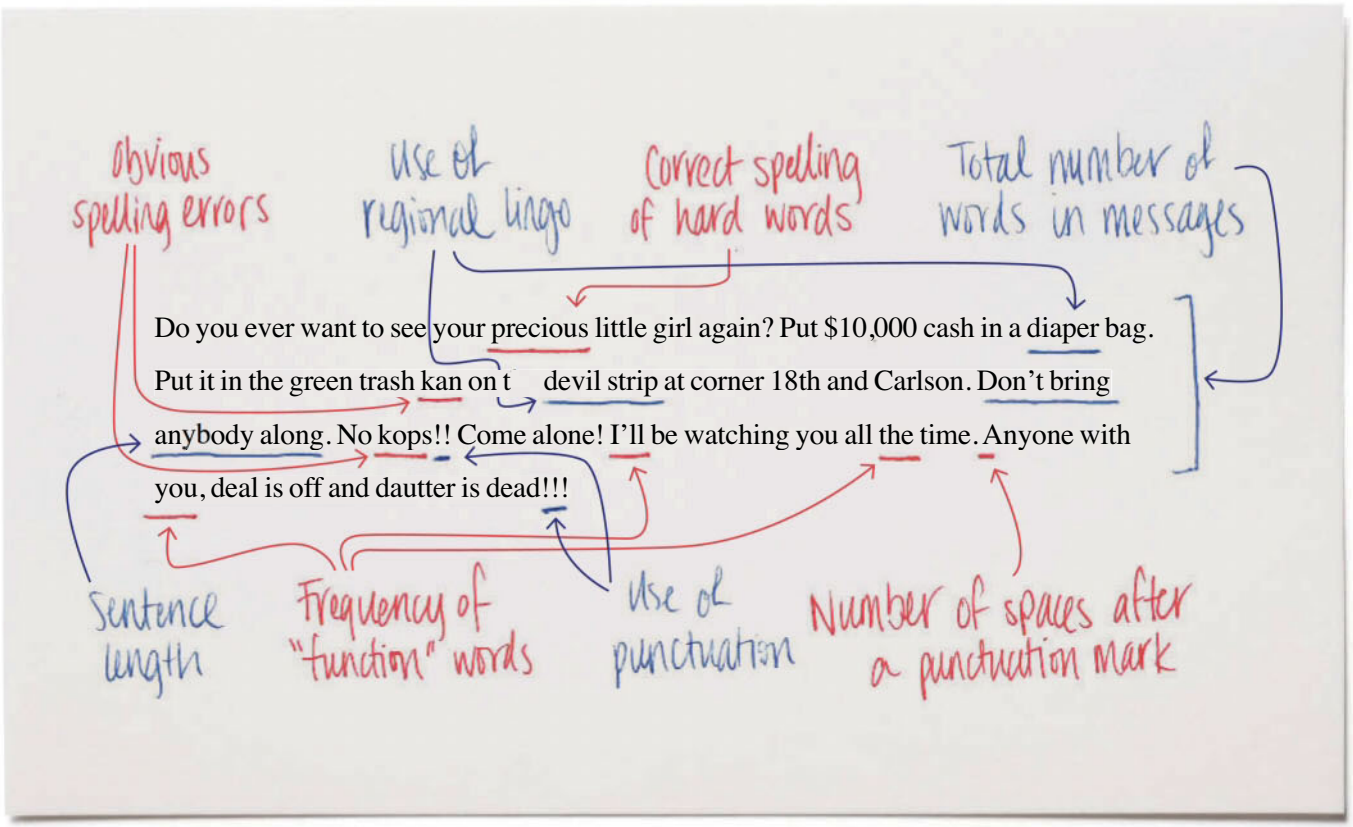
Unfortunately, people generally prove to be enduring amateurs at identifying the right changes to make. In the "devil strip" case, the writer of the ransom note deliberately misspelled some words (like "kop" for "cop" and "kan" for "can") to disguise himself as a less educated person. Unfortunately for his linguistic subterfuge, he spelled some difficult words correctly, an inconsistency that revealed the ploy (see "Bum note", right).

"If an individual tries to obfuscate through writing by making it look like someone different from themselves, they'll usually inadvertently create even more features that can be traced back," says Argamon. Tim Grant recalls being involved, along with his colleague Jack Grieve, in the case of Jamie Starbuck in 2013. Starbuck spent nearly three years travelling the world sending emails that purported to come from his wife, Debbie – it turned out that he had murdered her 31 months earlier, a week after their marriage – but only began imitating her writing style when her relatives became suspicious. "She was a heavy user of the semicolon and would use it in idiosyncratic ways," Grant says. "He suddenly started using many more semicolons, but he couldn't bring himself to use them in the right way." Starbuck was eventually arrested when he arrived back in the UK and sentenced to life in prison.

Could computers themselves be used to modify our writing and so outwit stylometric analysis? All you would do is upload your writing and a program then tells you what to change. The idea is now a burgeoning field called adversarial stylometry, and Afroz is one of the researchers trying to move things forward. Her involvement meant she was constantly being asked to unmask Nakamoto, she says, and eventually she put a note on her website saying she refused to do so. "My goal for working on stylometry is to make people

Bum note

The notorious "devil strip" ransom note contained many clues to its author's identity



aware of its harm, investigate the brittleness of machine learning and make tools to IMPROVE anonymity," she wrote.

Preserving anonymity can be a legitimate professional interest, as when academics want their anonymous peer reviews of grants or papers to stay that way. Anonymity can also be a matter of life or death for whistleblowers, activists and even programmers (see "Code within code", left). So the appeal of software that would anonymise text is obvious. But does it work?

So far, the only publicly available anonymising tool is Anonymouth, developed at Drexel University's Privacy, Security and Automation Lab. Released in 2012, it aims to reduce the accuracy of stylometric analysis to no better than random guessing. To achieve this, Anonymouth uses a stylistic analyser called JStylo, which builds a profile of each particular writer from a given sample of texts by assessing features like sentence length, word choice and the frequency of certain letters. Then Anonymouth suggests how the writer can alter the text to make it look less like this profile – switching tenses from past to present, for example, or using certain pronouns less frequently.

JStylo's creators claim that using 6500-word samples, it can match each text to its author from a set of candidates it has already been trained on, with 80 to 85 per cent accuracy. And earlier this year, an artificial intelligence program called Emma Identity was announced, claiming to need only 8000 words to build an author's profile that was 85 per cent accurate at matching anonymous samples.

> "People prove to be enduring amateurs at covering their tracks"

These success rates are far from perfect, but they are significantly better than chance. That's possible because the analyses are run in lab-like situations with specific instructions about what kinds of stylometric characteristics to look for. In the real world, however, the writing samples available to train an analyser like JStylo or Emma may be too short, or they might be hastily typed emails when the anonymous text is a carefully written letter or scientific paper.

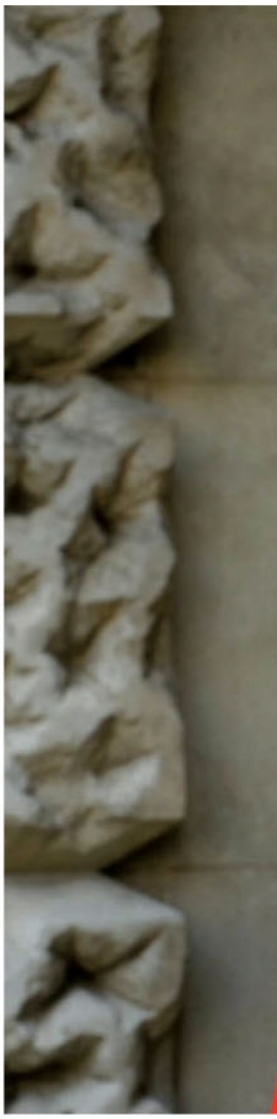
In future, we could see "adversarial authorship" – an accelerating arms race pitting technologies that identify writers against those that anonymise them. A tool called AuthorWeb, being designed at the North Carolina Agricultural and Technical State University, could enable writers to evade stylometric analysis. It gives them stylistic targets to hit as they write, using a visual dashboard that provides real-time feedback on how closely their writing matches certain features. This should help writers hide their style more easily and consistently over longer periods of time.

In the meantime, the most promising way to evade stylometric analysis is to write collaboratively, Argamon says: one person writes the text, someone else edits it. Rather than depending on a machine to alter your style or doing it yourself, this is a case of the linguistic fingerprints of two or more people cancelling each other out. And that may be exactly the tactic that has kept Satoshi Nakamoto hidden for so long: some suggest that a group, not an individual, lies behind bitcoin. With their linguistic fingerprints smudged together, they may safely continue to lurk, watching the chase go on. ■

Michael Erard is writer in residence at the Max Planck Institute for Psycholinguistics in the Netherlands

The day the Earth moved

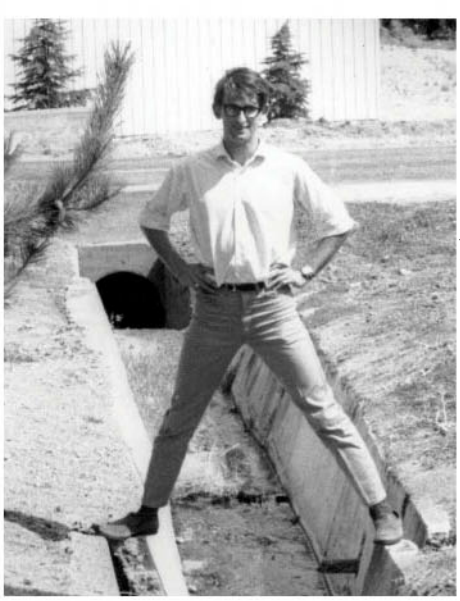
Fifty years ago, a radical theory shook up how we view our planet. **Dan McKenzie**'s ideas ushered in the era of plate tectonics



Right: still earning a crust at Cambridge
Below left: straddling the San Andreas fault in 1967

IT WAS 1967, and a profound shift in our understanding of the planet was taking place. In San Francisco, hippies gathered to celebrate counterculture and jolt our social consciousness. Meanwhile, in the far south of California, a young geologist was working on an idea that would cause as profound a revolution in Earth science as the discovery of DNA in biology. Dan McKenzie spent the Summer of Love figuring out the theory of plate tectonics.

For decades, suspicion had been growing that Earth's surface wasn't static, that the continents could and did move. In the early 1900s, Alfred Wegener proposed that continents drifted like giant icebergs floating on the ocean. It certainly looked as if they did, since the outlines of Africa and South America, and their rock types and fossils, matched up in ways that suggested the two continents had once been joined.



AMERICAN GEOPHYSICAL UNION (AGU), COURTESY AIP EMILIO SEGRÈ VISUAL ARCHIVES

But Wegener couldn't say why continents moved – so few people took his idea seriously. The fact remained, however, that certain things taking place on the surface of the planet just didn't make sense. Volcanic eruptions were a mystery, earthquakes even more so. And no one quite knew why mountain ranges formed.

In many ways, it wasn't surprising that people didn't understand what was happening, since there was so little to go on. In the early 20th century, there was no seismology, no accurate location data for earthquakes and no detailed knowledge of the sea floor. That all changed after the second world war.

In the late 1940s, researchers set out on ocean-mapping expeditions that led to the discovery of a global system of oceanic ridges. They had curious features. Running the length of the mid-Atlantic ridge, for instance, was a rift valley flanked by vast mountain ranges. The idea that some kind of movement might be taking place began to take hold.

As the cold war set in, seismometers were deployed to detect underground nuclear tests. They also spotted earthquakes – in specific areas, including along the mid-ocean ridges. Magnetometers designed to track submarines found patterns of magnetism in the rocks along the mid-Atlantic ridge that suggested crust was forming there and spreading outwards.

These findings demanded explanation. If more of this outer layer of the planet was being created, was this being balanced by destruction elsewhere? The earthquakes showed that dynamic processes were affecting parts of Earth's surface, which geologists began to refer to as plates, but exactly how remained unclear.

At the Scripps Institution of Oceanography in La Jolla, California, McKenzie began pondering how plates might move. At the time, everyone was thinking about what happened at the margins of plates; no one had worked out how entire plates might move relative to each other.

McKenzie had a stroke of insight: the plates were rigid. "The crucial idea was that the interior of plates did not deform internally," he says. It doesn't seem much, but by treating plates as rigid, it was now possible to think of them as geometric figures, like paving stones on a sphere. He and his colleague Bob Parker realised that the relative motion between two plates could be described by drawing a circle on the planet's surface whose axis goes through its centre – an idea that dates back to an 18th-century theorem by the Swiss mathematician Leonhard Euler. This allowed the pair to calculate the relative motion of plates in the North Pacific. They found it

THE ROYAL SOCIETY/ANNE PURKISS

tallied exactly with earthquake activity in the region, showing that their calculations were correct and that this movement must not only be happening but also be the likely cause of the earthquakes.

It was the last piece of the puzzle. Suddenly, they could see not just that plates shifted, but also that each was moving relative to the other. The entire surface of Earth was covered in rigid plates jammed up against each other, yet still in motion. McKenzie and Parker submitted their work to *Nature*, knowing they had hit on something big. As it happened, they weren't the only ones.

They say every idea has its time, and that was certainly true for plate tectonics. Unknown to McKenzie, Jason Morgan at Princeton University had arrived at exactly the same conclusion and had given a talk on the subject early on in 1967. Morgan could even identify three types of plate boundary: the ridges where new crust is formed, trenches where crust disappears and faults where crust neither disappears nor appears. The idea of plate tectonics was born.

Historians accord ownership of the theory to both McKenzie and Morgan, who is now a visiting scholar at Harvard University. But McKenzie says Morgan has priority. "There's no question about that at all," he says. "Morgan talked about it before I had even thought about it. It's just I didn't know about that."

What is indisputable is that geology was transformed in 1967. "The discovery of plate tectonics completely and profoundly changed the subject," says Nicky White, a geologist at the University of Cambridge. Earthquakes happen when pressure that's building up between moving plates is suddenly released. Volcanoes appear when magma from below Earth's upper mantle rises up at plate boundaries, and mountains form when one plate inexorably crunches into another. The idea of plate tectonics is so obvious in hindsight that we forget it is only 50 years old.

"The impact was immediate and profound. Geology was completely transformed"

The discovery rippled through geology with incredible speed. "The impact was immediate and profound to the extent that I was being taught about it in primary school in Dublin by 1973, which is amazingly fast penetration," says White.

McKenzie's world immediately changed too. "It was astonishing," he says. "Overnight, I became famous. I went from being a completely unknown, first-year postdoc to somebody who was invited to every international conference." But, "I didn't have a job. I was still a postdoc."

The jobs offers would roll in: a full professorship in Manchester and a grand one in Zurich. But McKenzie chose a more junior position at the University of Cambridge, where he'd studied for his first degree – in physics. "I didn't really fancy being the youngest whiz kid at somewhere like Zurich," says McKenzie. "I got married and stayed at Cambridge. And for a bit, we were very poor."

He kept working on plate tectonics, though, using it to explain the evolution of the Indian Ocean. Other researchers did, too, notably Xavier Le Pichon at the Lamont-Doherty Earth Observatory, who showed that Earth's surface comprised six major, interacting plates, and that the crust forming at ocean ridges was balanced by losses at subduction zones where one plate slipped beneath another.

But though plate tectonics explained a lot, some mysteries remained. Not all earthquakes and volcanic eruptions happen at plate boundaries for example. We now know that plates are not entirely rigid – and their flexure can lead to intraplate earthquakes. Also, massive plumes of hot magma rising up from the lower mantle can cause volcanic activity, as in Hawaii.

McKenzie is still at Cambridge, working not just on Earth's crust and upper mantle, but also on the tectonics of Mars and Venus. The focus of terrestrial plate tectonics research has shifted to the dynamics of the plates. Do those sinking at subduction zones stop at the core-mantle boundary, or do they go deeper? Knowing that could be key to understanding the forces driving plate tectonics. "Nobody really understands what's going on down there. That's going to be a really big thing," says McKenzie. And as with the discovery of plate tectonics originally, "it's now accessible with the technology we have." ■

By Anil Ananthaswamy

Hurrah for experts

In a confusing world, how we acquire and pass on knowledge is becoming a major challenge, finds **Mary Halton**

TYLER E NIXON/GETTY

POLITICS, extreme weather events, international crises: all instances in which you might feel you would want an expert handling things at the top. Someone experienced and with reasoned judgement would, you might hope, be able to anticipate, or at least handle, the unforeseen.

In *Forewarned: A sceptic's guide to prediction* (Biteback Publishing), Paul Goodwin reveals just how deeply the forecasting industry has become entwined in our everyday lives. It keeps supermarket shelves full, ensures that call centres are adequately staffed and anticipates demand on the electricity grid.

Yet prediction is far from an exact science. Walking us from the financial crisis of 2007-2008 to the perilous consequences of predicting elections, Goodwin provides a compulsively readable account of both the fallibility and necessity of human forecasters. We are still more likely to judge electoral candidates on appearance than competence, and even those experienced in prediction impart their own bias to algorithmic projections. *Forewarned* is a fascinating book, and not at all a reassuring one.

Minding the Weather: How expert forecasters think (MIT Press) is an altogether more academic exploration of the forecasting that we are most familiar with. Despite striking advances in meteorology, Robert Hoffman and his co-authors argue that forecasts are most likely to improve not with the arrival of software that can replicate the cognitive processes of human forecasters, but with programs that can model the weather itself with greater accuracy. Forecasting, they insist, remains very much the domain of human reasoning operating in the face of vast volumes of data.

In the 19th century, although meteorology was not yet recognised as a science, the professionalisation of surgery was gathering pace across London. Prior to the advent of anaesthesia and infection control, operations were quite literally a quick and dirty business. In *The Butchering Art: Joseph Lister's quest to transform the grisly world of Victorian medicine* (Allen Lane), Lindsey Fitzharris guides us through the transformation of the profession over the ensuing decades. Through a rich, lively and frequently gory read, we learn how in the Victorian era, the prospect of being operated on was, quite frankly, terrifying, and readers may find themselves in awe of Joseph Lister and his fellow practitioners who, dissatisfied with a post-surgery mortality rate that hovered around 20 per cent, crafted an expert, caring and entirely safer practice out of what was barely more than blind experiment and butchery.

"Even those experienced in prediction impart their own bias to algorithmic projections"

No wonder Charles Darwin couldn't stomach the operating theatre, and gave up an early foray into medicine. A career of extensive nautical voyages followed, but as James Costa explains in *Darwin's Backyard: How small experiments led to a big theory* (W. W. Norton), Darwin's expert knowledge of the natural world derived largely from his incessant questioning and experimentation at his own home. Costa appends a do-it-yourself guide to some of his experiments. Darwin frequently recruited his children to assist – although floating seeds across salt water for several weeks, for instance, may not hold quite

Human biases undermine the necessary art of forecasting

the fascination for today's aspiring scientists that it did then.

In *Reading the Rocks: How Victorian geologists discovered the secret of life* (Bloomsbury Publishing), Brenda Maddox evaluates an altogether less ordered rise in expertise, in this case Britain's "gentlemen geologists" of the 18th and 19th centuries. There were women among them, including novelist George Eliot and the "mother of palaeontology" Mary Anning, but the early practitioners were mostly wealthy men who were not that concerned with scientific enquiry. The search for coal seams and scientific evidence of biblical events such as the great flood proved far greater motivators.

Though somewhat defeated by a tendency to skip about, alighting on one historical figure only to jump back in time to another, and another, Maddox has assembled a keenly interesting account of an era in which the balance of knowledge (and consequently power) began to shift away from the church and into the hands of the public – or at least, an affluent quarter of it.

Figuring out a topic from scratch is no easy matter. *Little Ways to Live a Big Life*, a new series from publishers Quercus, imparts some limited expertise in under 60 pages on subjects ranging from drawing to playing the piano and from counting to infinity.

The usefulness of such slim volumes in the age of Wikipedia is questionable, but there's much to be said for brevity, and James Rhodes's piano guide is certainly welcoming and easy to follow. *How to Land a Plane* is the most enjoyable volume so far and (thankfully) the one least likely to come in handy. The author, British Airways's senior first officer Mark Vanhoenacker, ensures that readers will never look at an approaching runway in quite the same way again. ■

Mary Halton is a writer and theatre critic based in London

Very different lives

Individual fates increasingly depend on geography, finds **Alice Reid**

Our Shrinking Planet by Massimo Livi Bacci (translator David Broder), Polity

OUR planet feels like it is getting smaller. But just what is sustainable development for a growing population when each person occupies less space but uses more resources? To answer, argues Massimo Livi Bacci, we must grapple with demography.

Global population growth is slowing, with numbers predicted to peak at 11 billion by around the 2100s. But global demographic patterns have never been so varied. Life expectancy at birth ranges from not much over 50 years to well over 80, and the fertility rate ranges from more than six children per woman in many countries in sub-Saharan Africa to under two in most parts of Europe and other wealthy countries. "The world" won't have to accommodate 3.5 billion more people by 2200, Africa will.

Technological advances should let wealthy populations reduce the resources used per capita. But where living standards need to rise, resources are likely to be consumed at an increasing rate.

With the right development, the population increases in poorer countries will allow them to become more powerful economically, pushing Europe, North America and China into relative decline. The geopolitical repercussions will be profound.

"Faced with competing needs, societies may even make choices that reverse increases in longevity"

Others have pointed out the dangers of population growth, and what happens when living standards erode resources and, eventually, hit physical limits. It is less common, at least in a book aimed at the popular market, to point out the dangers of fertility levels so low that couples don't replace themselves.

Without immigration, such societies not only shrink, but fewer workers must support growing numbers of older people. Health spending on the elderly is inherently unproductive, and Livi Bacci raises provocative questions about a sustainable healthcare system when faced with so many competing needs. Societies may even end up making choices that reverse increases in longevity.

Migration is a demographically significant act, and a vehicle for reducing global inequality. Livi Bacci calls the choice to migrate a "personal prerogative" and an important strategy for individual and societal adaptation, along with the choice to reproduce (or not) and live life as one chooses.

In an echo of Amartya Sen's *Development as Freedom*, Livi Bacci portrays transitions from high birth and death rates to low ones as an unshackling from the constraints of biology, instincts and the environment. But oddly, while he defends migration as a human right, he downplays it as a solution for ageing societies.

Elsewhere, far from side-stepping problematic issues, Livi Bacci blindly ploughs through them. For instance, he ignores the potential racism of juxtaposing the goal of bolstering European fertility and reducing it in sub-Saharan Africa.

Given the all-but disappearance of population from the UN's Sustainable Development Goals, Livi Bacci raises many challenging questions. His book is a welcome reminder of how geographical differences in demography have a profound affect on people's lives. Whether we find this worrying is, of course, up to us. ■

Squeezed: Africa will bear the brunt of the world's population increase

JAMES MORGAN/GETTY

Alice Reid is a demographer, based at the University of Cambridge

Future by design

What happens when generative design meets AI, wonders **Simon Ings**

The Second Digital Turn: Design beyond intelligence
by Mario Carpo, MIT Press

THE Polish futurist Stanisław Lem once wrote: "A scientist wants an algorithm, whereas the technologist is more like a gardener who plants a tree, picks apples, and is not bothered about 'how the tree did it'."

For Lem, the future belongs to technologists, not scientists. If Mario Carpo is right and the "second digital turn" described in his extraordinary new book comes to term, then Lem's playful, "imitological" future where analysis must be abandoned in favour of creative activity, will be upon us in a decade or two. Never mind our human practice of science, science itself will no longer exist, and our cultural life will consist of storytelling, gesture and species of magical thinking.

Carpo studies architecture. Five years ago, he edited *The Digital Turn in Architecture 1992-2012*, a book capturing the curvilinear, parametric spirit of digital architecture. Think Frank Gehry's Guggenheim Museum in Bilbao – a sort of deconstructed metal fish head – and you are halfway there.

Such is the rate of change that five years later, Carpo has had to write another book (the urgency of his prose is palpable and thrilling) about an entirely different kind of design. This is a generative design powered by artificial intelligence, with its ability to thug through digital simulations (effectively, breaking things on screen until something turns up that can't be broken) and arriving at solutions that humans and their science cannot better.

This kind of design has no need of casts, stamps, moulds or dies. No costs need be amortised. Everything can be a one-off at the same unit cost.

Beyond the built environment, it is the spiritual consequences of this shift that matter, for by its light Carpo shows all cultural history to be a gargantuan exercise in information compression.

Unlike their AIs, human beings cannot hold much information at any one time. Hence, for example, the Roman alphabet: a marvel of compression, approximating all possible vocalisations with just 26 characters. Now that we can type and distribute any glyph at the touch of a button, is it any wonder emojis are supplementing our tidy 26-letter communications?

Science itself is simply a series of computational strategies to draw the maximum inference from the smallest number of precedents. Reduce the world to rules and there is no need for those precedents. We have done this for so long and so well some of us have forgotten that "rules" aren't "real" rules, they are just generalisations.

AIs simply gather or model as many precedents as they wish. Left to collect data according to their own strengths, they are,

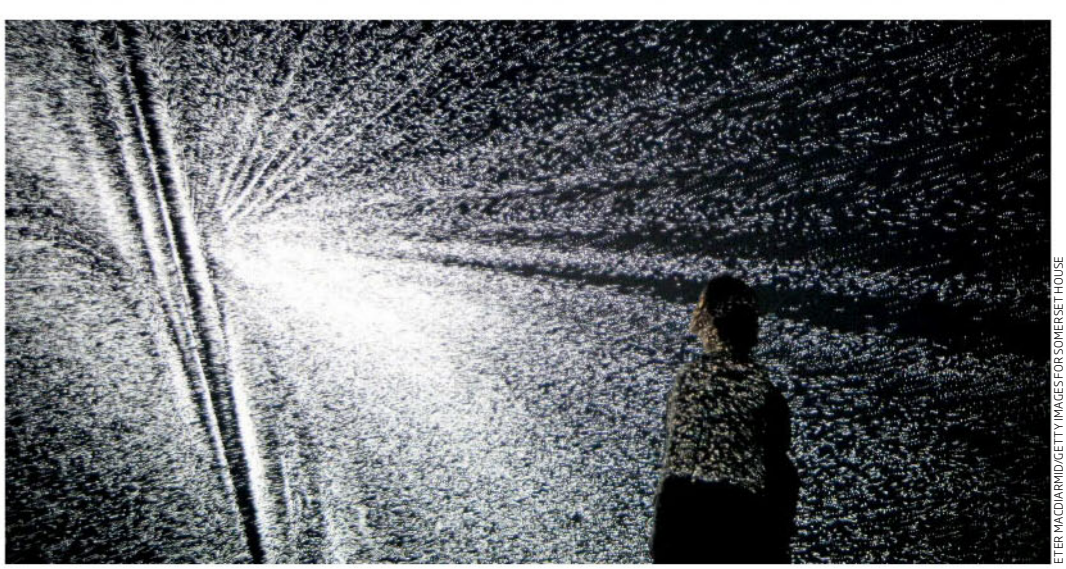
"Carpo shows all cultural history to be a gargantuan exercise in information compression"

Carpo says, "postscientific". They aren't doing science we recognise: they are just thugging.

Carpo foresees the "separation of the minds of the thinkers from the tools of computation". But in that alienation, I think, lies our reason to go on. Because humans cannot handle very much data at any one time, sorting is vital, which means we have to assign meaning. Sorting is therefore the process whereby we turn data into knowledge. Our inability to do what computers can do has a name already: consciousness.

Carpo's succinctly argued future has us return to a tradition of orality and gesture, where these forms of communication need no reduction or compression since our tech will be able to record, notate, transmit, process and search them, making all cultural technologies developed to handle these tasks "equally unnecessary". This will be neither advance nor regression. Evolution, remember, is maddeningly valueless.

Could we ever have evolved into Spock-like hyper-rationality? I doubt it. Carpo's sincerity, wit and mischief show that Prospero is more the human style. Or Peter Pan, who observed: "You can have anything in life, if you will sacrifice everything else for it." ■



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AIs gather or model data, while humans create the meaning

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EDITOR'S PICK

Stress destroys unconscious perfection

From Ros Groves, Watford, Hertfordshire, UK
Jessica Hamzelou's article on the default mode network in the brain was intriguing (28 October, p 9). We instinctively tend to think that accuracy is borne out of focusing intently on the job in hand, yet the article appears to contradict this.

Rather, the DMN apparently helps us achieve speed and accuracy in skills at which we are already highly adept, without the need to cogitate deeply.

This makes me think about skilled performers who "choke" under pressure. A tennis ace may suddenly miss shots when victory is in sight, despite achieving near 100 per cent accuracy on the practice courts. A talented musician or actor may suffer a memory lapse on stage, or a fluent public speaker may suddenly dry up. All of these swear to perfection in the comfort of their living room.

Could it be that stress deactivates the DMN, making us more prone to "overthink" when we are under intense pressure? Could it really be that despite our teachers' relentless warnings, we really do achieve more when we "couldn't care less"?

The price of specimens and what they show us

From Jean Allen, Caythorpe, Lincolnshire, UK
Your article on Lionel Rothschild's natural history collection reminded me of a visit to its museum in Tring, Hertfordshire (4 November, p 40). I was fascinated by a collection of domestic dogs that had been stuffed around 1900. The difference between the breeds then, when they were selected for purposes other than winning at dog shows, and the exaggerated versions that are their modern counterparts was striking.

From Ingrid Newkirk, PETA, Washington DC, US
You mention the human adventurers who succumbed to dysentry or charging buffaloes while collecting for Rothschild. It would seem only right to mention that all the "specimens" lost their lives. Today, the Smithsonian and other museums have drawer upon drawer of specimens that can only be described, even by enthusiasts, as overkill.

Plant species also lie undetected in collections

From Brian Lowry, Conondale, Queensland, Australia
Christopher Kemp's account of new species being discovered in old collections fascinated me (21 October, p 36). It is devoted to animals, and it is worth noting that plants suffer this fate too.

A particularly poignant case involves the plants the botanist David Nelson collected in the interior of the island of Hawaii in 1779 on James Cook's third and very final voyage of exploration. These lay in the British Museum

"...say scientists after a vat of LSD overturns in the lab. Also, drywall tastes of marshmallow"

Elon Musk responds to the idea that if driverless cars will save lives, perhaps armed machines can as well (11 November, p 22)

apparently untouched until, almost 200 years later, they were studied by Harold St John of the University of Hawaii. He described 19 new species. Many had since gone extinct and have not been seen again.

The nature of a universe made of mathematics

From Gabriel Carlyle, Hastings, East Sussex, UK
Ed Subitzky asks: if the universe consists of mathematics and Kurt Gödel showed that mathematics powerful enough to define arithmetic is incomplete, is the universe incomplete (Letters, 4 November). Gödel's famous result applies only to formal systems, whose theorems are the output of a strictly logical process like a computer program.

If we consider arithmetic to be part of our theory of the universe, then Gödel's result implies that any consistent formal theory of the universe that we construct will be incomplete.

If we do not include arithmetic, it is conceivable that there could be a complete, consistent formal theory of such a stripped-down physical universe. After all, Alfred Tarski famously showed that the elementary theory of Euclidean geometry is both complete and consistent.

From Andrew Whiteley, Consett, County Durham, UK
Subitzky refers to cosmologist Max Tegmark's contention that the universe is mathematics. Mathematics only makes sense in terms of a mind or minds capable of conceiving or grasping it. So this implies that, as astronomer Arthur Eddington put it in 1928, "the stuff of the universe is mind-stuff". Some scientists seem to be pretty close to what philosophers call idealism: holding that reality itself is a form of thought.

Seeing people around corners – to shoot them

From Ben Haller, Ithaca, New York, US
Douglas Heaven reports work to pinpoint people's locations using only light reflected on the floor in a doorway (14 October, p 9). He notes in passing that it was funded by the US Defense Advanced Research Projects Agency. The probable uses of this technology include killing people by sniper fire directly through walls.

Whether that is a positive development depends upon your opinion of the morality of US military actions. Scientists must think about ethical implications of their research: the alternative, that we seem to be sliding towards rather quickly nowadays, is guaranteed to be dystopian.

Organic produce doesn't do you more good

From Anthony Trewavas, Edinburgh, UK
Ann Wills claims organic produce is more nutritious (Letters, 7 October). Intake isn't the same as uptake. Experiments using organic tomatoes with 50 per cent higher levels of vitamin C and the vitamin A precursor lycopene failed to find any increase over controls of these constituents in blood (*Journal of Agricultural and Food Chemistry*, doi.org/bk9drw).

Of four detailed analyses of the scientific literature comparing the composition of organic with conventional produce, only that supported by the organic industry reported higher ›

antioxidant levels. It was heavily criticised by academic nutritionists for using very weak studies that should have been excluded.

Particles are the real problem in exhaust

From Roy Harrison, Verwood, Dorset, UK

You report that about 80 per cent of early deaths from air pollution are due to fine particles (21 October, p 4). Reducing all other pollutants to zero could not reduce early death from this cause by more than 20 per cent.

In the UK, at least, the target for nitrogen oxides is breached more often than that for particles. This suggests to me that the targets for particles in the emission standards we apply may be far too lax.

The particles produced by petrol engines are extremely small: they measure of the order of 0.03 micrometres and there are a lot in a microgram. For this reason, the most recent European Union standard, Euro 6, specifies both a particle mass and a particle count limit for both petrol and diesel cars. With new petrol cars routinely failing to meet the Euro 6 particle count limit, we should be asking whether they should be fitted with particle filters.

Artificial intelligence with no one to sell to

From Brian King, Barton on Sea, Hampshire, UK

Michael Brooks discusses how scaremongering stops us asking the right questions about artificial intelligence (7 October, p 28). The likes of Amazon's Alexa will never take over and eliminate humans. They exist to obtain data from humans to sell more unnecessary stuff to other humans. If they took over, they would have no one to obtain data from or sell to.

From John Minderides, London, UK

As data privacy and usage concerns increase, what are the optimal mechanisms for protecting online users in a business model where those whose data is being used by the platforms don't pay for access and aren't compensated for having their personal data and usage characteristics collected? Could we use experience from other industries and seek to regulate by making people accountable as opposed to the technology?

Changes to financial industry regulation since the crises of 2008 have moved towards making individuals responsible for what their companies do or don't do, to protect clients and the market.

Taxing short-term trades could tame algorithms

From Brian Horton, West Launceston, Tasmania, Australia

Alec Cawley wonders whether when most stock trades are done by algorithms we may as well abolish the stock market (Letters, 4 November). When humans did all the short-term trading, this tended to reduce instability because everyone had their own ideas about what to buy and sell, so anything below normal value would be snapped up by someone.

Now it is likely that a small number of algorithms will dominate the market, making instability much worse. Rather than abolish the market, though, a 1 per cent tax on transactions would have little effect on investors, but would remove the profits in short-term trading.

Autonomous cars should report ethical status

From Chris Womack, Bainton, Cambridgeshire, UK

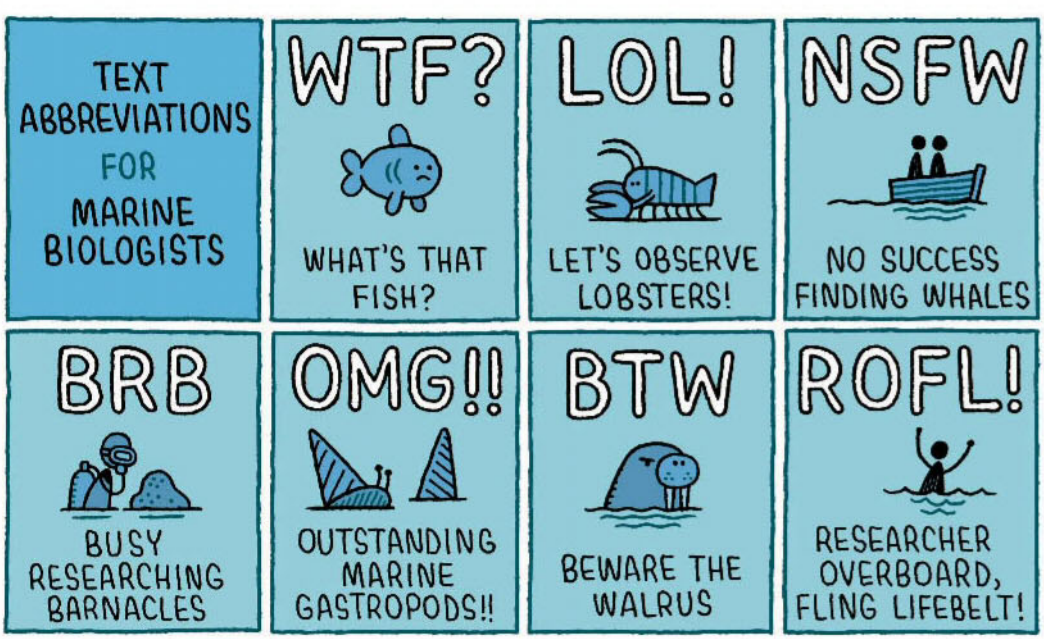
Abigail Beall describes the idea that a self-driving vehicle could have an "ethical knob" giving a human a choice over who it sacrifices in a crash (21 October, p 11). I have no objection, provided the ethical status of the vehicle is clearly displayed in real time, in a way that communicates this to all other road users in all weather and traffic conditions. Ethical status should also be reported electronically to other autonomous vehicles.

What's in a name?

From Martin Greenwood, Stirling, Western Australia

You seem coy about the "F" in Elon Musk's "BFR" to go to Mars (7 October, p 7). Surely it is a riff on Roald Dahl's well-known story of the BFG – the Big Friendly Giant.

TOM GAULD



For the record

- **The study of mouse pup weight compared 34 pups, delivered by caesarean section to five mice, with a control group of 35 born to six mice (21 October, p 19).**
- **Elephants may never forget, and we now remember that rhino horn is mostly keratin protein and one rhino farmer has more than six tonnes of it (4 November, p 7).**

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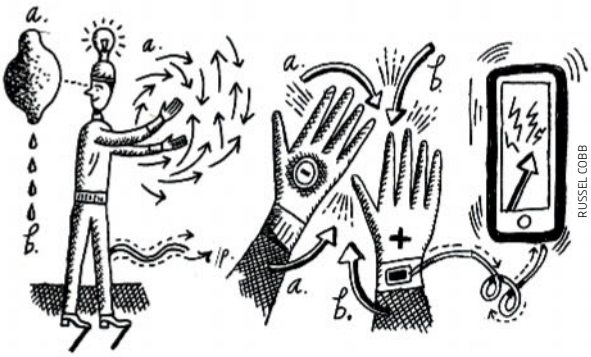


Put your hands together

Was it a good performance? Who cares! Applaud with reckless abandon and charge your phone at the same time

"Poetry nights at my local cafe are inspirational," says Alan Poe. "Trouble is, after hours jotting ideas on my phone between bouts of applause, I don't even have enough battery left to tweet a haiku. What can I do?"

Knowing when to start and stop clapping at a poetry slam can be awkward. Why not turn the emotional stress into mechanical stress? As someone who also lives life on the edge – by which I mean leaving the house with 2 per cent battery – I think it is time I take matters into my own hands.

Enter piezoelectrics. These materials have a special property that makes them like lemons: when you squeeze them, juice comes out. And you know what they say: when life gives you lemons, make electrical lemonade.

Piezoelectric discs are used everywhere, notably instrument pickups, which turn string vibrations into electrical signals. Wired into a quick test circuit, a firm prod could create enough charge to power an LED, but I foresaw a problem. I was producing alternating current and battery packs mostly require the direct kind.

No matter. As well as lemons, life has given us diodes. These circuit components only let current pass in one direction, so a clever combination forms a "rectifier" to sort the problem.

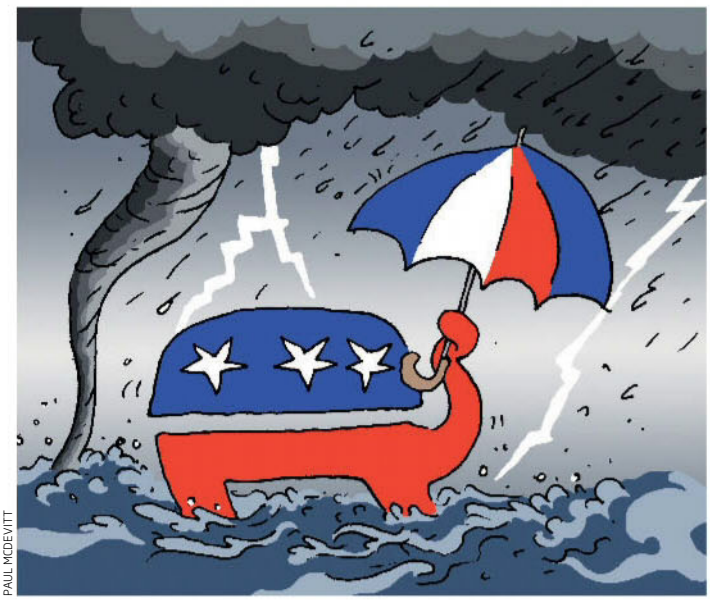
I spliced it all onto a cheap battery pack to test. My housemate thought I had seen a spider – she walked in on me aggressively slapping my desk.

How to attach it to me? My first thought was a hanky, a literal trick up my sleeve. But I opted for an elegant pair of gloves. They keep the piezos on my palms and hold the battery pack in a wrist pocket. Perfect for applauding at the opera, maybe less so for rock gigs. I can also charge up with a high five.

They are altruistic too: greater impacts generate a higher voltage, so enthusiastic clapping is encouraged. But even my most heartfelt standing ovation didn't charge my phone enough to call a cab.

A rough calculation based on figures for an average phone battery showed why: an hour of clapping would only add a few per cent. The world record for the longest applause is 2 hours. You just need some really good poetry. **Hannah Joshua** ■

For more Makes, visit **newscientist.com/make**



PAUL MCDEVITT

DONALD TRUMP may be wedded to the Republican dogma of small government, given that many key positions are still vacant almost a year after his inauguration. But Feedback suspects that if the president has been slow to choose his nominees, it is only because he is carefully selecting the ones who will most irritate his Democratic opponents.

Witness the most gripping TV to come out of the US recently, the bleakly comic series known as "hearings on nominees for the Environmental Protection Agency". Here, visibly exasperated Democrat senators interrogate the scientific credentials of candidates whose résumés might struggle to reach the bottom of the page they're printed on.

In a previous episode, we saw William Wehrum – nominated to lead US efforts to tackle air pollution – struggle to interpret a chart showing the concurrent rise in global temperatures and atmospheric carbon dioxide (28 October).

This week, it was Kathleen Hartnett White's turn in the hot seat. Selected to direct the Council on Environmental Quality, a role that oversees federal environmental policy, Hartnett White was grilled so thoroughly by senators that at times it felt like the Capitol's sprinkler system might kick in.

Asked if she stood by previous comments that carbon dioxide was not dangerous to the environment, Hartnett White said that atmospheric carbon was in fact a plant nutrient, with none of the characteristics of a pollutant that could harm human health. Excuse us while we hyperventilate into this paper bag.

SENATOR Sheldon Whitehouse wanted to know if Hartnett White thought the law of thermal expansion applied to seawater? "I do not have any kind of expertise or even much layman's study of the ocean dynamics and the climate change issues," she replied. Reassuring stuff.

And to the all-important question: Hartnett White told the panel that while she did believe climate change was real, there was much uncertainty over the extent to which human activity was to blame. Would she rely on scientists to clarify that uncertainty, Senator Ben Cardin wanted to know. "No, I've had that question for a very long time," Hartnett White replied.

With such a lack of confidence in our ability to change the environment, and a refusal to be informed otherwise, Feedback wonders what Hartnett White hopes to achieve in her role as the US environmental policy advisor.

FEW will have identified lumps of coal as the solution to sexual assaults – unless stuffed into a stocking as an improvised weapon. But one advocate of this unlikely ally is Rick Perry, US secretary of energy, climate change sceptic and the country's leading champion of all things combustible.

Speaking at an energy policy discussion earlier this month, Perry suggested that not only were fossil fuels instrumental in lifting developing countries out of poverty, but they also had the capacity to reduce sex crime. "When the lights are on," he told delegates, "you have light that shines, the righteousness, if you will, on those types of acts."

The remarks ignited a storm of criticism online (a source of energy we've yet to harness, sadly) with Michael Brune of the conservationist Sierra Club calling on Perry to resign from his post.

That might not be much in the way of punishment to Perry, who had previously called for the Department of Energy to be scrapped, and then took on its leadership without realising that the main focus of his role would not be governing oil, coal or other fuels, but overseeing the US nuclear arsenal.

IT MAY feel like the US strategy to tackle climate change is to will it out of existence by ignoring all evidence for it. Certainly, this would explain why so many Puerto Ricans are still reading by candlelight. However, do not despair. California's governor Jerry Brown has emerged as the leading voice of reason.

At the COP23 conference in Bonn, Germany, last week, Brown unveiled "America's Pledge", a movement to keep the US within the Paris Accord commitment to hold global temperature rise under 2°C. He told *USA Today*: "There is a large part of America – well over a majority – that is committed to serious climate action, because we know global warming is an existential threat."

The coalition includes Oregon, Washington, New York, New Jersey and Virginia. Is there something these states have in common that encourages preoccupation with rising sea levels, we wonder?

NOT content with cataloguing every aspect of our online lives, tech companies are keen to extend their services/surveillance apparatus into our homes. Devices such as Amazon's Echo offer an internet connected home assistant that constantly listens to its surroundings, ready to respond to voice commands.

The privacy concerns should be obvious to most, but perhaps not to the industrious minds at design studio Ninety7. They built a battery pack for the Echo Dot that allows you to take it anywhere for up to 10 hours. So naturally it was christened the DOX.

Perhaps someone should have told them that in internet slang, to "dox" someone is to release all of their sensitive personal information online.

"Modern air is a little too clean for optimum health." The surprising conclusions of toxicologist Robert Phalen, who is the latest addition to Trump's science advisory board

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Mental block

My elderly uncle is in hospital with a urine infection. His capacity for normal behaviour and thought is greatly reduced and I'm told the same happens when other older people have the same kind of infection. Why is this? If I (a 43-year-old) picked up a urine infection it might sting, but wouldn't lead to mental incapability.

■ A sudden alteration in normal behaviour and acute confusion can occur in people who have sepsis as a result of a urinary tract infection. This acute neurological dysfunction is termed "sepsis-associated encephalopathy" (SAE) and is more common in elderly patients.

SAE is probably caused by a diffuse neurological dysfunction as a result of the body's inflammatory response to an infection, as opposed to direct infection of the central nervous system. As we age, our immune system becomes less effective at fighting infections. This means older people contract infections more often and with greater severity, increasing their susceptibility to SAE.

Elderly patients often also have underlying chronic neurological disorders, such as dementia, which can increase the probability of acute confusion when sepsis is present.

There is no specific treatment for SAE. As a result, the approach tends to focus on dealing with infection and supportive measures, such as management of any organ failure, prevention of metabolic disturbances and avoidance of neurotoxic drugs.

Dr Matt Rowland
John Radcliffe Hospital
University of Oxford, UK

■ There are a few reasons why the writer's elderly uncle may react differently to a younger relative. First, his prostate gland will have enlarged with age and may be partially blocking the bladder outlet. So it probably doesn't completely empty each time he passes urine. This stagnation means an infection is not flushed out, as it would be in a younger man.

Then there is "cognitive reserve". Young people have tremendous redundancy built into their organs, but a man may have lost 10 per cent or more of his brain cells by the age of 85, and hence confusion is much more likely to appear with any general illness.

"People may have lost 10 per cent of their brain cells by the time they reach age 85"

The vigour of the adult immune system gradually fades with age. An older man isn't able to fight the infection as strongly, and less inflammation occurs with the infection, so there's less pain. As the infection lodges in a younger person's bladder, they would feel at least some lower abdominal pain, but it wouldn't lead to delirium and confusion. As it reaches the kidneys, you'd have quite incapacitating lower back pain, on one or both sides. And although it's unlikely, if the infection then spreads into your bloodstream with huge showers of bacteria, you might well feel quite delirious and have blood poisoning (septicaemia). But your uncle might not get any of these symptoms and merely become totally confused, while his organs suffer in silence.

Dr James Wakely
Boxted, Colchester, Essex, UK

■ The association between urinary infections and impaired mental capacity may be the other way around. Having cared for a 90-year-old with similar medical history, I can vouch that there are several aspects of behaviour and brain function that may predispose them to urinary tract infection.

For example, older people can suffer a loss of taste, so they consume too much salt. This is exacerbated by a failure to drink enough partly due to loss of sensitivity to thirst. Also an older person may be reluctant to get up for the toilet too often, especially at night in the dark, if they have arthritis, or impaired balance.

Food preferences may shift away from healthy foods such as fresh fruit and vegetables, partly because of reduced ability to taste, and partly because preparing meals takes more cognitive skill than, making sandwiches, say. If personal hygiene is lacking and dehydration is present (also a risk factor for high blood pressure and mini strokes), mental impairment may well be accompanied by kidney and bladder ailments.

Dr Hillary J. Shaw
Newport, Shropshire, UK

■ Delirium can affect older brains when someone is fighting an infection. The reasons are neatly explained on the Alzheimer's Society website, bit.ly/2gohGnN.

Avis Powell
Penn, Buckinghamshire, UK

This week's questions

FUZZY THINKING

What is the function of the fuzz on the skin of a peach? And is a nectarine a bald peach or a peach a fuzzy nectarine?

Roger Miles
St Albans, Hertfordshire, UK

FIRST NAME BASIS

My wife and I often mix up the names of our children and our grandchildren, calling our grandson by his father's name and so on. Sometimes we even switch the names of the grandchildren with those of our cats! But we never seem to mix up the sexes. Why is this?

John Harvey
Rodmell, East Sussex, UK

EASY ON THE EYE

The remedy for cataracts involves surgery, which carries a risk of blindness. Will it be possible to devise a non-surgical cure?

Joan Barrett
Cambridge, Massachusetts, US

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D850

I AM RELENTLESS

4K UHD FX

DAVID YARROW INTRODUCES THE NEW NIKON FULL FRAME D850. To launch the new Nikon D850, master wildlife photographer David Yarrow was given the creative freedom to capture the image of his lifetime, shot on the new D850. Thanks to the powerful combination of the 45.7MP FX format back-side illuminated CMOS sensor and the speed of 9*fps shooting, he could tell a story like never before. With ISO 64 to 25600, 153-point AF, 8K time-lapse** and full frame 4K UHD video, now you too can capture your masterpiece. David is passionate about wildlife conservation, and is the affiliated photographer of the Tusk Trust Foundation. To find out more about the D850, and David's story, follow Nikon on Facebook and YouTube.

*Requires the optional MB-D18 Multi-Power Battery Pack, EN-EL-18a/b battery, BL-5 battery cover and MH-26a charger. **Requires Interval Timer settings and 3rd party software.

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