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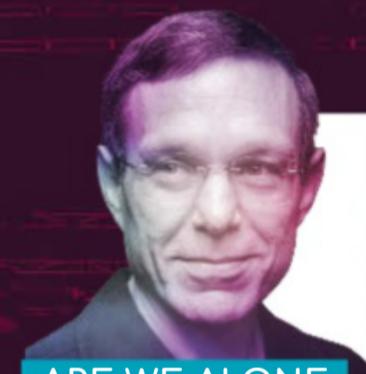
THE ASTONISHING  
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WHAT ARE THE LIMITS  
OF AI? OF INTELLIGENCE  
AND HUMANITY MORE  
BROADLY?

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ARE WE ALONE  
IN THE UNIVERSE?

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WEEKLY July 27–August 2, 2019

## OUTSMART YOUR BRAIN

Eight ways to break hard-wired habits  
... and live a happier, healthier life



## WELCOME TO THE NOVACENE

Visionary scientist James Lovelock on why humanity is entering a new era

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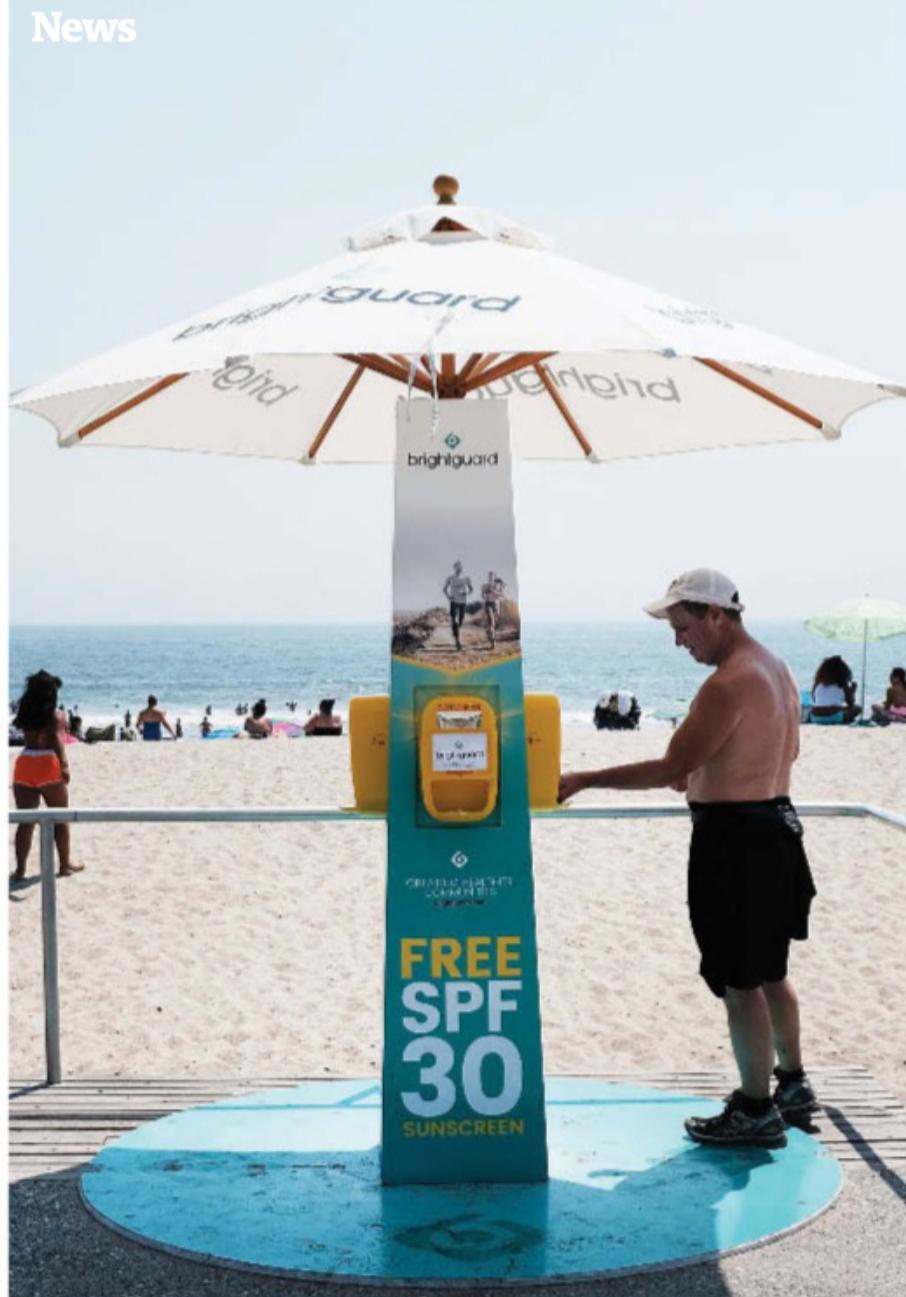
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# Earth's new era

Is our technology shifting us and the planet into a different age?

MOTHER EARTH. It is an idea stretching at least as far back as the ancient Greeks. Their Gaia was mythical: a goddess. Only in more recent decades has Gaia moved beyond metaphor to become a scientific hypothesis, thanks in large part to the visionary thinking of James Lovelock, who turns 100 this week. His conception of Earth as a self-regulating superorganism resonates more than ever in this age of concern over climate change and biodiversity loss.

As we celebrate the 50th anniversary of the moon landing, it is fitting that nothing is more evocative of Lovelock's elegant and inspirational thinking than the *Earthrise* photograph taken during the Apollo programme.

You might think *Earthrise* inspired Lovelock, who worked for NASA in the 1960s. In fact, his hypothesis predates



**Earthrise,**  
taken during the  
Apollo 8 mission,  
evokes the idea  
of our planet  
being a self-  
regulating entity

the photo (shown above) by several years. In this, as in much of his thinking, he was ahead of his time. So we shouldn't be surprised that while earth scientists still argue about how Gaia might work – and there is evidence that Gaia may be more robust than imagined (23 March, p 34) – Lovelock has moved on.

His thoughts have turned to the future of humanity (page 45). As he sees it, we are entering a new era in which "cyborg-type people" will replace

us as the dominant species on Earth. This may sound rather fanciful, but there are signs he could be right.

Take Elon Musk's new venture, Neuralink, which recently revealed plans for mind-controlled gadgets for the masses (page 15). The company wants to use thousands of tiny electrodes surgically implanted by a robot to read people's brainwaves.

Although Musk is known for his moonshot ideas, this one may be a little closer to home. People with debilitating conditions are already pioneering similar technology, with small trials seeing people use thought-controlled robotic arms to help them in their everyday lives. The technology is far from going mainstream, but the era of the cyborgs may indeed have already begun. ■

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### CONTACT US

[newscientist.com/contact](http://newscientist.com/contact)

**General & media enquiries**

**US** Tel +1 617 283 3213

210 Broadway #201, Cambridge, MA 02139

**UK** Tel +44 (0)20 7611 1200

25 Bedford Street, London WC2E 9ES

**Australia** PO Box 2315, Strawberry Hills, NSW 2012

**US Newsstand**

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## Strange supernovae

Exploded stars hint at exotic new physics **p7**

## Ancient barbecue

Cooking 1.5 million years ago may have made us human **p8**

## Opioid crisis

US overdose deaths have fallen, but don't celebrate just yet **p10**

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## Phantom mouth

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RONIT FAHU/ZUMA WIRE/ALAMY LIVE NEWS

# Telescope protests

The Thirty Meter Telescope could revolutionise our view of space, but its volcano-top location is a problem. **Leah Crane** reports

THE construction of the Thirty Meter Telescope (TMT) in Hawaii is facing big trouble. Many indigenous people in Hawaii say that the project to build an enormous telescope atop the dormant volcano Mauna Kea is steamrolling their culture.

The TMT would be the most powerful visible-light telescope ever, producing images more than 12 times as sharp as those from the Hubble Space Telescope. But many native Hawaiians take issue with its proposed location.

According to the Office of Hawaiian Affairs, "Mauna Kea is a deeply sacred place that is revered in Hawaiian traditions".

Some indigenous people in Hawaii and others, including

many in the astronomy community, have protested against putting the TMT at the summit of Mauna Kea since the location was announced in 2009.

A series of legal challenges to the project culminated in October 2018, when the Supreme Court of Hawaii upheld its building permit. Construction was scheduled to begin on 15 July.

Last week, construction



IMAGEBROKER/ALAMY

All 13 telescopes on Mauna Kea have been evacuated

companies tried to move their equipment to the summit, but hundreds of peaceful protesters blocked the road.

On 17 July, 33 protesters were arrested and Hawaii governor David Ige declared a state of emergency, authorising the state to bring in the Hawaii Army National Guard. The 13 existing telescopes on the volcano have evacuated their staff.

As *New Scientist* went to press, more than 800 astronomers and students had signed an open letter denouncing the criminalisation of protesters and the forceful building of the telescope.

If the TMT isn't built on Mauna Kea, there is a backup site for it in the Canary Islands, Spain. ■

## Engineering

### Deeper water wells are unsustainable

THE US's thirst for water is encouraging a trend of drilling ever-deeper for groundwater, according to an analysis of 11.8 million wells across the country.

But the strategy is unsustainable for reasons including the price of pumping such deep water.

Debra Perrone and Scott Jasechko at the University of California, Santa Barbara, argue that in areas where deeper groundwater wells are the only option, water quality must be protected: in the past, wastewater has sometimes been dumped in such deep reservoirs (*Nature Sustainability*, doi.org/c8pz). ■ Adam Vaughan

## The moon

### Mission to lunar pole takes off

INDIA'S second moon mission is on its way. After a short delay due to a "technical snag" that prevented lift-off a week earlier, the Chandrayaan 2 mission launched on 22 July. It is expected to touch down near the moon's south pole on 7 September.

The expedition is more advanced than India's first moon mission, and includes a six-wheeled rover that will trundle at about 1 centimetre per second across the lunar surface and study the chemical make-up of the dust. The accompanying lander will also be able to study moonquakes. ■ Leah Crane

## Deforestation

# Land grab in the Amazon

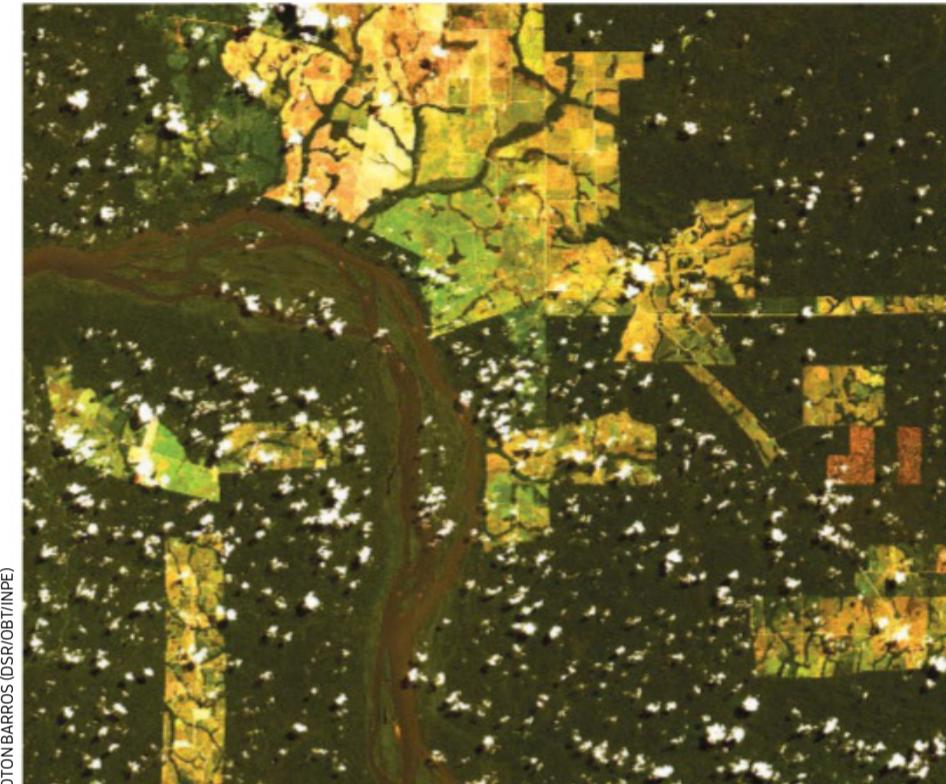
Deforestation has rocketed in Brazil since Jair Bolsonaro became president in January, reports Adam Vaughan

BEFORE July is even over, satellite images suggest this will be a landmark month for destruction of Brazil's Amazonian rainforest. More than 1250 square kilometres were lost between 1 and 22 July, figures from Brazil's National Institute for Space Research (INPE) reveal – more than double the area cleared in the whole of the same month last year (see graph, below).

The world's greatest rainforest is home to around 400 indigenous groups and a rich diversity of species. It is also a vital store of carbon. Increasing deforestation of the Amazon makes it much more difficult for us to reduce our global carbon emissions, says Mark Maslin at University College London.

This deforestation has accelerated since Jair Bolsonaro became Brazil's president in January. So far this year, more than 3700 square kilometres appear to have been lost – an area about a fifth the size of Wales.

The law hasn't changed: Brazil's decades-old forest code means landowners should be fined if more than a fifth of their land is deforested. But Bolsonaro has said that the rainforest should be exploited "in a reasonable



OTON BARROS (DSR/OBT/INPE)

way" and has sought to reduce the size of scores of protected areas.

The change in government rhetoric is driving landowners and entrepreneurs to deforest because of a lower threat of government intervention, says Maslin.

The satellite data used to assess this year's damage is intended for agencies so they can quickly detect and act on deforestation. The way it is collected isn't designed to tell us about annual trends, but

experts say it already looks likely that the full year's data will show a big increase when released in a few months. Last week, Bolsonaro said the data "lies".

"What we are observing is shocking but not a surprise," says Carlos Rittl of the Climate Observatory, a São Paulo-based group of non-governmental organisations.

Through a freedom of information request to Brazil's environment agency, he has discovered that the number of government enforcement operations in the Amazon region was down 70 per cent between January and April compared with the same period last year.

"What we can tell is that people are feeling more enabled by the government," says Erika Berenguer at the University of Oxford, who met landowners during a recent visit to Brazil.

Individual cases of deforestation have also been detected by satellite monitoring beyond Brazil's own schemes. The Global Land Analysis & Discovery



In this satellite image, recently exposed soil is orange and cattle ranches are light green

lab at the University of Maryland had 75 per cent more real-time deforestation alerts in June than last year. "We're definitely seeing a lot more alerts," says Mikaela Weisse of the US-based non-profit World Resources Institute, which works with the lab.

The big driver is to clear land for beef production, rather than the value of the timber or to make space to grow oil palms or soya beans, says Berenguer. Typically, gangs use a chain slung between two tractors to knock down trees at an industrial scale. Once dry enough, the felled trees are burned to clear the ground for ranching.

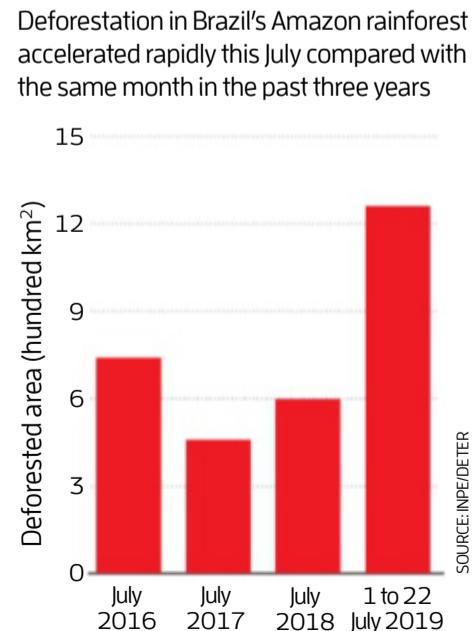
It isn't possible using satellite data alone to say that the clearance is definitely for ranching, but Weisse says the straight shapes and the size of the areas follow the same trend as land cleared for cattle pastures in the past.

Based on the preliminary data, it is thought that the full year's data, which will cover August 2018 to July 2019, could show an annual rise in deforestation of as much as 10 per cent. This would be relatively small compared with the early noughties, when tens of thousands of square kilometres were being deforested annually. But it would mark a significant departure from the past decade of relatively low, stable deforestation.

Fred Arruda, Brazil's ambassador to the UK, noted that deforestation fell by 72 per cent between 2004 and 2018. "The historical trend is undeniably still quite positive. Nonetheless, we acknowledge the challenges ahead of us," he says. "We have been working to make sure our historical trend remains on track." ■



DANIEL BELTRÁ/GREENPEACE



# Supernovae go rogue

Exploding stars that appear too faint point towards exotic particles

Leah Crane

THERE is a problem with some stars that have exploded in supernovae – and it might point to new physics. These stars don’t seem to have burned as brightly as we expected, and particles called axions might have dimmed them before they blew up.

Type II supernovae come from the collapse of a massive star called a red giant. Our best models for these stars predict a strict relationship between their brightness and mass. But Oscar Straniero at the National Institute for Astrophysics in Italy and his colleagues have found that some supernovae don’t follow the rule.

The mass of a star that goes supernova can be estimated in two ways. The amount of oxygen produced in a supernova depends on the mass of the star, so you can look at the explosion, measure the oxygen and estimate the mass. You can also study images of the star before it exploded and estimate its mass from its brightness based on a model of how the two should be related.

Straniero and his team used both methods to estimate the masses of eight red giants and found that the results of the two

ways didn’t match. Most of the stars were fainter than would be expected from the estimates of their mass based on oxygen.

Their luminosity depends on processes inside the star that produce energy, like nuclear reactions, and processes that remove it, like the outflow of photons and neutrinos. So what could be carrying the missing energy away?

Straniero and his team

considered several possibilities related to the uncertainties in their models. For example, they didn’t take into account that most stars rotate. They also include uncertainties about convection. But accounting for these made the discrepancy worse, not better ([arxiv.org/abs/1907.06367](https://arxiv.org/abs/1907.06367)).

**Eight exploding red giants have been found to be just a bit too faint**

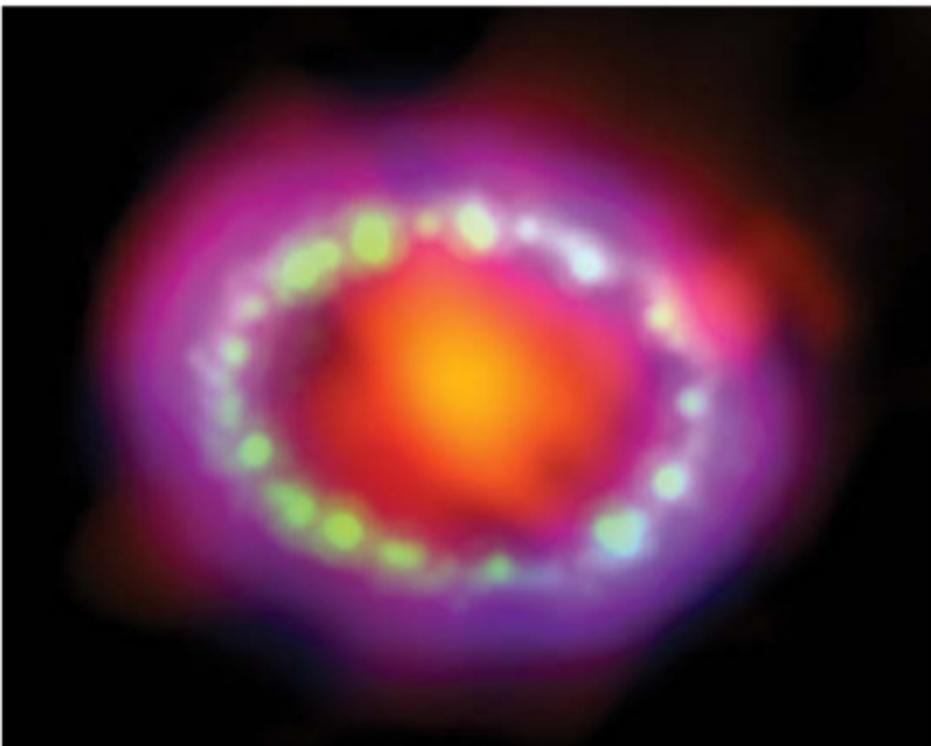
Straniero says there must be some unfamiliar physics leeching energy from the star. “We think there is some other mechanism that helps photons and neutrinos do this job.”

One fit is the axion, a candidate dark matter particle. It was hypothesised to solve the strong CP problem, which is related to the mystery of why there is more matter than antimatter in the universe. Axions could be made in environments like the cores of big stars and Straniero’s team shows that axions could account for the discrepancy between the stars’ brightness and mass.

These hypothetical particles could be spotted by experiments that are already being developed. “If this discrepancy that we find originates from axions, they will be found in the next decade,” says Straniero.

But even finding axions in red giants won’t solve the mystery of dark matter. “There are different ways to make axions, but the highly energetic environment one won’t produce enough axions to explain the dark matter density,” says Chanda Prescod-Weinstein at the University of New Hampshire. ■

ESO/NAOJ/NRAO/NASA/ESA/HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS/CXC/PENN STATE



## Origins of life

### Early life on Earth may have existed as droplets of jelly

BLOBS of simple, carbon-based compounds may have been the precursors to the first living cells. Such droplets could have formed quickly and easily on early Earth.

All modern cells are surrounded by an outer wall called a membrane, which is made of long, chain-like molecules called lipids. Many researchers argue early cells must

have had these membranes too.

The droplets made by Tony Jia at the Tokyo Institute of Technology in Japan and his colleagues are different. “They don’t have an outer layer,” says Jia. “In that sense they’re membrane-less.”

The team made them from simple chemicals called alpha hydroxy acids that may have been present on early Earth. They are made by the same processes that create amino acids, which researchers think formed early in Earth’s history, says team member Kuhan Chandru of

the National University of Malaysia.

The team dissolved the acids in water, then left the solution to evaporate at 80°C for a week, mimicking the conditions near a hot volcanic pond.

As it dried out, the solution turned into a thick jelly. When the researchers added water, the jelly formed hundreds of droplets

**“Crucial biological molecules, including proteins, could enter the jelly droplets and function”**

a few micrometres across.

The team showed that crucial biological molecules, including proteins and RNA, could enter the droplets and still perform their functions (*PNAS*, doi.org/c8pt).

The idea that life began without membranes is now gaining support, says Kate Adamala at the University of Minnesota in Minneapolis. The first cells would have struggled to transfer food and waste across membranes, she says, so membrane-less droplets would be better. ■

Michael Marshall

## Human evolution

# A Stone Age barbecue

Evidence of cooking 1.5 million years ago could explain how we came to be human

Colin Barras

DID cooking make us human? Evidence from Kenya suggests early hominins were roasting meat over fires 1.5 million years ago. The discovery pushes back evidence of fire use by hundreds of thousands of years, and lends weight to the idea that cooked food helped trigger the evolution of big-brained humans.

"It's very exciting," says Sarah Hlubik at Rutgers University in New Jersey. "This is the oldest site to date with evidence of human ancestors using fire."

Hlubik and her colleagues collected thousands of archaeological items from a dig

in Kenya's Koobi Fora region. The site contains patches of reddened dirt surrounded by relatively dense clusters of stone artefacts and burned bone, as might be expected if hominins were sitting around a fire to eat cooked meat and prepare stone tools (*Journal of Human Evolution*, doi.org/c8nc).

A handful of the collected fragments from stone tools have a distinct curved appearance. The team found that this unusual curving occurs only when a stone tool is being made near a fire (*Journal of Archaeological Science*, doi.org/c8nd). Chipping away at a stone to turn it into a tool seems to

introduce physical stress lines in the fragments that ping off, says Hlubik. If those fragments happen to fall into a hot fire, they then crack and curl along the stress lines, she says.

The researchers say that their findings don't prove hominins were using and controlling fire 1.5 million years ago, but they say the evidence they have collected does support such an idea.

Clear signs of controlled fire appear in the archaeological record only about 400,000 years ago. But we shouldn't be surprised if the practice began much earlier, says Wil Roebroeks at Leiden University in the Netherlands.

The bigger question, says Hlubik, is how often hominins used fire to cook food 1.5 million years ago. Some researchers argue that cooking became such a common practice between 1.5 and 2 million years ago that it shifted the course of hominin evolution.

Cooked food is easier to digest, the idea goes, so hominins could "afford" to simplify their digestive tract and divert energy to brain growth instead. *Homo erectus*, arguably the first hominin with a larger brain, appeared



SARAH HLUBIK

**These stones, excavated at Koobi Fora (left), are made of the same material, but the bottom one has been exposed to heat**

about 1.9 million years ago.

Under this scenario, we should find evidence of fire use at many ancient sites across the landscape. "That's what we're working on now," says Hlubik. The Koobi Fora region covers thousands of square kilometres and contains many sites of hominin occupation dating back 1.5 million years or more. Hlubik and her colleagues hope that they can find more evidence of possible fire use in some of these other places. ■



SARAH HLUBIK

## Energy

## UK spends billions on fossil fuel projects abroad

AN ANALYSIS of spending has revealed that the UK gave £4.6 billion to overseas fossil fuel projects between 2010 and 2017.

More than half of the support for energy projects abroad – provided in the form of overseas aid and lines of credit via the UK's credit export agency – went on fossil fuels during the period. Just 17 per cent was

spent on renewables, found the analysis by Catholic charity CAFOD and the Overseas Development Institute think tank.

"It's a bit of a no-brainer: if we want to get to net zero and keep below 1.5°C, we shouldn't be using public money for fossil fuels," says Sarah Wykes of CAFOD.

Despite the UK signing up to the 2015 Paris climate change agreement and committing to the UN's sustainable development goals in 2016, there is no clear downward trend in the funding.

"It's inconsistent to have fossil fuel funding when you have the climate goals and poverty reduction goals the UK has," says Wykes.

The top recipient of the support was Brazil with £2.3 billion over the period, followed by Ghana and Russia. Former UN secretary general Ban Ki-moon has been calling for an end to this kind of support for years.

Attitudes in government may be

**"If we want to get to net zero, we shouldn't be using public money for fossil fuels"**

changing. As international development secretary, Rory Stewart said earlier this month that he felt "very strongly" that his department shouldn't be spending on fossil fuels. However, Stewart confirmed on Tuesday, after Boris Johnson was named the UK's next prime minister, that he would resign.

A government spokesperson said: "As the prime minister [Theresa May] announced at the G20 last month, in future we will look for the greenest way to deliver UK aid." ■  
 Adam Vaughan

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## Space

### Planets spin the right way when made from pebbles

Leah Crane

**IT HAS long been a mystery why planets tend to spin in the same direction as their stars do. The answer may lie in whether they are made from huge rocks or pebbles.**

**The standard model of planetary growth states that planets coalesce from giant rocks that are kilometres across. But models of that process result in planets that barely spin at all because similar amounts of boulders hit the fledgling planet from all sides.**

Rico Visser at the University of Amsterdam in the Netherlands and his colleagues examined an alternative model of planetary formation called pebble accretion. In this, planets form from lumps that are between a millimetre and a metre across. These rocks are more affected by friction from gas surrounding stars than bigger boulders would be.

**"It has long been a mystery why planets tend to spin in the same direction as their stars"**

Visser and his colleagues simulated individual pebbles on trajectories around a growing planet. "For pebbles to be swept up by the protoplanet, the key is long-lasting encounters of pebbles with protoplanets," he says.

The team's models suggest that small rocks circulating between a nascent planet and its star keep being pushed back towards the planet by the friction they experience from the surrounding gas. This increases the time they spend near the planet.

This means that when the rocks fall onto the protoplanet, they tend to hit it at an angle that spins it in the same direction that the star is turning – called a prograde direction. Rocks coming in from the other side of the planet, away from the star, tend to fly past without colliding. ■

## Analysis Opioid crisis

### Annual drug overdose deaths have fallen in the US For the first time since 1990, fatalities from overdoses have dropped. Has the opioid painkiller crisis peaked, asks Chelsea Whyte

PRELIMINARY figures from the Centers for Disease Control and Prevention (CDC) suggest that there has been a 5 per cent fall in the number of annual drug overdose deaths in the US. The drop is almost entirely due to a fall in deaths from prescription opioid painkillers, prompting questions over whether the worst may finally be over.

The numbers indicate that there were 68,500 drug overdose deaths in the US in 2018, down from 72,000 the previous year. However, it isn't known whether overdose deaths will continue to fall, says Tisamarie Sherry at the Rand Corporation think tank in California. "The CDC data shows that overdose deaths from fentanyl, synthetic opioids, cocaine and methamphetamines are still increasing, which is an ominous sign."

US drug overdose deaths related to prescription opioids rose from just over 3400 in 1999 to about 17,000 in 2017. This dramatic upwards trend reflects a nationwide epidemic of opioid use and abuse. Recent

numbers from the US Drug Enforcement Administration revealed that, between 2006 and 2012, 76 billion pills of common prescription painkillers oxycodone and hydrocodone were distributed in the US. That is about 248 pills per person.

The epidemic has hit US states differently, and the new numbers bear that out. Deaths have continued to rise in some eastern states where the illicit use of fentanyl, a highly potent synthetic opioid, is spreading. But deaths are dropping in some Midwestern states where local governments have expanded treatments for addiction and monitoring of prescriptions.

Despite this recent reduction in overdoses, tens of thousands of people are still overdosing on opioids each year in the US. The recent decrease may be due to increased availability of naloxone – which blocks the effects of opioids and is used by emergency medical practitioners to reverse overdoses – and better training in how to use it.

If emergency treatment, rather than reduced drug use, is largely behind the fall, this would mean an increasing number of US adults are living with substance abuse disorders. Prescribing restrictions mean that many of these people are probably being pushed towards using street drugs.

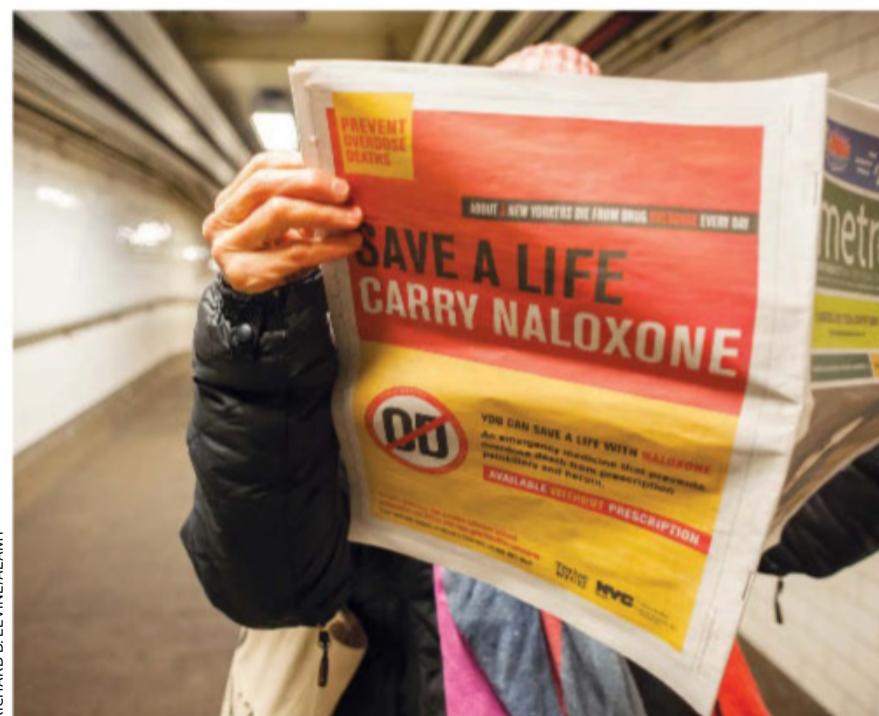
# 68,500

**Estimated number of overdose deaths in the US in 2018**

This isn't the first time the rate of opioid deaths has slowed. They appeared to stall in 2011 and 2012, but the death rate then shot back up as fentanyl made its way into the US. Fentanyl deaths in 2018 continued to rise, but grew at a slower rate than they have in recent years. So, it is fair to be only cautiously optimistic when it comes to a possible break in the wave of opioid-related deaths.

The 2018 numbers are still being finalised, and may increase when the CDC publishes its final report later this year. They also don't include deaths related to infection from intravenous drug use.

Complicating matters, renewed attempts to overturn the Affordable Care Act are under way. Should these succeed, many people who currently receive legal pain relief may end up turning to illegal drugs if they lose their health insurance. Celebrating the end of the opioid epidemic now would be extremely premature. ■



RICHARD B. LEVINE/ALAMY

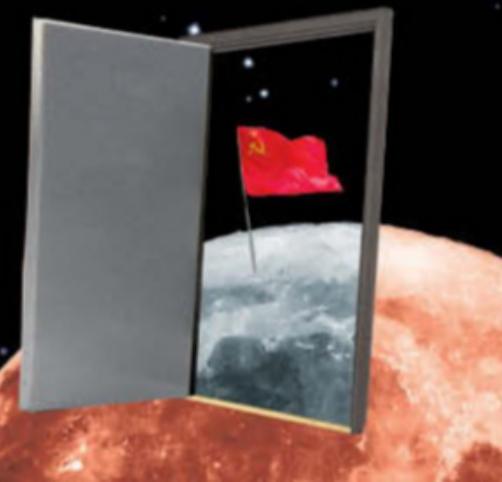
**Naloxone can be used to reverse opioid overdoses**

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## Space

# Milky Way devoured another galaxy

Leah Crane



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EARLY in the Milky Way's history, it gobbled up another, smaller galaxy and made that galaxy's stars its own. Now, astronomers have pinpointed some stars that survived the calamity and have been here all along.

Carme Gallart at the Institute of Astrophysics of the Canary Islands in Spain and her colleagues used data from the Gaia space observatory to determine the

## 10bn

Years since the Milky Way ate the Gaia-Enceladus galaxy

ages of nearly 600,000 stars in our galaxy. Some of those stars are in what is known as the thick disc, just above and below the galaxy's main disc, and some are in the halo, a spherical structure that extends beyond the main disc.

The halo sample contained two types of stars, one bluer and one redder. Previous work had shown that the bluer stars were originally part of a galaxy called Gaia-Enceladus, which was absorbed by the Milky Way.

Gallart and her team found

We've identified some of the oldest stars in our galaxy

that both groups of stars had similar ages. They were probably about 3 billion years old when the Milky Way devoured Gaia-Enceladus around 10 billion years ago. Some of the halo stars had similar properties to the redder thick disc stars, leading the researchers to infer that they had been tossed from the disc into the halo. These stars are some of the oldest in the Milky Way.

"It's fascinating that we can identify the first stars that were here in the progenitor of the Milky Way and how they were modified by this merger," says Gallart. "We're uncovering the story of our own galaxy and how things happened at the beginning."

The gas from Gaia-Enceladus probably fed stellar nurseries, the birthplace of stars, as it fell into the Milky Way: half a billion years after the merger, there was a peak in star formation (*Nature Astronomy*, doi.org/c8pv). This was probably the largest and most recent galactic merger in the Milky Way's history, says Gallart. ■

## Machine learning

# AI learns how to imagine itself in another's shoes

Donna Lu

ARTIFICIAL intelligence has passed a classic theory of mind test used with chimpanzees. The test probes the ability to perceive the world from the point of view of another individual and so AIs with this skill could be better at cooperating and communicating with humans and each other.

To create their AI, Raul Vicente at the University of Tartu in Estonia and his colleagues were inspired by an animal study that looked at the feeding habits of dominant and subordinate chimpanzees. "Chimpanzees have these hierarchical structures in their society and, in principle, the dominant one almost always gets the food," says Vicente.

The chimp study showed that the subordinate animal would only go for food that it knew the dominant animal couldn't see, suggesting an ability to place itself in another's position.

To replicate this set-up, Vicente and his colleagues created a virtual 11-by-11 grid in which they placed two AIs – one dominant and one subordinate – and a single piece of food in different orientations and locations.



MATIJAZ SLANIC/GETTY

Machines with theory of mind could be better at interacting with humans

The subordinate AI was able to move within the grid, and was given points if it ate food that the dominant agent couldn't see, but lost points if it ate food in the dominant agent's sight.

It learned via trial and error,

in a process called reinforcement learning, whether or not to move towards the food (arxiv.org/abs/1907.01851).

A key difference between apes and the AI is that the AI required several thousand trials before it learned the task, while chimpanzees understood it intuitively.

Being able to understand the perspective of other individuals enables communication, cooperation and competition, says Vicente. "It is absolutely essential for survival for any social species."

AIs with theory of mind are key to building machines that can understand the world around them. In recent years, the skill has been developed in a robot whose memories are modelled on human brains and in DeepMind's ToM-net, which understands that others can have false beliefs.

The ultimate goal of this kind of research is for machines to become better at communicating with people, but it will be a long time before AIs develop theory of mind at a level comparable to humans, says Vicente.

"It will be fun and effective to interact with these agents when they are able to put themselves in our perspective," says Vicente, because AIs with theory of mind would be able to communicate things that we don't know or can't see.

But Joanna Bryson at the University of Bath in the UK says that AIs that develop the ability to see from other perspectives won't necessarily lead to machines that are more like humans, as there are other aspects of theory of mind that aren't yet well-captured in virtual tests. ■

# Denisovan art uncovered?

Carvings on bone may be the handiwork of ancient humans

Alison George

THEY might not look much compared to the work of Michelangelo or Vincent van Gogh. But a couple of abstract etchings discovered in China could be a sign that the Denisovans, our mysterious extinct cousins, were artists.

The 100,000-year-old marks on two pieces of bone also bolster the idea that Denisovans, like Neanderthals, were capable of symbolic thought – once regarded as something only modern humans could do.

The bones were unearthed at Lingjing in Henan Province, China. They come from a site where a population of archaic humans, thought to be Denisovans – though this needs to be confirmed – lived between 125,000 and 105,000 years ago.

Detailed analysis of the Lingjing engravings showed that they had been carefully drawn with a sharp point, and weren't cutmarks from processing meat. "The microscopic analysis of the lines shows that they cannot be interpreted as marks of butchery, the alternative interpretation," says Francesco d'Errico at the

University of Bordeaux in France.

To enhance their visibility, the lines on one of the bones had been rubbed with reddish ochre, a pigment often found on prehistoric ornaments (*Antiquity*, doi.org/gf43nn).

We can't yet be certain that it was the Denisovans who engraved these bones, especially as we now know that modern humans reached China between 80,000 and 120,000 years ago. "It's difficult to be 100 per cent sure," says d'Errico. "However, the skull

**The vertical lines on this bone may have been etched by Denisovans**

of an archaic hominin was found in the same layers in which the engraved bones were found. This strongly suggests the authors of the engravings were archaic hominins."

There are profound implications if a Denisovan or other archaic human was the artist. The Denisovans are thought to have occupied a vast territory in east Asia, but few artefacts dating to the time of their existence have been uncovered in the region. A bracelet made of green rock, rings and beads dating back to 45,000 years ago have been found in the Denisova cave in Siberia, where Denisovans were first identified



back in 2010. But some researchers suspect they were produced by modern humans, who arrived in Siberia at this time.

Though apparently simple in design, the Lingjing bone engravings suggest that the people who made them had the advanced cognitive skills needed to represent information through abstract symbols. No other living animal, not even a chimpanzee, has been known to produce abstract, non-functional designs.

"This finding is really quite groundbreaking," says Genevieve von Petzinger at the University of Victoria, Canada, who specialises in geometric symbols in cave art.

"[The marks] are an artificial memory system – a way to retain information over time and space. To see closely related human species making these graphic marks is absolutely fascinating," says von Petzinger.

The researchers are hopeful that more finds will be uncovered soon. "China and other regions of Eurasia have been under-investigated and it is very probable that in a near future we will have more discoveries," says d'Errico. ■



D'ERRICO/D'YON

## Psychology

### Strange illusion makes people lose track of their teeth

AN ILLUSION can trick people into thinking their teeth are closer to their neck than they are, showing that our bodily perceptions are easily influenced.

Davide Bono and Patrick Haggard at University College London were inspired by the rubber hand illusion, a famous illusion in psychology where the participant is tricked into believing a rubber hand is their own.

In Bono and Haggard's version, the participant wears a blindfold and is told that Bono will take their right hand and use it to stroke their own teeth.

Instead, he uses the person's hand to stroke a model set of human teeth made of plaster placed 8 centimetres below their real teeth. Simultaneously, Bono uses his own hand to stroke the person's teeth in exactly the same way. Once the stroking has stopped, the participants are asked to point to their teeth.

Eight people took part in the

experiment and on average they pointed 1.5 centimetres below their own teeth in the direction of the dental model (*European Journal of Neuroscience*, doi.org/c8m5).

The experiment suggests that our perception of where our mouth is is flexible, an effect called proprioceptive drift.

The pair found that even if the strokes on the model teeth and

**"They also found that the illusion worked when the model teeth were covered in Velcro"**

the participant's real teeth were in opposite directions, as long as they started and finished at the same time the illusion still persisted.

They also found that the illusion worked when the model teeth were covered in Velcro. But it didn't work with a different model that had gaps between the teeth.

It isn't clear why there would be this difference. Bono says we may have some higher-level conception of what our teeth should be like, but one that can still be easily manipulated. ■

Jason Arunn Murugesu

# Experimental Alzheimer's drug

Treatment targeting gum disease bacteria shows early promise

Clare Wilson

ENCOURAGING results have been announced from a small trial of a new kind of treatment for Alzheimer's disease, which targets gum disease bacteria.

Trial participants showed improvements in the levels of certain molecules in their blood and spinal fluid, says Cortexyme, the US firm developing the therapy. However, the company hasn't yet shown that the treatment can reduce the severity of dementia.

"It isn't enough to get excited about, but it's enough to say this hypothesis is interesting," says Carol Routledge of the charity Alzheimer's Research UK.

The new approach is at odds with decades of thinking about Alzheimer's. It was believed that the condition is caused by a build-up of toxic plaques in the brain made of a protein called amyloid. But numerous therapies that block amyloid failed to halt progression of the disease in trials. Many researchers now think the protein may be a side effect of Alzheimer's, not the root cause.

Cortexyme believes Alzheimer's may be due to bacteria called

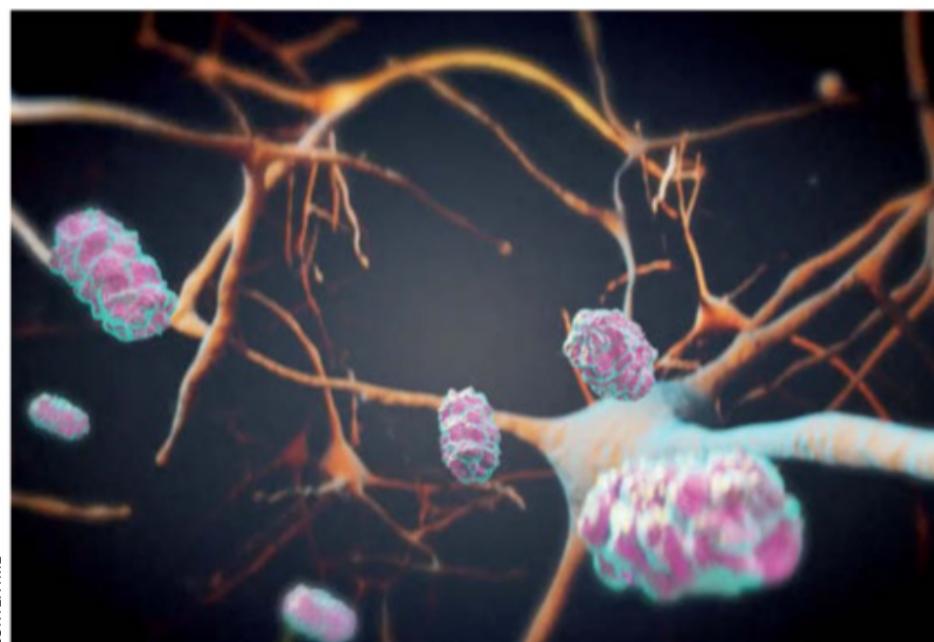
*Porphyromonas gingivalis* – better known for causing gum disease – somehow getting into the brain and sparking inflammation. The microbe and its toxins have been found at somewhat higher levels in the brains of people with Alzheimer's, and can trigger amyloid build-up if put into the brains of mice.

Cortexyme has developed an oral medicine called COR388 that can block the activity of the toxins released by the bacteria. Last year, the firm carried out short trials in

healthy volunteers and nine people with mild to moderate Alzheimer's disease, six of whom got twice-daily capsules, while the rest got a placebo version.

After four weeks, there were small improvements in two kinds of tests for dementia severity for those who got the medicine, but these were too small to be classed as statistically significant.

**Could these pink bacteria below cause Alzheimer's by harming brain cells?**



Cortexyme says that is because the trial was designed as a safety test and was too small to show efficacy.

Yet there were falls in a marker of inflammation in the blood, the firm told the Alzheimer's Association International Conference in Los Angeles last week. There was also a drop in fragments of a protein called ApoE in people's spinal fluid. This protein is damaged by the bacterial toxin, and people who make a particular genetic variant of it are more likely to develop Alzheimer's.

The drop in both molecules suggests the medicine is working as intended, says Mike Detke of Cortexyme. "It's very promising."

Routledge says we shouldn't assume changes in blood or spinal fluid substances will translate into reduced dementia symptoms, as similar ones have given false hope in past trials of other approaches. "We definitely need some more data before we can understand the consequences of having this bacteria in the brain," she says.

Cortexyme has now begun a year-long trial in 570 people with Alzheimer's disease. ■

## Climate science

### Controversial climate study under investigation

A HIGH profile scientific journal is investigating a study it published that suggests global warming is largely down to natural solar cycles.

The study was published online on 24 June by *Scientific Reports*, an open access journal run by Nature Research. The authors say that Earth's 1°C temperature rise over the past two centuries could largely be explained by changes in

the distance between Earth and the sun as the sun orbits our solar system's centre of mass, called the barycentre.

Ken Rice at the University of Edinburgh, UK, criticised the paper for an "elementary" mistake about celestial mechanics. "It's well known that the sun moves around the barycentre of the solar system due to the influence of the other solar system bodies, mainly Jupiter," he says. "This does not mean, as the paper is claiming, that this then leads to changes in the distance between the sun and the Earth."

Rice is urging the journal to withdraw the paper.

"The sun-Earth distance does not vary with the motion of the sun-Earth system around the barycentre of the sun-Jupiter system, nor the sun-galactic centre system or any other purely mathematical reference point," says Gavin Schmidt of the NASA Goddard Institute for Space Studies. He says

**"The sun moves, but this doesn't change the distance between the sun and Earth"**

the journal must retract the paper if it wants to retain any credibility.

Lead author Valentina Zharkova of Northumbria University, UK, defended the study. "The close links between oscillations of solar baseline magnetic field, solar irradiance and temperature are established in our paper without any involvement of solar inertial motion."

A *Scientific Reports* spokesperson told *New Scientist* that it is aware of concerns raised over the paper, and that it has begun an "established process" to investigate the paper. Adam Vaughan

# Mind-controlled gadgets

Elon Musk wants to meld our minds with machines. Can it be done, asks **Ruby Prosser Scully**

ELON MUSK'S brain-computer interface company Neuralink has finally broken its silence. Since the company was formed in 2016, it has kept its plans secret, but in a presentation last week it showed off its vision and explained what the firm has done so far.

#### What is Neuralink making?

At the event, the company unveiled a brain-computer interface: a technology that allows machines to read brain activity. Neuralink says its device will have some 3000 surgically implanted electrodes, each of which will be able to monitor 1000 neurons at a time.

The electrodes will be embedded in about 100 threads between 4 and 6 micrometres wide, which is much less than the width of a human hair. The threads collect the measurements from the electrodes and will be connected to hardware through a small incision behind the ear, which will use bluetooth to send the data to a smartphone app.

#### Why would anyone want that?

Neuralink says uses could range from helping people with paralysis control prostheses to allowing us to directly interact with AI. "This is going to sound pretty weird, but [we want to] achieve a sort of symbiosis with artificial intelligence," said Musk (pictured above) at the event.

We rely on an interface with technology such as laptops that is slowed by our fingers or our eyes. Inserting a chip into our brains to speed things up will be key to overcoming that, he said.

#### Will it work?

Many research groups are working on brain-computer



DAVID CALVERT/BLOOMBERG VIA GETTY

interfaces and there has been some progress in recent years. One system, called BrainGate, is being trialled for people who have lost control of their limbs.

The implant converts brain activity to digital commands that can control prostheses. People have used similar devices to move a cursor on a screen, play *Pong* or control a robotic hand.

But mastering such devices takes time, and using them usually involves laboriously thinking about performing an intended action, for example selecting something on a screen.

**What has Neuralink done so far?** The company has tested the concept in mice and a monkey, although details are still sparse. With the mice, Neuralink says it used a bespoke robot, which the firm likened to a sewing machine, to individually insert 1500 electrodes into the brain.

During the Q&A session, Musk also revealed that a monkey has used the device to control a computer. This was later confirmed by a spokesperson, but we don't have any further information. Musk said the primary aim of the event was to recruit people to work for the company.

#### Are people excited about this?

The sophistication of Neuralink's technology is "very exciting", says Anthony Hannan at the Florey Institute of Neuroscience and Mental Health in Australia. He says the project could progress more rapidly than those of other smaller competitors because of Musk's entrepreneurialism and funding.

But it isn't all praise. Hannan is concerned about the idea that this technology could be used by people with no medical need for the device. Not only is it dangerous to perform an invasive surgery unnecessarily, but caution should be taken with any technology that has the potential to enable somebody else to read or control one's thoughts or actions, he says.

#### How soon might this happen?

Musk said that Neuralink's brain-machine interfaces could be ready for medical trials in humans by 2020.

Earlier this year, the US Food and Drug Administration released guidance on what firms



NEURALINK

Will a small device behind the ear one day relay your thoughts to your phone?

will need to demonstrate to get devices such as this approved, and the Neuralink team says it is working through that with the intention of having these implanted in people with spinal cord damage by the end of next year. ■

# Most online pornography sites leak user data

Adam Vaughan

MORE than 90 per cent of pornography sites leak data about the people browsing them to third-party companies including Google and Facebook.

Elena Maris at Microsoft Research and her colleagues analysed almost 22,500 pornography sites around the world. On average, sites leaked data to seven different locations, and in total to 230 different companies and services. Google received data from 74 per cent of sites, US tech giant Oracle 24 per cent and Facebook 10 per cent.

Tracking by advertising companies and other firms is widespread on many websites, but the team warns that the addresses of pornography sites could reveal uniquely compromising information about a user's sexual preferences to companies without consent.

"The consequences of just the URLs you've visited being revealed without your consent could be dire," says Maris. "Imagine the

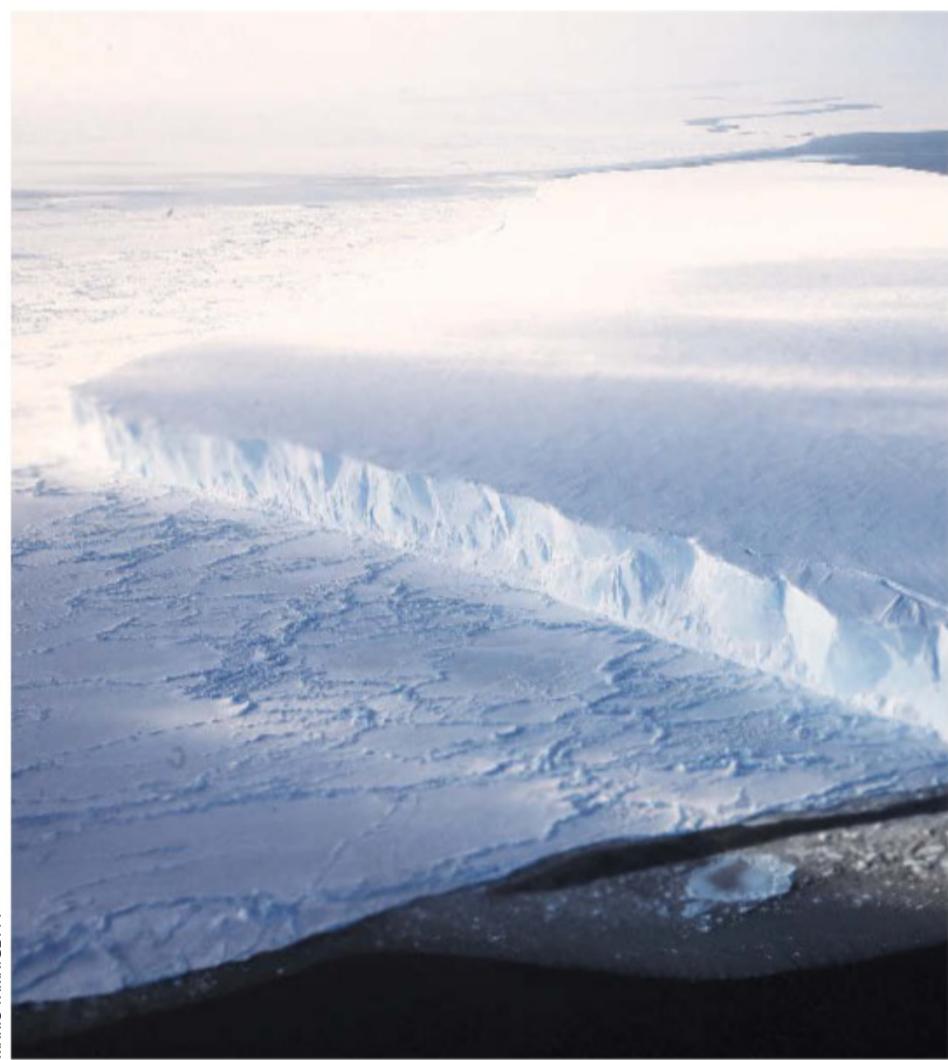
**90%**

of online pornography sites track visitors in some way

consequences for, perhaps, a conservative religious leader who regularly views gay porn having these interests revealed to his community."

Almost 45 per cent of the addresses gave an idea of the site's content, suggesting a user's sexual orientation and preferences, the team found after analysing the URLs for 378 of the total 22,484 sites ([arxiv.org/abs/1907.06520](https://arxiv.org/abs/1907.06520)).

Less than a fifth of all the sites had privacy policies that the team could extract. Those with a policy listed only a tenth of the third parties tracking people, which the team says means users have no way to learn which firms have "troves of data" on their pornography use. ■



MARIO TAMA/GETTY

## Climate change

# Drastic geoengineering could help stem rising seas

PUMPING huge amounts of ocean water onto the West Antarctic ice sheet could stop it collapsing and raising sea levels so much that they would threaten cities like New York.

But researchers who explored the idea admit the intervention would require an unprecedented effort in one of the harshest places on the planet. It would cost hundreds of billions of dollars and could devastate ecosystems there.

Five years ago, studies suggested that the West Antarctic ice sheet had begun an unstoppable collapse. While the process would take centuries, it would raise sea levels enough to hit major coastal cities.

So Anders Levermann of the Potsdam Institute in Germany and his colleagues simulated the idea of pumping ocean water onto the sheet, adding it either in liquid form

or as snow. They say stabilising the collapse would require at least 7400 gigatonnes of the stuff over 10 years (*Science Advances*, doi.org/c8jg). Levermann says he is against global geoengineering such as giant sunshades, but this idea is different and more surgical.

Even if we agreed to do it, there are big obstacles. About 145GW of wind farm capacity would be needed to power pumps, 12 times that installed in Europe last year. New turbine materials would be needed to cope with the cold and the area would become an "industrial compound", says Levermann.

Clive Hamilton at Charles Sturt University in Australia says: "The conditions under which such a scheme could be implemented are beyond anything feasible. It's not going to happen." Adam Vaughan

## Bionics

# Smart skin for sensitive robots

AN ARTIFICIAL skin that senses temperature and pressure can send signals 1000 times faster than the human nervous system.

Benjamin Tee at the National University of Singapore and his colleagues created the rubber and plastic skin, which has tiny sensors that can detect pressure, bending and temperature.

When the skin presses against something, the sensors transmit electrical pulses back to one receiver. Each sensor has a unique pulse to make it identifiable, meaning multiple signals can be combined through the one receiver, speeding up delivery.

Unlike in most electronic systems, all of the sensors are connected together using one wire, meaning that measurements from across the skin arrive at the same time. Human skin sensors send signals at a maximum

frequency of less than 1kHz, or 1000 times per second. In contrast, Tee's sensors send back signals at 9MHz, or 9 million times per second.

The team designed different types of sensors to better mirror human touch. One responded to quick, dynamic changes, another to static forces, producing signals that increased in frequency as the force on it increased. A third type sensed temperatures.

Tee and his colleagues then put the skin onto a prosthetic hand that grasped a hot cup of coffee and found that all three types of sensations were recorded (*Science Robotics*, doi.org/c8jq).

"[This] has the potential to greatly simplify and make it possible for robots to have whole-body skin, just like humans," says Tee. Another possible use of the skin could be to cover prosthetic limbs. This might one day help people use them better, and restore sensation to those who have lost it. **Ruby Prosser Scully**

## Antibiotics

# Secrets of how vital drugs harm hearing

SOME life-saving antibiotics that kill a broad range of bacteria can also cause hearing loss, and we may now know why.

Known as aminoglycosides, these drugs are useful for treating infections in newborns, which can prove fatal within one or two days, too soon for tests to reveal the microbe responsible.

To better understand why this class of antibiotics is linked with

hearing loss, Peter Steyger at Creighton University in Nebraska and his colleagues tested the effects of one such drug, gentamicin, on hearing in mice.

They found that infection and inflammation left ion channels in sensory hair cells (pictured) more permeable to gentamicin, leading to more of it being taken up by the sensitive cells in the cochlea of the inner ear. This amplified the toxic effects of the drug on the cells.

Steyger and his team found that one particular protein, called TRPV1, facilitated gentamicin's entry into hair cells in the presence of inflammation or an immune response. Mice bred without working TRPV1 were protected from hearing loss caused by gentamicin (*Science Advances*, doi.org/c8jn).

Steyger hopes new techniques that can identify microbes more rapidly will mean doctors may soon be less reliant on broad-spectrum antibiotics to treat newborns. **RPS**



P. MOTTA/DEPT. ANATOMY/UNI. LA SAPIENZA, ROMA/SPL

## Really brief



### Psychology

## Money influences our view of luck

DO PEOPLE owe their wealth to skill or luck? Your views on this may be set by your own financial gains, at least according to a study of people playing a card game.

In a simplified two-player version of card game President involving cash prizes, winners were more likely than losers to credit skill not luck. This was the case even though it was clear the game involved little skill and the odds were rigged in their favour.

Mauricio Bucca of the European University Institute in Florence, Italy, recruited about 1000 people to play through a website, giving people \$2.50 for taking part and a \$5 bonus if they won.

Whoever was randomly picked to play the first card in round one always had an advantage that meant they were most likely to win that round. In some versions, this advantage was boosted in round two. In other versions, the opposite happened: the round one loser was given an unfair advantage.

At the end of their game, people were asked if it had been fair.

Winners of the bonus were more likely to say yes than losers. Even when the winners benefited from receiving either one or two strong cards from their opponent, they were twice as likely to judge it a fair game as the losers.

What is more, in most versions of the game, winners were more likely than losers to attribute success in the game to talent (*Science Advances*, doi.org/c8js).

The phenomenon is probably even stronger in real life because we are more likely to be influenced by personal circumstances, says Bucca. **Clare Wilson**

### Parasite brings down mosquitoes

A bacterial parasite that hampers fertility in Asian tiger mosquitoes (*Aedes albopictus*) has been used to reduce the number of biting female insects by more than 80 per cent at two sites in Guangzhou, China (*Nature*, doi.org/c8kg). Similar approaches have been tried elsewhere before, but are yet to be used on a large scale.

### Chimps bond after watching movies

Chimpanzees who watch a short film with a human or another chimp are more likely to then approach that individual or spend time near them, a study has found. This suggests chimps feel closer to those they have shared an experience with, just like we do (*Proceedings of the Royal Society B*, doi.org/c8j6).

### Drones can keep white rhinos safer

Protecting southern white rhinos from poachers in South Africa is costly, so could cheap drones be the answer? Researchers found that drones can be used to scare rhinos away from poaching hotspots, such as near buildings and roads (*Proceedings of the Royal Society B*, doi.org/c8kb).

### Animal behaviour



## Scratch used as a stealthy signal by some great apes

ORANGUTAN mothers use loud scratches to tell their infants that it is time to leave an area and move to another, possibly to avoid attracting predators or other orangutans.

Marlen Fröhlich at the University of Zurich in Switzerland and her colleagues noticed wild Sumatran orangutans in the Suaq Balimbing forest in Sumatra, Indonesia, would sometimes scratch themselves in a loud and exaggerated way.

Fröhlich and her team analysed 1457 bouts of scratching produced by 17 different orangutans, including four mothers and their dependent offspring. They noted the behaviour that occurred before

and after each of these occasions.

Exaggerated scratches were overwhelmingly produced by mothers shortly before moving. They were usually directed towards a dependent offspring who was paying attention to them and who responded by moving towards the mother, says Fröhlich.

As a result, these loud scratches could be distinguished from normal scratches and appear to be used to tell infants that it is time to leave (*Biology Letters*, doi.org/c8jj).

Fröhlich says that looking at other orangutans may reveal whether this is evolved behaviour or culturally learned. **RPS**

### Nanotechnology

## A liquid magnet that keeps its attraction

NOT all magnets have to be solids: a type of liquid magnet has been developed that may eventually help control wireless soft robots.

Liquid magnets of a sort already exist, called ferrofluids. These are a mixture of a non-magnetic liquid and solid magnetic nanoparticles. However, they act like magnets only when under the influence of an external magnetic field. Now Thomas Russell at the University of Massachusetts, Amherst, and his colleagues have been able to turn a ferrofluid into a fluid that retains its magnetic properties.

They did this using magnetic nanoparticles containing iron oxide. When those particles float freely in liquid hydrocarbon, they create a ferrofluid. The researchers found that when there are enough particles to cover the surface of a droplet and jam together, the droplet stays magnetic. The interior remains liquid.

When exposed to magnetic fields, the droplets could move around or change shape, and if the magnetic field rotated, the drops spun too. This means they could eventually be used to move parts of soft robots. That would require an external magnetic field, but no wires or internal batteries (*Science*, doi.org/c8jv). **Leah Crane**

# Goodbye fishbowl helmet

The next generation of astronauts will be wearing a zip-uppable "space hoodie"



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Sun protection

# Sunscreen safety fears

Common ingredients in sunscreens have question marks hanging over them. Should we be worried, asks **Jessica Hamzelou**

SUMMER has returned to the northern hemisphere, and many will be reminded to slather on the sunscreen to keep sunburn at bay. But after recent developments, some may hesitate, wondering if sunscreen is totally safe.

In the past five months, the US body that regulates sunscreen has declared that 12 active ingredients used in sunscreens might not actually be safe. And in a study published in May, the organisation found that four of these ingredients enter the bloodstream through the skin.

The revelations have come from the US at least partly because sunscreens there are, unusually, regulated as over-the-counter drugs. But similar products are sold around the world. And sunscreens may be only the tip of the iceberg, with general

**Sunscreen protects the skin, but we know less about its other effects**

cosmetics starting to come under scrutiny too.

There is no need to drastically change your behaviour just yet as none of the commonly used ingredients have been decidedly declared unsafe, but questions remain. Why are these concerns only coming now? And how worried should we be about the stuff we put on our skin?

In most countries, sunscreens are classified as cosmetic products. In the European Union, they are subject to rules on which ingredients can be used, and must pass tests for skin and eye irritation, for example.

In the US, however, sunscreens, including cosmetics marketed with a sun protection factor, are regulated like drugs because they make specific health claims: to reduce the chances of sunburn, skin ageing and skin cancers. The US Food and Drug Administration (FDA) issues rules for industry to follow and new drugs must

undergo rigorous clinical trials in people, but because sunscreens were already marketed before these rules took effect, their safety has been reviewed after the fact.

Although the first sunscreens came onto the market in the 1920s, it took the FDA 50 years to issue any regulations. In 1978, it finally

**"Only two of the original 16 'safe' ingredients can actually be considered safe and effective"**

issued a tentative set of rules and updated them in 1999, listing 16 active ingredients as safe. However, these ingredients are now coming under scrutiny.

Take oxybenzone, for example, which is widely used in sunscreens. In 2008, the US Centers for Disease Control and Prevention found traces of it in the urine of 97 per cent of the 2500 people it tested. Other studies have found the chemical in breast milk.

"There is some evidence that oxybenzone may be a hormone disruptor, and act as a very weak oestrogen," says Kim Harley at the University of California, Berkeley. Some cancers have an oestrogen component. "The issue is that there's so much we don't know," she says.

Similar questions have been raised about the other ingredients.

The FDA issued new proposed rules in February this year, saying that only two of the original 16 "safe" ingredients can actually be considered safe and effective: zinc oxide and titanium dioxide. Of the remaining ingredients, two will be banned, while the rest, including oxybenzone, have big question marks over them.

Then, in May, the FDA published a study looking at four of these ingredients, again including oxybenzone. Researchers including Theresa Michele, who directs the organisation's Division of Nonprescription Drugs, applied one of four sunscreen products to 24 volunteers, following the products' instructions for maximal use, four times a day for four days. They then looked for traces of the chemicals in the volunteers' blood.

Not only did all four chemicals turn up in the blood, they did so at levels that demand further research to make sure they aren't causing cancer, says Michele.

Dermatologist Kanade Shinkai, based at the University of California San Francisco Medical Center, says she thought sunscreen would pass through the skin. But what was a surprise was that it was absorbed after the first application and that it persists for days, she says.

So, is it time to throw out your sun protection? Not so fast. "I think sunscreen is important because we know the sun causes



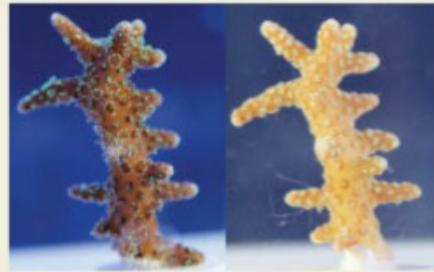
KOEN SUYK/EPASHUTTERSTOCK

## Toxic for reefs

As of January next year, visitors to Palau, an island country in the western Pacific, will be prohibited from buying or using a range of sunscreens. The country has classified products containing any of 10 commonly used sun filters and preservatives as "reef-toxic", as they are thought to harm coral reefs. Other places have followed suit, and similar bans will come into effect in 2021 in Hawaii and in Key West, Florida.

Craig Downs at Haereticus Environmental Laboratory in Virginia and his colleagues ran laboratory experiments to assess the problem. They found that immature corals exposed to oxybenzone (see main article), an ingredient that is commonly used in sunscreens, die.

The corals became deformed and pale in colour, and were



unable to eat, as depicted in the images above. "Their mouths just opened, and it looked like a horror movie scream," says Downs. "They were as good as dead in the first 8 hours."

Sunscreen manufacturers have said that lab-based experiments can't tell us what happens in the real world, but more bans are likely. "We have one reef, and we have to do one small thing to protect that," Teri Johnston, mayor of Key West, was quoted as saying before the city's vote on sunscreen. "It's our obligation."

CRAIG DOWNS/HAERETICUS

cancer," says Harley. "But these compounds are getting into our bodies, and what's concerning is that there's a real lack of information on what the consequences could be."

Manufacturers can point to the fact that all these ingredients were deemed safe by the FDA and we have been using sunscreen for decades without seeing detrimental effects.

"Back in the 70s, we thought that anything you put on the skin just stayed there," says Michele. "We never thought that things could be absorbed by the skin."

Similar concerns are now being raised about the chemicals in cosmetics too. They face little regulation in the US and have had the same level of scrutiny as sunscreen in the EU. This means that few studies have

been done about which chemicals in cosmetics can enter the bloodstream and what their effects may be.

Part of the problem comes from complaints falling through the cracks. If someone in the US complains of an adverse drug effect to its manufacturer, then the company has to report it to the FDA. But this isn't the case for cosmetics, meaning issues can go unnoticed.

Take the case of hair product WEN by Chaz Dean Cleansing Conditioners. In 2014, the FDA began investigating the product after it received 127 complaints directly from consumers. It later discovered that, by this point, the company had already received 21,000 complaints of hair loss and scalp irritation. The FDA hasn't yet announced an end to its

investigation, but its options are limited. The product is still on sale.

In the European Union, people are expected to report issues to their national authorities.

Problems persist with other cosmetic products too. Despite this, Steve Xu at Northwestern University in Chicago and his colleagues found that, between 2004 and 2016, only 5144 adverse events were submitted to the FDA.

## Cosmetic issues

"What we saw was very low," says Xu, who, as a dermatologist, says he sees patients with skin irritation resulting from personal care products on a daily basis. "That tells me people are not going to the FDA, they're going to the manufacturer, and the manufacturer is a black hole."

There have been attempts to tighten regulation of cosmetics in the US, but without much success.

In the meantime, researchers aren't saying that cosmetics are unsafe. Just that their full effects are unknown.

As for sunscreen, while the recent FDA rules are due to be finalised by November, it is unlikely we will have the final word on the 12 ingredients still under investigation then. Michele says the industry has asked for eight of the ingredients to be left off the list to allow for extra data to be collected. "This is a proposed rule, so it's not final yet," she says. "We're currently reviewing comments."

In the meantime, if you are worried about sunscreens, one option is to stick to products that use zinc oxide or titanium dioxide as an active ingredient. These are "generally recognised as safe and effective" by the FDA. And taking other sun protection measures, such as covering up and seeking shade in peak hours, is also vital. ■



## ▲ Penguins

Criminals always return to the scene of a crime. Two penguins were removed by police from a New Zealand sushi shop only to return a few hours later.

## ▲ Steep streets

Residents of Harlech have been left feeling on top of the world after one of the Welsh town's streets was named the steepest on the planet.

## ▲ Robot umpires

You're outta there! A robot baseball umpire ejected a pitching coach from a game in the US for arguing with its decision.

## ▼ Airline tweets

A tweet by Dutch airline KLM crashed and burned, after it revealed the seats with the highest risk of death during an accident.

## ▼ Tech names

Need a name for your child, then why not try Google? One family took this a little too literally by naming their newborn after the search engine.



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USA

# Cruise Hawaii with Richard Dawkins

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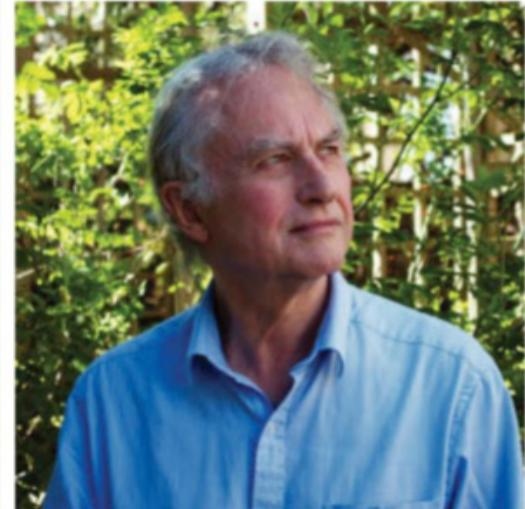
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Richard Dawkins will discuss what Hawaii reveals about evolution

## The columnist

Annalee Newitz on the monetisation of online emotion **p24**

## Letters

The different ways people use language about time **p26**

## Aperture

Whale sharks stuff their faces off the Indonesian coast **p28**

## Culture

Your garden can be every bit as exciting as the rainforest **p30**

## Culture columnist

Games on mental illness need depth, says Jacob Aron **p32**

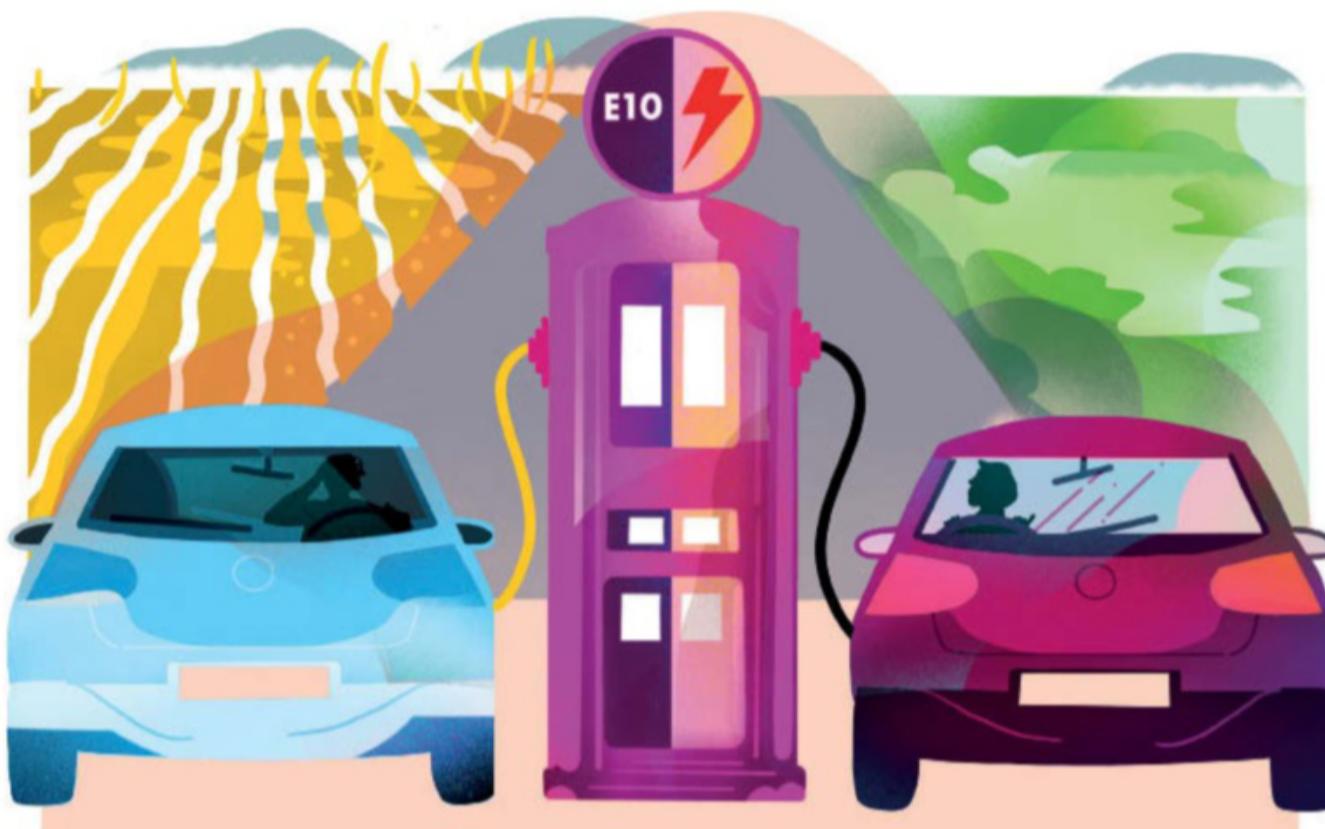
## Comment

# The biofuel delusion

UK parliamentarians want to add more bioethanol to petrol. That is a dangerous distraction from real climate action, says **Michael Le Page**



Michael Le Page is an environment reporter for New Scientist @mijflepage



THE UK should burn more alcohol to go greener, a group of MPs styling themselves the All-Party Parliamentary Group for British Bioethanol said last week. They want the UK government to increase the amount of bioethanol in standard unleaded petrol from 5 to 10 per cent.

Such "E10" fuel is already sold in many countries, including the US, Australia and several European nations. Yet it is a social and environmental disaster.

Biodiversity is under threat, and we need to preserve habitats, not destroy them. But growing crops to make biofuel increases

the global demand for farmland and results in the loss of ever more wilderness. By pushing up food prices and encouraging land grabs, biofuels also deepen poverty and social division.

They aren't even that great at limiting climate change. Growing them produces greenhouse gases in all kinds of ways, from carbon dioxide when fertilisers are manufactured to nitrous oxide when they are applied to fields. Add to that people cutting down forests that store lots of carbon to create more farmland.

The official carbon footprint of petrol and diesel in the European Union is 84 grams of

carbon dioxide or the equivalent for every megajoule of energy ( $\text{CO}_2 \text{ eq/MJ}$ ). According to a 2017 study by the Royal Academy of Engineering in the UK, producing bioethanol from wheat – the main crop used for this purpose in the UK – emits around 100g  $\text{CO}_2 \text{ eq/MJ}$  on average, once land-use change is taken into account.

Other sources at least emit less than petrol and diesel. Bioethanol made from sugar beet – another crop used in the UK – comes in at around 50g  $\text{CO}_2 \text{ eq/MJ}$  on average, counting land use.

But the UK's official aim is to reduce its emissions to net zero by 2050. Even using only sugar-beet

bioethanol for blending with petrol wouldn't get us close to what is needed.

Not all biofuels are bad. Those made from genuine waste really can tick all the boxes, but they are in limited supply. When it comes to petrol, there is a far better alternative: electricity. So say the UK government's official climate advisers. "We don't see a long-term role for biofuels in surface transport given other low-carbon options available," a spokesperson for the Committee on Climate Change tells me. "The shift to electric cars and vans is both low carbon and cost saving."

A pity, then, that while others such as China and Norway motor ahead, the UK is going backwards. If the UK is to meet its net-zero target, radical change is required, including ending the sale of petrol cars by 2030.

Cutting emissions is admittedly not the main driver behind the MPs advocating for more biofuel. Instead, the key reason they give is to save "the British bioethanol industry" and prevent "the loss of thousands of jobs".

The saving jobs argument can be used to justify anything, from coal mining to whaling. Suffice to say that the all-out effort needed to get to net zero would generate a huge number of jobs. We need to get on with it instead of wasting time and money on E10 fuel. ■

## This changes everything

**You've been monetized lol** We are free to express our emotions online using animations and wacky videos set to music, but there are costs ahead, writes **Annalee Newitz**



Annalee Newitz is a science journalist and author. Her novel *Autonomous* won the Lambda Literary Award and she is the co-host of the Hugo-nominated podcast *Our Opinions Are Correct*. You can follow her @annaleen and her website is [techsploitation.com](http://techsploitation.com)

### Annalee's week

#### What I'm reading

*Mike Chen's moving and action-packed novel Here and Now and Then, about a stranded time traveller.*

#### What I'm watching

*I just saw the pilot of the new Batwoman TV show at San Diego Comic-Con and it was delightful.*

#### What I'm working on

*Making my first TikTok video.*

This column will appear monthly. Up next week: James Wong

**M**Y TEXTING style is pretty salty. I curse a lot, generally in a friendly way, but my phone's autocomplete functionality is really cramping my style. No, I didn't mean "duck". I wasn't typing "fick", "five", "dock" or (when my poor algorithm gets desperate) "Fuchs". You know what I wanted to say, dear reader, and it's one of the most commonly spoken words in English. And yet I have to correct my phone's autocorrection to write it.

I'm not the only one with this problem. Linguist Gretchen McCulloch, whose new book *Because Internet* is a fascinating exploration of how the internet is changing our language, points out that spellcheckers have quite literally divided nations.

Although the spellings "accessorize" and "accessorise" are both technically correct in British English, localized spellcheck programs had to settle on one, and so programmers chose the "ise" ending. Writing this in the US, I'm getting an angry red line under "accessorise" because my localized spellchecker was programmed to prefer "ize". As a result, says McCulloch, people in the UK are now convinced there is only one proper spelling of any of a number of words that end in "ise", even though that's not grammatically true.

McCulloch has tracked the evolution of internet language across generations, starting with "Old Internet People" who came of age in 1980s forums like Usenet, and ending with "Post-Internet People" whose parents had Facebook before they did. Despite everything that has changed, one thing has remained steady: "lol", which started as all-caps LOL (laughing out loud) in 1980s chat forums, and has now taken on

so many subtleties that several linguists have subjected it to study.

Ultimately what they found was that young internet users add "lol" to sentences where they want to indicate a second layer of meaning. Sometimes it signals sarcasm (studying is fun lol), but at other times it is meant to soften what could seem like an insult (don't be a git lol) or for half-serious flirting (u r cute lol). "Lol" has come to stand in for what McCulloch calls "nervous laughter, social laughter, and polite smiles".

The thicket of meaning that has grown up around "lol" is nothing compared with the complexity of

#### "What does the exploding head emoji mean? And let's not even start on the upside-down red triangle"



emoji. What does the exploding head emoji mean? How about the X-eye face? Is it dead or drunk or both? And let's not even start on the eggplant, the upside-down red triangle and clapping hands in between every word in a sentence.

Chinese artist Xu Bing wrote an entire novel in emoji and international symbols called *Book from the Ground*, which he claimed anyone can understand. Meanwhile, cultural critics worry that emoji limit our ability to express emotion by forcing us to use symbols of consumer capitalism (high-heeled shoes, men in suits, purses, cocktail glasses) to say how we feel. Even if you don't buy that, there's no

denying that emoji paralysis – that uncertain feeling as you hover between picking the super smiley face and the semi-smiley face – is real. Emoji sometimes trap us into expressing feelings we aren't sure we have.

These issues are heightened on social apps like TikTok, which allows users to shoot 15 seconds of video and set it to pop music. With its parent company claiming a billion users, TikTok is one of the world's fastest growing social media fads among people under 25. TikTokers communicate entirely by sharing videos, usually with music as a major component.

For people without TikTok, though, there's an old-fashioned version of the same thing. Gifs, or short animations on loop, have become the flashier version of emoji everywhere from Slack to instant messaging apps. Some Twitter threads consist entirely of people posting gifs at each other. One firm, Giphy, provides most of the gifs that pop up helpfully when you're searching for the perfect vid to express your emotions.

Although many of us use Giphy every day, few realize what its ultimate goal is. Eventually it wants to monetize gifs, and the easiest way to do it will be to supply branded ones. So the next time you are texting your friends and you search for an animation of Iron Man raising his eyebrows and expressing your dubious feelings, you may wind up inserting an ad for Disney's Marvel Studios into what you thought was just a funny exchange with a pal.

So far, no firm has been able to turn chat into an advertising platform like Facebook, but Giphy is hoping to. Now your emotions won't just be turned into little smiling faces, or wacky videos set to music. They will be branded and monetized. ■



CZECH REPUBLIC

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- › Exploring Benatky Castle, where Tycho Brahe lived
- › A visit to the National Technical Museum and its fascinating astronomical section, as well as Tyn Church where Kepler's mentor Tycho Brahe is buried.

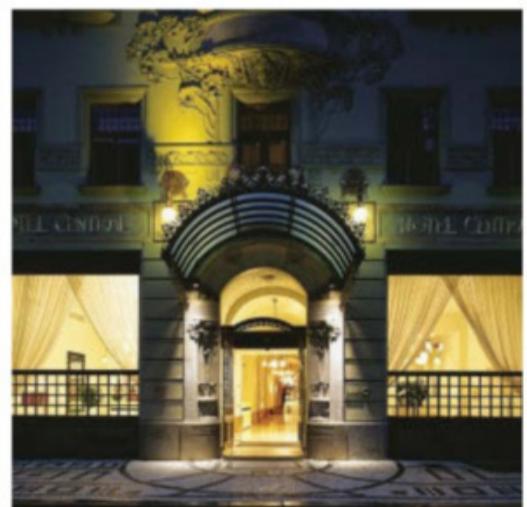
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## Editor's pick

### How different peoples use language about time

6 July, p 32

From Chris Sinha and Vera da Silva Sinha, Norwich, UK

"When we talk about time, we frame it in terms of space", writes Daniel Cossins. Indeed, "we" do, and "time as space" is a common metaphor in many languages. It reflects the close link between the way the human brain processes spatial and temporal sequences. But it equally reflects the cultural and historical invention of "time" as an independent domain – "time as such" – that contains events or strings them along a mental line.

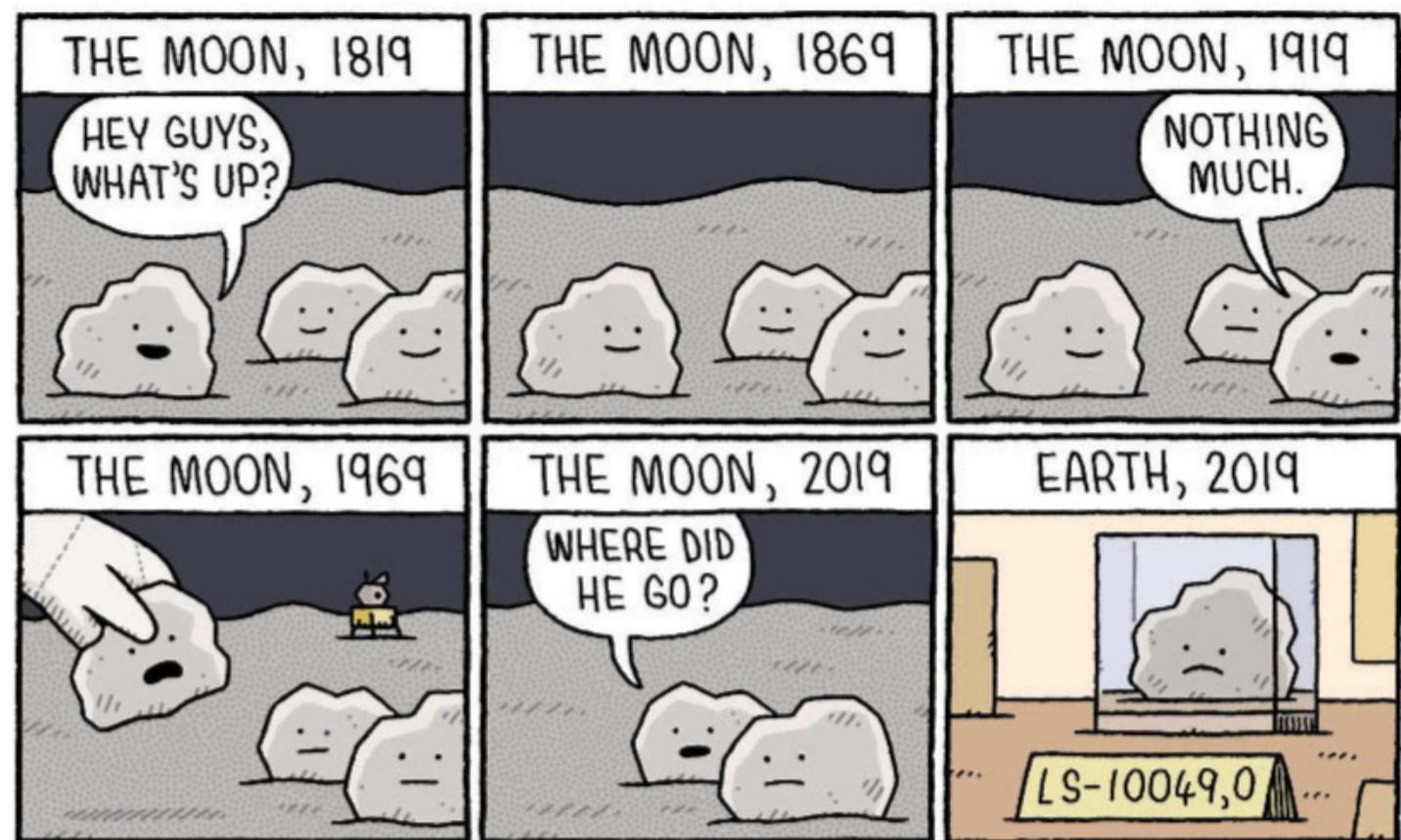
For nearly a decade, we have been documenting languages of small-scale indigenous communities in South America in which there are no spatial metaphors for time (8 October 2011, p 47). These communities don't, traditionally, use clocks and calendars. Their members don't conceptualise time as extended along a mental timeline. Instead, they think and talk about time in terms of events recurring in the natural and social world. Time metaphors in their languages are based on human psychological capacities such as vision and memory.

Event-based time is a human universal – we use it when we agree to meet someone at lunch or decide to have a holiday in the spring. The use of clock and calendar-based metric time intervals is the foundation of the concept of "time as such". We believe that this invented cognitive technology is also the basis for spatial metaphors for time.

Many cognitive scientists have yet to fully take on board the challenge of representing cultural and linguistic diversity in their theories about the human mind.

From Phil Ball,  
London, UK

Cossins suggests that people who speak different languages represent the passing of time in



TOM GAULD for NEW SCIENTIST

different ways – left to right in English and vertically in Mandarin speakers. Couldn't this just be due to the writing systems they use? How do speakers of Arabic, written from right to left, represent time?

### Hand weeding really isn't effective for most crops

22 June, p 12

From Mary Rose,  
Goolwa, South Australia  
Discussing superweeds, you say that hand weeding crops is effective, though costly. But it can be effective only for crops grown in narrow rows with wide spaces between rows that people can walk along. Otherwise the weeders will trample the crop.

Some vegetables are grown like this. But here in Australia, commercial crops of cereals, oil seeds, field legumes and grass for hay are grown in a way that leaves no room for hand weeding.

A wheat crop could have 100 plants per square metre and 50 seedlings of the weed annual ryegrass per square metre. Not only would the wheat be trampled by hand weeding, but I suspect it would take more energy to weed

than the crop would produce. Are there enough people in the world to weed the extensive areas that the world now farms to feed us all?

### Let data storage means not slip from human memory

6 July, p 15

From Judith Phillips, Swansea, UK  
You report researchers encoding the Gettysburg Address in DNA. This reminded me of the pilot project I worked on in the late 60s at the British Museum Department of Printed Books, cataloguing part of its 18th-century newspaper collection into a machine-readable format. We shared the project and computer time with the Bodleian Library.

Once a week, what I had typed was taken to Oxford to be entered onto the system. The raw data were stored on reels of punched tape, as in your photo (not punched cards, as you captioned it). I realise that all of this was a very long time ago, but card and tape are very different ways of storing information. I would hope that these earliest ways of storing computer data haven't passed altogether beyond living memory.

### Build a better hearing aid and they will come

25 May, p 16

From Alan Gordon,  
Shoreham-by-Sea, West Sussex, UK  
Michael Le Page writes about work towards hearing aids that monitor the user's brainwaves to tell which voice they are trying to pay attention to. This is leaping to the roof without climbing the stairs.

The more urgent, and easier, task would be to redesign hearing aids so that they don't lose the directionality given by the shape of the ear. As a user of an in-ear moulding hearing aid, I suffer from this lack. As an engineer, I can see the start of the solution but, being 86, don't have the resources to do my own redesign.

### This could be a better way to visit Proxima Centauri

Letters, 1 June

From Aidan Karley,  
Perth, UK

John Fewster is concerned that the Breakthrough Starshot swarm of microprobes could be viewed as a hostile act by inhabitants of the Alpha Centauri system it is aiming

for, as their kinetic energy is equivalent to half a kiloton of TNT explosive. Routinely, Earth is hit by bolides with energy equivalent to tens or hundreds of kilotons of TNT, and nobody but a few astronomers and the Nuclear Test Ban Treaty monitors notices.

The Breakthrough Starshot project talks of zipping past Alpha Centauri. A quick way to the nearby Proxima Centauri and its putative planet has been proposed by astrophysicists René Heller and Michael Hippke. It involves braking at Alpha Centauri and performing a gravitational slingshot, before drifting to Proxima Centauri at a relatively sedate pace. This braking could be achieved by sending probes with light sails large enough that they can be "flipped" and so decelerate using the light of Alpha Centauri.

## Successful surgery isn't just about surgeons

15 June, p 20

From Andrew Vickers,  
Lancaster, UK

Ruby Prosser Scully highlights the growth of robotic surgery and questions whether it achieves better outcomes. Many factors may contribute to this growth, including profit from offering "space-age treatment" and the temptation of toys for the boys.

But assessing the outcome of surgery based solely on the skill of the surgeon hasn't been appropriate since 1847, when anaesthesia was introduced. Now surgery is a team effort, including pre-operative optimisation, management by an anaesthetist and others during surgery and post-operative care. All these factors need to be considered when assessing putative benefits of robot-assisted surgery.

In extremis, I would be happy to accept a skilled surgeon

operating at a distance via a robot, with supporting staff who are unfamiliar with the procedure. For planned surgery, however, I want to be managed by a team working in a centre where the procedure in question is carried out regularly and successfully.

## Our brains may depend on a discovery of cooked food

22 June, p 34

From Neil Doherty,  
Wilthorpe, South Yorkshire, UK

Sam Wong writes that our intelligence was possibly enabled by the invention of cooking. But to say that we invented cooking is to suggest that someone once sat down and thought: "I could set some stones up in a ring... then rub a couple of sticks together" – and simultaneously invented fire and cooking.

Injured or slow-moving animals caught in fires caused by volcanoes or lightning provided plenty of opportunities to discover cooked meat. Tens of thousands of years later, perhaps our brains had wired up sufficiently to invent a place suitable for us to cook in.

## What should get in a flap over this tiny flying robot?

6 July, p 16

From Steve Dalton,  
Chipstead, Kent, UK

The RoboBee X-wing is an amazing piece of engineering. But is it bird and bat-proof? More importantly, are birds and bats it-proof?

## For the record

**I**The primary motor cortex is nearer the front of the brain than we showed it (22 June, p 34).

**I**Still floating in a tin can: the Apollo 11 mission took 75 hours 49 minutes to get from Earth to lunar orbit (13 July, p 37).

## 25 years ago, *New Scientist* was viewing an eagerly anticipated astronomical catastrophe



IT WAS, we wrote on 23 July 1994, the astronomical event of the century: the first time we had ever had advanced notice of a collision between a comet and a planet. And it lived up to its billing. "Only the most naive amateur astronomers could have been disappointed by the fireworks when the fragments of Comet Shoemaker-Levy 9 hit Jupiter this week," wrote our correspondent Jeff Hecht.

The comet had been discovered by astronomers Carolyn and Eugene Shoemaker and David Levy the year before, orbiting Jupiter on a wildly eccentric course – one that would lead to its spectacular end in the upper atmosphere of the gas giant.

Better still, from a planetary science point of view, there would be more than one collision to observe. When the comet was spotted, it had already been broken up into pieces by Jupiter's gravity, thought to have happened in 1992, with the rocks strung out in a line like pearls.

"The fragments hit the far side of Jupiter, so the collisions could not be observed directly from Earth," we advised anyone worried they might have missed something. "However, they were close to the visible edge of the planet," Hecht wrote, "and Jupiter's rapid rotation – its day is only 10 hours long – brought the crash sites into view a few minutes after the fragments hit the Jovian atmosphere."

Fragment A entered Jupiter's southern hemisphere on 16 July 1994. Over the next six days, 21 impacts were seen. The largest was on 18 July, when fragment G hit, creating a dark spot over 12,000 kilometres across.

The following week, on 30 July, Hecht catalogued an exhausting week of feverish observation. "During the week-long spectacle, telescopes around the world recorded thousands of pictures at every possible wavelength – visible, infrared and ultraviolet," he wrote. "The cataclysmic images included fireballs 2000 kilometres across rising above the rim of Jupiter."

The images were enough to frighten the US Congress into taking the possibility of asteroids and comets heading towards Earth a bit more seriously. "As pieces of comet pelted Jupiter last week," Hecht reported, "the House Committee on Science, Space, and Technology decided that NASA should be required 'to catalogue and track any major comets or asteroids that may cross the orbit of the Earth!'" Simon Ings

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## A real mouthful



Photographer **Michael Aw**  
Agency **Image Quest Marine**

"FISH are friends, not food," goes the famous line in the film *Finding Nemo*. But these whale sharks clearly didn't get the memo. The filter feeders strain small fish and plankton from the water using their large mouths, which can reach 1.5 metres wide in the biggest individuals.

Whale sharks, *Rhincodon typus*, are the biggest fish on Earth, reaching up to 20 metres long and weighing up to 20 tonnes. Despite their size, the slow-moving giants aren't dangerous to humans – juveniles have been known to play with divers. But humans are a threat to them, with the species considered endangered as numbers decline from fishing, accidental capture alongside other fish, and collisions with vessels.

This photograph was taken in Cenderawasih Bay, off the coast of the Indonesian provinces of Papua and West Papua. Whale sharks are found year-round here, often emerging at the water's surface and swimming close to bagan, mobile fishing platforms with attached fish traps or nets. The sharks have learned to feed on fish through nets, and also receive handouts from locals.

Around the world, whale sharks are found in tropical waters. They tend to cluster at various coastal areas, drawn by seasonal increases in prey, including zooplankton blooms and fish spawning. While they spend the majority of their time in the top 200 metres of the ocean, the sharks regularly dive to more than 500 metres, with some dives to depths of more than 1 kilometre recorded. ■

**Donna Lu**

# Your very own Serengeti

Our gardens can be every bit as enthralling as a slice of savannah or rainforest if you know where to look – and who to ask. **Adrian Barnett** explores



## Book

### The Garden Jungle: Or gardening to save the planet

**Dave Goulson**  
Jonathan Cape

HERE in Manaus in the heart of Amazonia, my garden may not house the tapirs, jaguars and monkeys that are ecotourism's poster species in this part of the world, but it still has an impressive array of predators and potential prey lurking in the undergrowth. They are smaller than the average mammal, often with more limbs.

But what they lack in size and furriness they make up for in diversity. A crab spider sits poised on the petal of a hibiscus flower, waiting to pluck spiderlings from mid-air. Centimetres away, a lime-green grasshopper chews the top off a flower bud, ensuring its wine-red petals will emerge with a rather elegant ornamental pattern. Above, in the passion vine, a hummingbird chitters as it finally frees itself from the web of a *Nephila* spider.

But this is the Amazon and even a medium-sized garden will bustle with biodiversity. Very Darwinian and to be expected in what is in fact a garden in a jungle – just not the type Dave Goulson reveals in his new book, *The Garden Jungle*.

His compelling view of gardens needs a perspective shift. Goulson, an entomologist at the University of Sussex, UK, recalls the words of TV naturalist Chris Packham saying "he would rather spend 10 minutes lying on his tummy watching a woodlouse than an hour watching a glossy television programme about lions".

So Goulson swaps my tropical hibiscus for hydrangea and passion flower for pansy, getting



down into the urban undergrowth with a hand lens to find an ecosystem every bit as surprising and enchanting as any tropical forest. There are odd mammals, bizarre birds and very strange fish, but for sheer exuberant oddness and elegant strangeness nothing beats insects in their millions of forms, living all around any garden path.

### "My garden is a little corner of Earth I can control, small enough to comprehend, where I can make things right"

It is this, literally, overlooked diversity that excites Goulson. British biodiversity may be in decline even at this level, but what exists is extraordinary in its range. *Garden Jungle* celebrates, explores and explains in equal part, with the wildlife corralled into neat sections focusing on places (borders, trees, ponds) and groups

(ants, moths and non-insect invertebrates such as worms). And there is a charming touch: each chapter starts with a garden-grown fruit recipe.

Ever since Jean-Henri Fabre's *Souvenirs Entomologiques*, written in the late 19th century, the world has been aware of the magic and mystery of the invertebrate world. In the intervening century, we came to realise that awareness is nothing like enough. People like Goulson encouraged us to do more, even as they conjured up the delights of the natural world and unexpected fun of fieldwork.

Following on from his highly successful *A Buzz in the Meadow*, Goulson has upped his mission to match the individual-action zeitgeist. He explains wildlife-gardening techniques and how to use them to launch your campaign to save the planet, and adds a reading list, organisations to join and practical tips on how to ensure your patch is as biodiverse as it can be. Thanks to Goulson, you can

### All insects, from wasps to ants, become exciting as you learn more

relax about your choice of plants: "Any plant is better than decking or paving and the more... you have, and the more variety, the better."

So, yes, hug that tree, but after reading *Garden Jungle* you will probably do so more carefully to avoid disturbing bark beetles. Goulson's book is a very worthy successor to Fabre, and in a world where traipsing to the tropics is increasingly seen as irresponsible, backyard safaris may substitute.

Importantly, for an out-of-control world, Goulson also injects a sense of proportion. His garden (and yours) is "a little corner of Earth that I can control, that is small enough for my brain to comprehend, and where I can make things right". Amen to that. ■

**Adrian Barnett** is a rainforest ecologist at the National Institute of Amazonian Research in Manaus, Brazil

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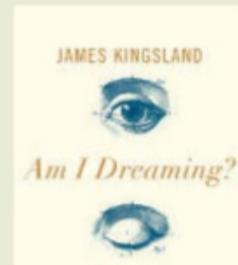
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are explored by Carmine Pariante in a talk at the Bethlem Museum of the Mind in Beckenham, London, on 3 August. What therapeutic tools will help the troubled souls of the future?

# Secrets and spies

The kid in you (and your kids too) will love this amazingly detailed glimpse into the secret state, says **Simon Ings**



Exhibition

#### Top Secret: From ciphers to cyber security, Science Museum, London, to 23 February 2020

HOW'S this for a cool recruitment campaign? In 2015, people on their way to work at tech companies in London paused, drawn by a curious message pressure-washed into the paving stones outside their offices. "GCH-WHO?" the message ran, "TECHNICAL OPPORTUNITIES", with a website address.

It was the work of GCHQ – the UK's Government Communications Headquarters (before 1946, the Government Code and Cypher School). It is, and always has been, quite unnervingly on-trend. During the second world war, it wove recruitment adverts into crossword puzzles to attract the sort of people who could break the German Enigma and Lorentz ciphers.

Today, among other duties, cryptanalysts and other specialists help foil terrorist attacks (20 since the beginning of 2017), and still find time to tinker with Lego (their model of the Doughnut, GCHQ's main building in Cheltenham, resembles a souped-up Millennium Falcon).

Only officially acknowledged since 1994, GCHQ is 100 years old this year and a new exhibition called Top Secret is a sort of celebration. It isn't a history of GCHQ, but a series of snapshots which, while putting a positive spin on the work of the country's intelligence agencies, still manages to ask pointed questions about cryptography, privacy, espionage and the right to know.

A map of trench communications

Special phones and ciphers made secure communications possible

lines and telephone points from the first world war introduces us to the messy world of communication in wartime. GCHQ was born out of a need to build a safe, coordinated system comprising electronically secure Fullerphones, ordinary telephones, telegraph signals, Morse and semaphore signalling, messenger dogs, carrier pigeons, lights, message-carrying rockets and dispatch messengers.

This daunting task hasn't got any easier. But it has vanished from sight, as communications were first electrified, then digitised, before vanishing into a near impossible-to-comprehend cryptographic cloud.

During the second world war, GCHQ's Bletchley Park base played a leading role in the development of information technology. Here the story is reduced to fascinating essentials: a copy of a German Lorentz machine, one of the few surviving components from an Alan Turing decoder known as a bombe, and, most evocative of all, a set of homemade rod-and-spindle calculating devices, used by human "calculators" early on in the war.

The story of UK-based Soviet agents Helen and Peter Kroger and the activities of the frighteningly effective Portland spy ring in the 1960s (they stole plans for the UK's first nuclear submarine) stand in for the whole cold war. The couple's elaborate equipment for hiding and transmitting secret messages is exhibited in a loose mock-up of their dreary suburban living room.

Volunteers are on hand to flesh out the stories. But don't expect anything after 1983 to make sense. That was the year the internet was invented, scrambling our notions of privacy, anonymity and public interest. Now, every time we search, chat, date and shop, we feed vast data sets, from which commercial companies, states and rogue actors extract many kinds of profit.

There are now more internet-connected devices in the world than people, some almost as terrifying as the My Friend Cayla doll on show, condemned in Germany in 2017 as an "illegal surveillance" device. Look into its dead eyes and remember: no one can claim with confidence that they aren't being watched. ■



THE BOARD OF TRUSTEES OF THE SCIENCE MUSEUM, GCHQ

## The games column

**Feeling the pain** Great storytelling and rounded characters don't feature that often in video games. A new genre tackling issues around mental health will only work if that changes, says **Jacob Aron**



Jacob Aron is New Scientist's deputy news editor. He has been playing video games for 25 years, but still isn't very good at them. Follow him on Twitter @jjaron



VIDEO games, as a medium, normally see you saving the world rather than saving yourself. The technical challenges and large teams involved in creating lavish 3D worlds and complex scenarios means that there is rarely room to also tell the kind of personal stories that lie at the heart of novels or films. But this is starting to change with titles tackling issues around mental health.

*Sea of Solitude*, released earlier this month, places you in the shoes of Kay, a young woman cast adrift in a small boat on a dark, stormy sea. Immediately, you can tell something isn't quite right, as Kay appears to be a furry humanoid with glowing red eyes, but for the first few minutes, at least, it is quite fun. Quickly, the inky black gives way to gorgeous sunshine in a flooded city and you meet a strange flying girl.

Then the darkness returns. A gigantic, crab-like monster blocks Kay's path, berating her: "You worthless piece of shit, you have no idea what you are doing!" The game involves navigating around a series of these large creatures, all

of which represent some aspect of Kay or her family.

It is clear she is lonely, unhappy and struggling to relate to others: as the game goes on, audio clips from her "real" life play out, detailing how she failed to notice her younger brother was being bullied at school, or how her parents met and eventually

**"*Sea of Solitude* felt unsophisticated compared to a recent novel that tackled similar issues"**

divorced. Kay absorbs their darkness, restoring them and the landscape, but at a cost to herself.

I admire what *Sea of Solitude* is attempting, and found myself feeling for Kay and her family, but the metaphors are fairly basic. It felt unsophisticated compared to something like *Eleanor Oliphant is Completely Fine*, a recent novel by Gail Honeyman that memorably tackled similar issues.

The biggest effect *Sea of Solitude* had on me was to trigger a form of

**In *Sea of Solitude*, heroine Kay battles the red-eyed, furry monster within**

climate anxiety, as flying over abandoned rooftops made me worry about the floods to come.

That isn't to say games can't successfully examine mental health. In *Hellblade: Senua's sacrifice*, the titular Senua experiences psychosis and hears voices. This is brilliantly realised with the aid of binaural audio – sound recorded with two microphones placed in the ears of a model head. Played with headphones, you can be bombarded with sounds from all sides or hear someone whisper directly in your ear.

The game, partly funded by the Wellcome Trust medical charity, sees Senua explore a dark version of Norse mythology as she tries to resurrect the soul of her dead lover. The origins of Senua's hallucinations are ambiguous – some may represent real people from her past, while others are like facets of herself.

It is also unclear exactly what role the player has in all of this. You control Senua from a third-person perspective, but at times she seems to speak directly through the screen to you.

Like *Sea of Solitude*, *Hellblade*'s mental health metaphors also lack subtlety – darkness abounds, you literally fight demons and must often examine the world from a new perspective to progress. But the superb audio elevates the experience. The game also warns you that failing too often leads to your progress being deleted, lending a sense of genuine peril.

When I finally reached the end of Senua's journey, I felt glad to have accompanied and learned from her, but also pleased to leave her finally in some kind of peace. ■



### Games

#### **Sea of Solitude**

Jo-Mei Games

On PC, PlayStation 4 and Xbox One

#### **Hellblade: Senua's sacrifice**

Ninja Theory

On PC, PlayStation 4, Xbox One and Nintendo Switch

# WHY ARE DOGS' NOSES WET?

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# Outsmart yourself

To be fitter, healthier and wiser you often need to overrule the way your brain is programmed. Here's a scientific guide to gaming your mind and achieving your goals – in spite of yourself. By **Caroline Williams**

"JUST do it," they say. If only it were that easy. It doesn't seem to matter how much you want to get fit, eat better, spend money more wisely or work towards a promotion, something always comes along to knock you off course.

The good news is that it doesn't make you a bad person, it just makes you human. The human mind didn't evolve to love exercising and eating veg. The reality of the hunter-gatherer life that shaped us was that exercise was non-negotiable and if you found something sweet, fatty and edible, resistance was an option – just not a very sensible one. As for sitting still and concentrating for hours on end, forget it. Our minds were shaped to scan the horizon for danger and opportunity.

Unfortunately, this means that most of our long-term goals work against what our bodies and minds have evolved to do. So, what's a modern human to do? The only thing for it is to game your brain. So here are the most scientific ways to do just that and reach your goals, in spite of yourself.

## Change your surroundings

We like to think we are creatures of reason and purpose. In reality, we mostly sleepwalk our way through life, responding to whatever is under our noses. "Environments cue our behaviour – often without our awareness," says Theresa Marteau, director of the Behaviour and Health Research Unit at the University of Cambridge. Worse, the environment often has a stronger influence on our behaviour than the beliefs we hold in our heads.

This is a problem, because, like it or not, we live in an environment that encourages a sedentary lifestyle packed with calories and adverts that put cravings into our heads. Most of the time we don't even know that we are acting on them. According to one study, adults mindlessly drink 1.5 glasses more booze after seeing people drinking on TV. And adults and children alike snaffle more snacks after watching food-based adverts.

Ads are only a part of the problem. Our routines become automatic programs that run without any conscious input: reaching for a biscuit to go with a cup of coffee, or a beer when you get home from work, for example. These kinds of habits are tough to break, so your best bet is to make them more difficult to unthinkingly enact.

Marteau says that the only environment we really have control over is the home, so start there – perhaps by ridding the kitchen cupboard of high-calorie snacks and booze,

and putting healthier options in their place. Using smaller plates and glasses can also reduce the amount we eat and drink in one sitting. Muting adverts on the TV may help stem the flood of bad ideas.

And if you are trying to lose weight or save money, always eat before you shop – and not just when getting food. Research suggests that shopping hungry is a sure-fire way to spend more than you intended.

## Remember your future self

"Shark sighted today. Enter water at your own risk."

As warning signs go, it is persuasive. The possibility of being bitten or killed is enough to put anyone off a swim.

But, let's get real: sharks killed five people in 2018. About 3.2 million deaths every year are attributed to inactivity. So why do we find adverts warning of the perils of a sedentary lifestyle, like ones admonishing us to get off the "killer sofa", less scary?

Simple, says Huda Akil, a neuroscientist at the University of Michigan. Our brains are wired to prioritise present, certain risks over something that may happen further in the future. "Immediate response to threat is very strongly wired in all organisms, as it is essential to survival," she says. Longer-term threats are less obvious, so don't kick off a stress response.



Instead, they rely on our ability to think ahead while also having to combat the emotional lure of short-term pleasure.

This tendency to prioritise the certain present over the more nebulous future is the reason we spend money now and worry about our retirement later, or eat the cookie now, leaving our summer selves to worry about the spare tyre.

Brain-imaging studies provide clues about why this might be. They show that when we think about our future, brain regions that process information about the self stay silent, and areas of the brain that process information about other people come online. It is as if we

consider our future self to be a stranger whose problems are nothing to do with us.

There are ways to look out for future you, though. People who see computer-generated images of how they may look in old age, or who are asked to consider ways they will remain the same years from now, make more future-friendly choices.

In the here and now, though, the best bet might be to load the good choices with emotion, or try to engineer a sense of urgency. "For example, having a baby can suddenly motivate someone to stop smoking when no amount of information and prodding had worked before," says Akil.

## Don't rely on conscious thoughts

When it comes to changing your behaviour, knowledge isn't necessarily power. A 2016 analysis of more than 10,000 people who were told that their lifestyle and genetics are speeding them towards an early grave found that while it changed the way they thought, it made no difference to what they actually did.

It is something that we are all guilty of to some extent, and it happens not because we are weak, but because, most of the time, we aren't consciously in charge of our actions. The vast majority of the time, our brains tick over at the unconscious level, responding to cues and enacting habits that are often at odds with our conscious intentions.

Habits are enforced by a deep brain structure called the striatum, which coordinates the way our decisions and behaviours add up to a feeling of pleasure (see "The brain's decision-making battleground", page 37). While a habit is developing, there is conscious input from the prefrontal cortex, which is involved in planning and impulse control. If we repeat the behaviour enough, the prefrontal cortex is taken out of the equation, leaving only reward and action parts of the loop, so our planning skills are free for other things.

The good news is that these loops can be rerouted, but it takes a huge amount of conscious effort. To stand any chance of success, says Marteau, the first step is to admit to ourselves that we aren't consciously in charge of our own behaviour.

Believing in willpower can help too. For decades, psychologists thought that when we exert self-control we run down our reserves of mental strength, leaving us vulnerable to a slip later in the day. But recent research suggests that it might be more to do with attitude. This showed that people who believed willpower was an unlimited resource were not only better at self-control tasks in the lab but also had better exam grades, ate more healthily and spent money more wisely than those who considered self-control to be limited.

## Chill out

Being stressed is about the worst thing that can happen if you want to get the best out of your brain, and this is especially true when it comes to sticking to good intentions.

## Will decluttering keep your mind on track?

Our ability to ignore the call of immediate pleasure in favour of a less pleasurable long-term goal relies on a complex back and forth between two bits of brain circuitry. Stress throws a spanner in the works, short-circuiting the network that takes care of self-control and boosting the one that tells us it is good to be bad.

Todd Hare, a neuroscientist at the University of Zurich in Switzerland, put volunteers under stress and then asked them to make a choice between tasty unhealthy food and less

**Think of what you could have achieved if you hadn't wasted all that time searching for your keys beneath piles of papers.**

If this sounds familiar, you're not alone. "People waste up to 3 hours a week finding things that are lost in clutter on their desk," says Joseph Ferrari, a psychologist at DePaul University in Chicago. His research has shown that people with more clutter in their homes and offices are less likely to get stuff done, and more likely to be stressed and unhappy than people with less clutter. Sabine Kastner, a neuroscientist at Princeton University, has an idea why. She has found that when an object in our field of view is surrounded by clutter, the brain receives a weaker signal from whatever it is we are trying to look at.

So can clearing the decks keep the mind on track? Not necessarily, warns Kastner. The brain's attention system evolved to deal with the busyness of the natural world. Making everything too shiny and clean might backfire, by stopping our attention system from kicking in at all. "For people with a very strong attention system, it might be beneficial to have clutter because it stimulates that system," says Kastner.

For people who struggle with attention, though, it is a different story. Clutter can be mentally exhausting leaving little in the tank to take care of other goals in life, says Kastner. "If a person is highly distractable, yes, reduce the clutter," she says.

and to reduce intrusive thoughts in people experiencing anxiety. This is effective because it brings our unconscious habits to our conscious attention, both encouraging us to make better choices and chipping away at the unconscious desire as we forge new habits.

There is a catch, though: it only works on things that are true habits, in other words, things that you aren't aware you are doing. Tracking alcohol intake doesn't seem to make people drink less – perhaps because most people don't tend to drink alcohol without at least a modicum of conscious thought. You also have to be unhappy with the behaviour in the first place. If you consider your vices to be normal – or something you deserve after a hard day – then monitoring won't make any difference.

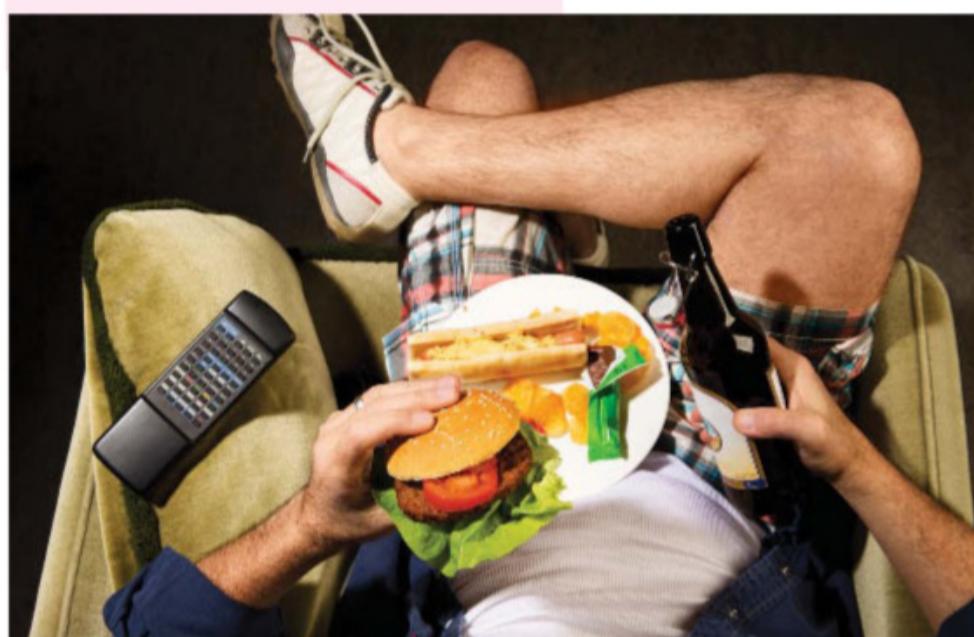
Another catch is that self-monitoring can sometimes backfire. A large randomised study has shown that people following a weight loss intervention who used an exercise-tracking app lost less weight over two years than people in the study who didn't use the app. One explanation is that the monitoring might lead people to overcompensate in other areas, like diet.

## Don't think positive

Beware the cult of positivity. Research suggests that fantasising about successfully reaching your goals – whether it is losing weight, snaring your dream partner or landing a promotion – makes it less likely that you will actually achieve them.

That's because fantasies conveniently skip to the end of a challenge, remaining sketchy on what is needed to get there. This tricks the body into relaxing as if it had already crossed

**Blame your brain for being unable to resist**



ROMAN MÄRZINGER/GETTY

## Nag thyself

As every dictator knows, the best way to get people to behave is to put your face everywhere, the larger the better. Being watched – even by a photo showing a pair of eyes – has been shown time and again to make us watch our behaviour.

It also works when we keep an eye on ourselves. Keeping a diary of unwanted behaviours has been shown to reduce mindless snacking, nail-biting and smoking,



Caroline Williams is a consultant for New Scientist and author of *Override* (Scribe UK)

the finish line. Blood pressure drops, robbing the brain of the fuel it needs to really get stuck in. Several studies have also linked positive fantasies about the future to an increased likelihood of depression months later.

Strangely, focusing on the worst-case scenario might actually be more effective. In one study, people who were anxious about public speaking performed better if they were first allowed to focus on the likelihood of messing it up. This “defensive pessimism” works because, unlike fantasising about success, it gives your brain a much-needed kick up the backside.

## Train your brain

Everything you do changes your brain – at least temporarily. Whether it is possible to deliberately change your brain to achieve a specific goal, however, is an open question.

Turning good intentions into restraint is the job of the brain’s executive control system, much of which is found in the prefrontal cortex. This cortex works with the parietal lobe to keep our attention on a goal for long enough to make progress towards it, while inhibiting our less-than-sensible impulses.

Some people believe that activity in these networks can be boosted with training. For example, Barbara Sahakian, a neuroscientist at the University of Cambridge, has found that an iPad game called *Decoder*, which involves cracking numerical codes while ignoring distractions, improved people’s ability to stay “in the flow” and, potentially, to stick to their goals. “I think that cognitive training is a way for people to change and develop improvements in cognition and behaviour,” says Sahakian.

The million-dollar question for all types of cognitive training, though, is whether improvements seen in the lab translate into lasting real-world change. So far that hasn’t been shown. In one recent study, cognitive training did improve volunteers’ diets for the month after the study but didn’t translate into lower weight after six months.

Andrew Jones, a health psychologist at the University of Liverpool, UK, recently reviewed the evidence that health behaviours can be trained. “These kind of cognitive training paradigms might demonstrate some promise under laboratory-based conditions, [but] they very rarely translate to sustained behaviour change in the real world,” he says.

The good news is that in future we might be able to work more directly on the brain’s motivation and impulse control systems.



**Believe in willpower but don't think too positively**

## The brain’s decision-making battleground

**What we do in the face of temptation depends on the activity in several brain regions, some devoted to pleasure and others that are in charge of our long-term goals. Your chances of staying on track depend on which circuit is dominant at any one time.**

**In the pleasure corner, the ventromedial prefrontal cortex, which is involved in emotional decision-making, links to the amygdala, which processes emotions, and the striatum, which is involved in putting rewarding plans into action. This network, which chugs away below the level of consciousness, is what makes us choose fun, chocolate and beer, or whatever happens to feel good at any given moment. This might not always be the unhealthy option – if you happen to love vegetables, exercise and work.**

**If, however, your long-term goals don’t match what feels good, another circuit needs to cut in to help you stay on track. The dorsolateral prefrontal cortex is in charge of inhibition, attention and switching behaviours, and can override the will of the ventromedial prefrontal cortex.**

**But you need to keep your eyes on the prize. Being distracted, overloaded or stressed is likely to take your attention elsewhere and leave you vulnerable to fun, but unhelpful, slips.**

In one recent study, applying a small electrical current over part of the frontal cortex enhanced decision-making and impulse control. In another, volunteers were trained to increase their own brain activity in the ventral tegmental area, which is involved in the release of the motivating neurotransmitter dopamine. In theory, this should have boosted their motivational levels.

Neither technology is available outside of the lab – yet. But one day taking direct action on your flawed human brain might be possible.

## Do something else

If you want to eat better, join an exercise class. That was the conclusion of a 2015 study that followed more than 6000 people for four years. People who upped their exercise during the study period increased their intake of fruit and vegetables more than people who already exercised regularly or who gave up their fitness plans early on.

The explanation for this is that, since both behaviours share the same goal, doing one gives you a head start on the other. These “behaviour spillovers” can affect many aspects of our lives. Research shows that taking up recycling at home can lead to more environmentally friendly shopping decisions, and giving money to charity makes it more likely that you will do the same again.

But beware. These spillovers don’t always have positive effects. Doing a “good” thing – going for a run, for example, or eating a healthy snack – can sometimes lead you to feel that you have earned the right to do something “bad”.

No one said that outsmarting yourself was going to be easy. ■

# Breaking the glass orbit

Space travel has mostly been a male affair. But the balance is finally starting to shift, reports **Abigail Beall**

**I**N MARCH, the International Space Station was set to strike a blow for gender parity. NASA astronauts Anne McClain and Christina Koch were scheduled to perform the station's first all-women spacewalk, a mere 20 years and 214 spacewalks after the first pair of men stepped off the ISS into the starry darkness.

In the end, the long-anticipated spacewalk didn't take place for an entirely trivial reason: the only spacesuit available for McClain to wear was a large, and she was a medium.

The history of space travel is full of such incidents. An industry predominantly designed for and tested by men, it has always struggled to understand and accommodate the different needs of women. In the early years of space travel, one group of researchers said women were advised not to operate any complicated machines while on their period. When the US's first female astronaut, Sally Ride, was going on a seven-day stay in space, she was offered 100 tampons along with a make-up bag. Even today,

space radiation shields designed for women struggle to fit the female body.

There have recently been signs that things are getting better. Space agencies are accepting more women onto their astronaut training programmes, and are starting to learn from the experiences of those who have already visited space. The first all-women spacewalks are coming.

The role of women in crewed space exploration goes all the way back to its beginnings. On 16 June 1963, only two years after Yuri Gagarin became the first human to leave Earth's atmosphere, the Soviet cosmonaut Valentina Tereshkova replicated his feat with a solo trip on Vostok 6. Her mission proved that women could join men as equals in this burgeoning field, their roles not relegated to that of passengers or, in the words of one NASA report, "improving crew morale".

In the 56 years since Gagarin's first trip into space, 58 women have made it into orbit. The number of men to do so in that time? 504 (see "The final frontier", page 41). This lack of

women has consequences beyond mere equal representation. The fewer women who go into space, the less data we have on how women's bodies respond to this unique, low-gravity environment, and the more dangerous future missions are likely to be.

### Fit for flight

At present, we are aware of only a few ways in which men and women experience space differently. A review of available information in 2014 found that women report more instances of motion sickness in space, and soon after returning to Earth are more prone to a condition called orthostatic intolerance, which includes symptoms like blood pressure dropping when someone stands up. Men, in comparison, are more likely to experience visual changes, caused by space flight-associated neuro-ocular syndrome, which can result in increased intracranial pressure. They are also more prone to hearing loss than women. None of these differences, however,



has an effect on any individual's ability to perform as an astronaut.

"About the only thing that is impactful in terms of being able to perform your duties is really the difference between men and women in their susceptibility to cancer from radiation," says Dorit Donoviel at Baylor College of Medicine in Houston, Texas, who co-wrote the review's executive summary. Women are more likely to develop such radiation-based cancers than men, even in the comparatively low-radiation environment of Earth's surface. Up on the International Space Station (ISS), far from Earth's protective magnetic field, such a variation could be a cause for concern.

This doesn't mean women shouldn't be going into space, just that they might need more protection, either in the form of bulkier spacesuits or by limiting their time outside a spacecraft. "We are working to reduce the radiation risk for all astronauts by developing countermeasures," says Donoviel. On long-term missions, protection barriers could be

built out of materials already in space, like clay from asteroids, she says.

Since that review was published five years ago, most of these conclusions have held up, says Donoviel, but more research is needed. A sample size of 171 men and 30 women, the number of people who had spent time on the ISS by the time the study was published, is both too small and too skewed to come to any meaningful conclusions.

Even less well understood is the question of reproductive health. Most of the findings we have come from animal studies, and are scant and often conflicting. Research on men suggests sperm count and testosterone levels decrease in space, but return to normal 120 days after returning to Earth. For women, though, there is simply no long-term data available about menstruation or ovulation, says Varsha Jain, a gynaecologist at King's College London.

That lack of knowledge comes, in part, because astronauts find it easier to take contraceptives to avoid menstruating in

**Clockwise (from top left): Tracy Caldwell Dyson, Naoko Yamazaki, Dorothy Metcalf-Lindenburger and Stephanie Wilson on the International Space Station in 2010**

**"None of these differences affects an individual's ability to perform as an astronaut"**



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space. There are many reasons why astronauts make the choice to control their periods, says Jain. One is that NASA forbids pregnancy during some astronaut training activities, like diving, as well as in space. Another is that spacesuits are designed to absorb bodily fluids such as sweat, but not period blood.

The toilets on board the ISS don't help either. Water from urine is recycled into drinking water. If any foreign material, like menstrual blood, is detected in the toilet, the entire contents are expelled instead of being recycled. When the toilets were designed, period blood wasn't considered. "The engineering was not built for women," says Jain.

So far, most of the astronauts studied have only spent months at a time in space. On longer missions, such as those headed for bases on another planet, questions of pregnancy and childbirth are likely to arise. A central concern is the risk of giving birth in space, not only because of the risks it involves on Earth, but the increased chance of infection. On Earth, says Donoviel, we know that women mount a stronger immune response than men, but we don't know what happens in space. There, microgravity makes it difficult to sterilise anything, meaning a routine intervention during childbirth could quickly lead to infection. In addition, there is a chance that microgravity could lead to new pathogens being created. On top of this, the distances involved on deep space missions mean help is far away, often with a significant time delay in communications. "We know there are differences between men and women in how



**Mae Jemison inspires a new generation (above); Anne McClain and Christina Koch were due to perform the first all-women spacewalk (below)**

their immune systems are regulated," says Donoviel. "On a long duration deep-space mission, where an infection could become life threatening, we need to enable the crew to treat themselves effectively."

We also don't know enough about the consequences of space flight on any children conceived once astronauts have returned to Earth. While women returning to Earth have a higher rate of miscarriage than the average population, this effect disappears when age is taken into account. "No data from the

literature suggests the rate of miscarriage is higher in astronauts compared to women of the same age," says Jain. Both male and female astronauts have become parents to healthy children after going into space.

Although there is a lack of data, we are lucky to have any at all, says Jain. "These women are just going to do their jobs," she says. "They are not participants in a study." Whether women decide to menstruate in space or have children afterwards is a personal choice. Perhaps more data will be gathered when commercial space flight takes off and more women go into space.

Until then, women find themselves penalised in more everyday ways. Take the spacesuits on the ISS, for example, which were built in 1978, and originally came in small, medium, large and extra large. An attempt to cut back on costs in the 1990s led NASA to stop repairing the small and extra-large sizes. This may have seemed financially sensible, but the loss of small sizes has had serious consequences for women's ability to function in space.

At 5 foot 4, Catherine Coleman is the shortest person to have qualified to perform a spacewalk on the ISS. In order to prepare herself for the task, she had to teach herself to work inside a medium suit that was much too large for her. Coleman compares the experience to swimming underwater while attached to an inflated exercise ball. As soon as you start to dive down, the buoyancy of the ball forces itself towards the surface, flipping you upside down and dragging you up with it.

This makes it much more difficult to perform tasks, with rogue air bubbles moving every time you adjust your position. For those unaware of the difference a badly fitting suit makes, says Coleman, it could seem like you aren't up to the task. "People could assume that you're just kind of clumsy," she says.

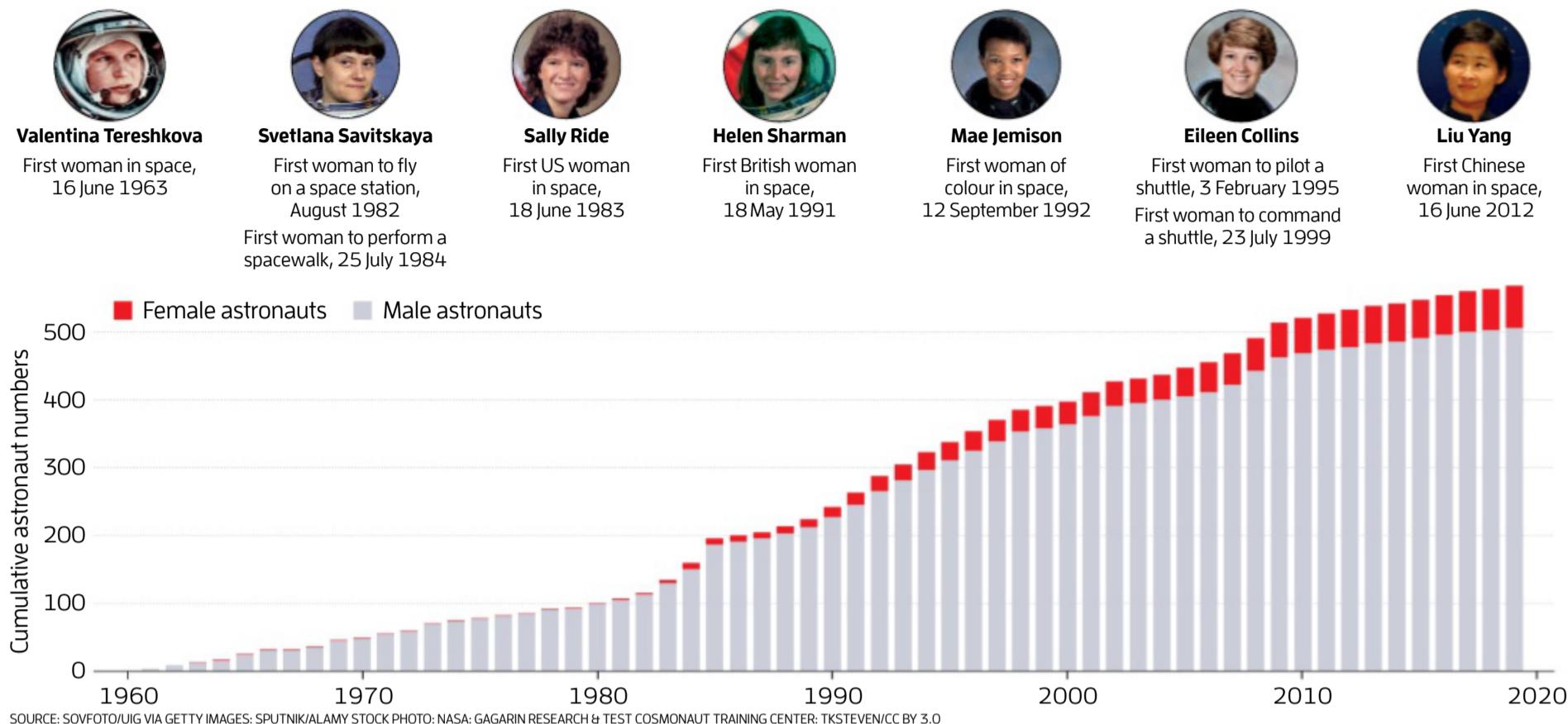
Luckily, when Coleman joined NASA she met Kathryn Thornton, whose experience spacewalking included time on the Hubble Space Telescope. "She told me, 'When they put you in that medium, call me,'" says Coleman. Together, the pair worked out how to create padding to fill out the empty space in the suit so that the air was distributed evenly. Without Thornton's expertise, says Coleman, "I wouldn't have known what to ask for".

Almost 25 years after Coleman's first mission, women like Anne McClain are still encountering problems with the spacesuits. "They didn't plan to do a spacewalk with two women," says Coleman. If the small spacesuits hadn't been eliminated, she says, there would probably be a longer history of women successfully completing spacewalks.



## The final frontier

Women have always been a minority in space travel, but the situation is slowly improving



SOURCE: SOVFOTO/UIG VIA GETTY IMAGES; SPUTNIK/ALAMY STOCK PHOTO; NASA: GAGARIN RESEARCH & TEST COSMONAUT TRAINING CENTER; TKSTEVEN/CC BY 3.0

That being said, she supports NASA's freedom to choose the right astronauts for the spacewalk. This year's planned all-female line-up, for example, was a fluke of scheduling rather than NASA having explicitly picked the candidates only because of their gender. "I can't speak for others, but I would be insulted if they did," says Coleman. Others agree that the system is ruthlessly meritocratic. "Once you get in the corps, you're treated the same across the board," says NASA astronaut Serena Auñón-Chancellor, who came back from her latest role as flight engineer on the ISS in December 2018. "Nothing is altered because you're a man or a woman – whether it's an exam on space station systems or an exam on how to do spacewalks in the pool, which is a very physically demanding task."

### Level launchpad

But the barriers to equal representation in space start long before you get to the ISS, says Libby Jackson, author of *A Galaxy of Her Own*, a book telling the stories of women in space. "One of the barriers is society saying to young people that there are boys' jobs and girls' jobs," she says. Being an astronaut is seen to be a boys' job, says Jackson.

NASA requires all astronaut candidates to have a bachelor's degree in biology, mathematics, physical sciences or engineering. According to the US Department of Education, for all bachelor's degrees earned in 2015, 43 per cent of students getting mathematics and statistics degrees and 38 per cent

**"Increased diversity is enormously important. It's hard to imagine things you can't see"**

obtaining physical science ones were women. But for engineering, that number dropped to 20 per cent.

Additionally, NASA requires three years of experience in academia or 1000 hours at the controls of a jet aircraft. According to the International Society of Women Airline Pilots, only 5 per cent of the pilots at 34 major airlines in the US are women. Back in the 1960s, it was even worse: the first astronaut candidates had to be test pilots, roles that were off limits to women in the US military.

With similar barriers to entry in existence elsewhere in the world, it is small wonder that women make up a mere 10 per cent of all space travellers. But after decades of disparity, the situation finally appears to be improving. The Canadian Space Agency's most recent intake consisted of one man and one woman, and NASA accepted five men and seven women in its most recent class.

This increased diversity is enormously important, says Jackson. "It's very hard to

imagine things you can't see," she says. This rings true for Coleman, who didn't consider working as an astronaut until Sally Ride visited her college to speak. "I just thought, wow, she seems like me," says Coleman. "And maybe that means that if I worked really hard at this, I could do this too."

Once Coleman arrived at NASA, she received direct support from Kathryn Sullivan, who had been the first US woman to do a spacewalk. She told Coleman that being an astronaut didn't mean giving up on having a family. "I think there's really a huge, enormous value in having people that you can identify with," says Coleman.

Getting more women in space means more women need to apply, says Auñón-Chancellor, and that requires more women to feel that becoming an astronaut is within their reach. "I think a lot of women believe they aren't qualified enough, and that's just inherent cultural beliefs," she says. "We need more women to try."

We will know that we have really arrived at equality when women, like men, don't have to be extraordinary in order to become engineers and scientists, says Coleman. Until then, she says, "if they're not incredible superstars, women are still considered to be not satisfactory". ■



Abigail Beall is a freelance writer based in Leeds, UK

# Honey, we shrunk the accelerator

Huge particle smashers have ruled the roost for decades. **Jon Cartwright** meets the physicists learning to think small

**T**O GET to the very bottom of physics, there has always been one rule: size matters. The first particle smashers of the early 1960s were little wider than a dining room table. A decade later, the Tevatron, a circular collider in the US, had a circumference of 6 kilometres. Today's largest machine, the Large Hadron Collider (LHC), has one four times as long. Now there are plans to build colliders 100 kilometres in circumference: about the size of New York City.

Physicists get a lot of flak for these enormous – and enormously expensive – aspirations. Nature is tenacious, however, and wresting its most closely held subatomic secrets from it has always meant accelerating particles over longer and longer distances before smashing them together. But a new shortcut is emerging in a weird, cloud-like state of matter known as a plasma. Inject particles into this febrile stuff, and they can accelerate a thousand times faster than before.

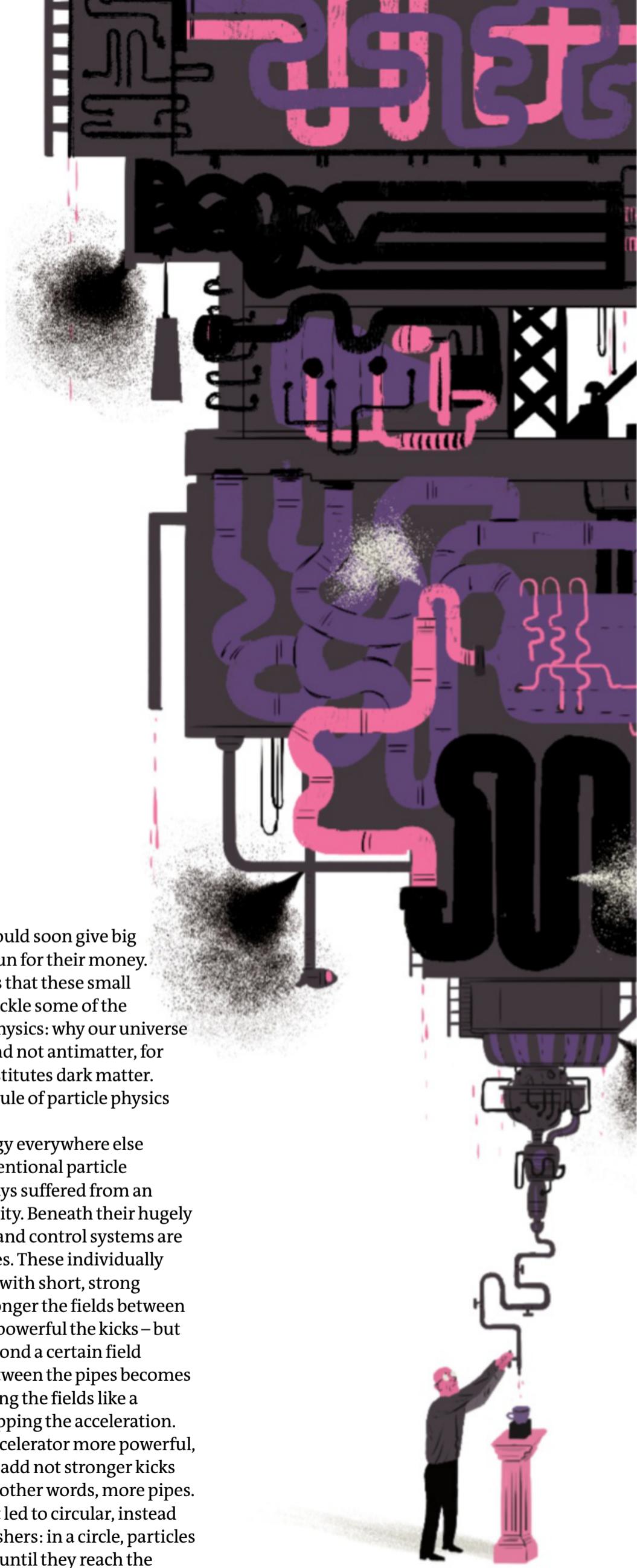
This is more than wishful thinking. Plasma accelerators have been advancing steadily over the past few decades, and while they have yet to pose a serious threat to the dominance of conventional facilities, that might be changing. Several recent developments suggest that

plasma accelerators could soon give big beasts like the LHC a run for their money. Ultimately, the hope is that these small machines will let us tackle some of the biggest questions in physics: why our universe is filled with matter and not antimatter, for instance, or what constitutes dark matter. It seems the ironclad rule of particle physics is about to be broken.

Certainly, technology everywhere else is shrinking. But conventional particle accelerators have always suffered from an intrinsic unshrinkability. Beneath their hugely complicated steering and control systems are lots of little metal pipes. These individually kick particles forward with short, strong electric fields. The stronger the fields between these pipes, the more powerful the kicks – but only up to a point. Beyond a certain field strength, the space between the pipes becomes conducting, discharging the fields like a lightning bolt and stopping the acceleration.

To make the overall accelerator more powerful, therefore, you have to add not stronger kicks but more of them – in other words, more pipes.

It was this limit that led to circular, instead of linear, particle smashers: in a circle, particles can keep going round until they reach the





"Plasma accelerators could soon give big beasts like the LHC a run for their money"

desired energy. Within reason. Even circular accelerators have to be very big, otherwise particles simply shed their energy as radiation – or else get flung out of the ring as they skid around tight corners. Hence the LHC. Only a circular collider 27 kilometres in circumference could smash opposing beams of protons with enough energy – up to 13,000 gigaelectronvolts (GeV) – to produce the famous Higgs boson. Although impressive for confirming a decades-old prediction, the finding of the Higgs in 2012 has been the LHC's only elementary particle discovery to date, and has left particle physicists wondering what, if anything, to do next. "Many of us thought 27 kilometres was the limit," says Ralph Assman, a leading scientist at the German accelerator lab DESY.

### Very large hadron colliders

Not everyone, though. One long-mooted successor to the LHC is the International Linear Collider (ILC), a \$7.5 billion machine up to 30 kilometres long. Japan was set to host it until its government failed to commit in earnest this year. If the plan still goes ahead, the ILC wouldn't technically be as powerful as

the LHC, but it would allow much more precise studies of the Higgs and other particles by smashing together not protons, but electrons and positrons. As these are simpler particles, they would generate very clean collisions.

CERN, the particle physics laboratory near Geneva, Switzerland, that hosts the LHC, has a similar plan to the ILC, albeit up to 50 kilometres long, in the form of the Compact Linear Collider (CLIC). But even that is dwarfed by the lab's proposed Future Circular Collider (FCC), a machine that would have a whopping 100-kilometre circumference to smash together either electrons and positrons, or protons and protons, at energies up to 100,000 GeV. This would cost up to \$25 billion. Meanwhile, China is mulling over a Circular Electron Positron Collider (CEPC) with an equivalent 100-kilometre circumference, but a more economical \$6 billion price tag.

These gargantuan machines seem essential to the future of particle physics. But for some researchers, a cheaper, smaller alternative is worth pursuing. As a senior scientist at CERN during the time of the celebrated Higgs discovery, Assman could easily have gone on to work on ever bigger colliders. But scarcely had the champagne corks landed at CERN than he had chosen a new path: plasmas. "I thought the main challenges with conventional accelerators had been overcome," he says of his decision to move to DESY in 2012. "I thought it would be cooler to innovate new technology, and make it smaller, instead of bigger."

After solids, liquids and gases, plasmas are sometimes considered the fourth state of matter: an ethereal mix of electrons and the positively charged atomic nuclei, or ions, from which they were stripped. As the electrons and ions move around, tiny electric fields are created and destroyed, making plasma the perfect medium for carrying charged particles. Unlike the hollow space separating a conventional accelerator's metal tubes, for example, plasma is at no risk of suddenly becoming conductive and neutralising an electric current: it is conductive already.

Appropriately for a technology that has been likened to particles going surfing, plasma acceleration originated in California, a half hour's drive from the beach. In 1979, John Dawson and Toshiki Tajima at the University of California, Los Angeles, (UCLA) published a theoretical paper that would form the basis for all subsequent work on plasma accelerators. The pair's idea was to fire a laser into a gas of ➤





**The AWAKE collaboration at CERN aims to build a small plasma accelerator**

atoms, creating a plasma and dividing its electrons from its positively charged ions. Trailing in the wake of the laser, this division of negative and positive charges would create a hugely enhanced electric field. Any additional electron injected at just the right place would be propelled across this field, surfing the plasma wake and accelerating over a thousand times faster than it would in a conventional machine.

More than a decade after Dawson and Tajima's proposal, a group led by Dawson's colleague at UCLA, Chandrashekhar Joshi, managed to put this into practice, accelerating injected electrons by 7 megaelectronvolts over just a few millimetres. Lasers at that time were comparatively weak, however, and, in order to reach higher energies, he and others realised it could be better to use a pulse of electrons from a conventional accelerator to create the plasma, divide it and be accelerated by it. In this set-up, most of the electrons would lose their energy in creating the wake, while those at the back of the pulse would catch the surf. "Quickly, people realised you didn't need lasers at all," says Assman.

## Gaining momentum

Led by accelerator scientist Robert Siemann, the Stanford Linear Accelerator Centre (SLAC) in California took up the challenge. By 2005, it had demonstrated that some of the electrons from its existing accelerator could be turbo-boosted by 3 GeVs over 10 centimetres.

**"One plasma beam boasts 10,000 times the LHC's rate of acceleration"**

Two years later, it demonstrated 15 times the energy gain in under a metre – nearly 10,000 times the rate of acceleration at the LHC. "That's still the record," says Joshi, whose UCLA group worked with SLAC on the experiment. "But it's not a fundamental limit."

Such swift progress obscures a few sticking points. While maximum energy is important, so is giving all particles about the same boost. Assman believes that the spread of energies generated by plasma accelerators is currently 10 times too broad, which would make the interpretation of particle collisions difficult. Meanwhile, Joshi is concerned by reliability. "Particle colliders are big and expensive for a reason," he says. "Just like when you turn a switch and expect a light to come on, so particle accelerators have to work 24/7 continuously for weeks at a time."

One barrier to reliability could be linking and aligning a series of laser or electron pulses, which would be needed to reach the highest

energies. Unless, that is, you take the approach of AWAKE, an international collaboration at CERN, which is experimenting with protons – veritable cannonballs next to electrons. Send protons into a plasma, and they can generate an almighty wake that flings injected electrons forwards in one fell swoop. "You don't need several stages, which complicates a beamline," says Edda Gschwendtner, the project leader.

Even then, electron acceleration is only one half of the puzzle. To make sure all the energy from a collision goes into making new stuff, electrons need to be collided not with other electrons, but with their antimatter opposites, positrons. These, says Assman, are a different ball game entirely. "If you inject positrons in the same place as you would electrons, they are not accelerated, but decelerated." Joshi's group at UCLA did manage to accelerate positrons in 2004, using a positron beam to both create the plasma wake and serve as the source for the accelerating particles, but even he admits that progress on positron acceleration is "way behind" electron acceleration.

In the meantime, plasma accelerators may be of more immediate practical benefit. Without generating any collisions, compact accelerators could make advanced types of radiation therapy for cancer more widely available. They could also probe cutting-edge materials, or enable security staff to check for hidden explosives. In fact, plasma accelerator spin-offs like these could be just five or 10 years away, says Gschwendtner.

Still, a future in particle physics beckons. Earlier this year, building on a recent surge in laser technology, Berkeley Lab in California used a laser pulse with a power of 850 trillion watts to achieve electron energies of nearly 8 GeVs over 20 centimetres in a plasma accelerator.

Numbers like these should give pause for thought: they imply that energies on a par with those achieved at the LHC could be reached in less than a couple of hundred metres, instead of the marathon distances needed at present. If you weigh up the rate at which the new technology is progressing against the 30 years or so necessary to build a next-generation circular collider, says Assman, then plasma accelerators look like a decent bet for the future of particle physics. "On this timescale, we might have a good alternative." ■



Jon Cartwright is a consultant for New Scientist based in Bristol, UK



Dawn of a  
new age:  
James  
Lovelock  
at 100

# “The chemical-physical type of humanity has had its time”

We are heading into a new geological era, the Novacene, visionary scientist James Lovelock tells **Gaia Vince**

Photographed by David Stock  
for New Scientist

AMES LOVELOCK turns 100 this July. One of the most influential scientists of our time, he worked for the British government during the second world war and later for NASA on the Mars Viking mission. It was then that he was inspired to develop the Gaia hypothesis, the idea that Earth is a massively interconnected, self-regulating system. His new book, *Novacene: The coming age of hyperintelligence*, argues that the Anthropocene era of human influence over the planet is coming to an end and that an age of superintelligent beings is about to begin.

**Thanks for the coffee and, er, the saucer of ice...**  
That's to make it drinkable. A chunk of ice cools the coffee 80 times more effectively than the equivalent volume of water at 0 degrees.

**Ever the scientist. How did your interest in science and problem-solving start?**  
Well, my dad was a hunter-gatherer and that's where I learned my ecology. He used to take me for walks and knew the nesting places of all the birds, and the names and homes of all the animals, plants and insects. He gave me training in the environment. ➤

**A British hunter-gatherer? You aren't that old! But did that training make you an environmentalist?**

No! That immediately makes me think of a city-based academic type of person who has strong views on how things ought to be. I am a much more laid-back person who just takes the world as it comes. I get an intense feeling of happiness from the environment.

**You have come under fire for some of your attitudes, like your pro-nuclear energy views.**  
Has it occurred to you that most of the large money that circulates in this country comes from the fossil fuel industries? And they probably spend huge sums of money on anti-nuclear propaganda.

**So you think it is a contrived argument?**

Yes, the anti-nuclear argument is very much so. It's so safe, it's almost ridiculous. And it's improving. The latest form of nuclear energy being worked on uses thorium, rather than uranium, and it's almost impossible to get it to go into a runaway chain reaction or to do anything nasty.

**How did a poor south London boy become one of the most influential scientists of our time?**  
An aunt married into the Leakey family and they gave me elocution lessons to get rid of my working class accent. I couldn't afford to go to university so I got an apprenticeship and my boss sponsored my degree in the evenings at Birkbeck [College, London].

**The war broke out when you were 20.**

**Did you fight?**

No. This country called up all of its scientists and I was involved with all manner of strange scientific things that I still can't talk about. It was very interesting but there were crazy ideas. They set fire to the sea off Studland [in Dorset, UK], as Churchill thought this would frighten the Germans away. They poured petrol onto the ocean in huge quantities when it was desperately short for fighter planes and the like.

**After the war, you did some pretty far-out stuff at the National Institute for Medical Research in Mill Hill, London.**

My main line of work was freezing whole animals and bringing them back to life to test resuscitation techniques. I discovered that if you wanted to find an animal that survives for a long time in the frozen state, you need one with a certain composition of fatty acids in its blood, and hamsters fit this. But we needed to check this to prove it. Two

ANTHONY HOWARTH/SCIENCE PHOTO LIBRARY



## **“During the war I was involved with all manner of strange things that I still can’t talk about”**

floors from where I worked, Archer Martin had just invented the gas chromatograph, which could analyse the fatty acids in the animal's fat. So I went to see him with my sample, but he said he'd need 100 times more – it would mean a mass slaughter of hamsters. I was crestfallen. Then he said, “or you could invent a more sensitive detector for us”. Within two weeks, I had built the detector and that put the gas chromatograph on the market and made a lot of money for the institute.

**And it took you to California...**

One morning in 1961, there was a letter on my desk from the director of Space Flight Operations at NASA asking me to come and help them design equipment to send to Mars and the moon, to analyse soil and see if there's any life there. They had a very small rocket,

Pioneer 1, that didn't use a lot of fuel, and I'd built by far the most sensitive chemical detector in the world. It was only a few inches in size and used very little power: a few watts could send a signal from Mars to Earth.

**What was it like at NASA in those early days?**

It was marvellous. But I was disappointed by the biologists: they didn't have any understanding of what they should be looking for. I got in trouble with the boss man for making the biologists lose their morale. He then asked: “What would you do if you wanted to detect life on Mars?” Without thinking, I said I would look for an entropy reduction. Well, that made him spurt with laughter, but he gave me two days to come up with a practical experiment to find life on Mars or I was out.

James Lovelock in his home laboratory in 1980

**A reduction in entropy means an increase in complexity; it implies that life is creating order. But how could you measure it?**

In bed at night, it suddenly came to me: all you have to do is analyse the atmosphere of Mars. If it has got gases in it that react with one another, then it is at a low entropy.

**Because otherwise, they would have reached an equilibrium, which implies raised entropy?**

Exactly. He got very excited, as we had a real practical experiment to send, which became part of the Viking mission. So I can look up at the night sky and see Mars knowing I've got two bits of stuff on it that are responsible for showing that there isn't any life on Mars.

**And this led to your hypothesis of Earth as a self-regulating living system?**

Yes, because the amount of oxygen in our atmosphere is far too high – it's a huge entropy reduction and it doesn't make sense. But if you look at it as a system that produces organic matter and oxygen in the atmosphere, making a combustible mixture, and that energy then feeds back into the living system...

**...You can view it as a giant superorganism.**

**How did you come up with the theory's name?**

My friend and neighbour was the author William Golding, who had studied physics at Oxford and was very interested in space. He said, "if you're going to come up with a big theory about planets, you better give it a good name. I suggest you call it Gaia".

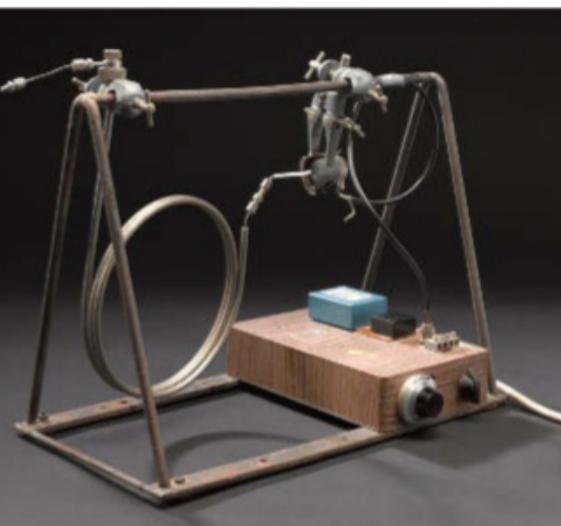
**What a truly fabulous name...**

Well, my reaction was puzzlement. I thought he meant "gyre", because we'd been talking about whorls. He meant the Greek goddess, and it stuck. The biologists hated it and so did the Americans, but it was well-received by most of the European geophysicists.

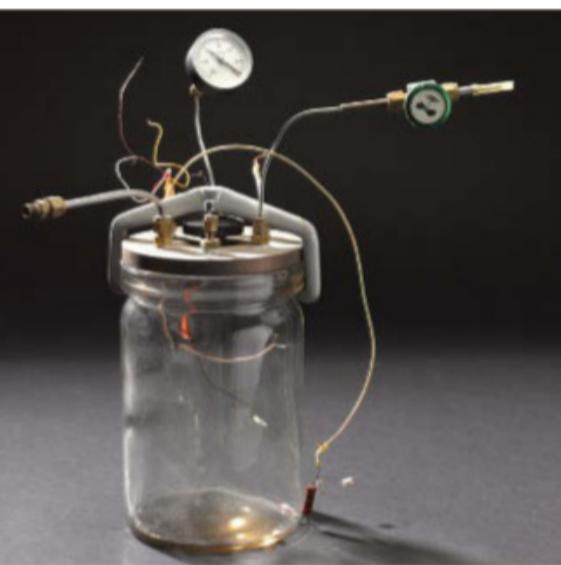
**Was it harder because you were an independent scientist?**

NASA advised me to become a contractor, as I'd get more money that way. But without an affiliation, I couldn't get papers published. The first paper on the entropy reduction that I did for NASA, I sent to *Nature*. I had published dozens of papers from Mill Hill in *Nature* before without any trouble, but this one they sent back straight away. "We don't publish papers from home addresses. They mostly

DAVID EXTON/SCIENCE MUSEUM/SCIENCE & SOCIETY PICTURE LIBRARY



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Lovelock's 1950s gas chromatograph (top) and vacuum pump (c.1960s)

come from cranks," they said. A friend, a professor of cybernetics at the University of Reading, suggested I become a visiting professor there. So I did, and then they accepted it. That was the first paper from Britain on the exploration of the other planets.

**In the four decades since you published the Gaia hypothesis, the idea of interconnected earth systems has become mainstream. There is growing concern about how humans are affecting these planetary systems, pushing us into the Anthropocene, the age of humans.**

I think we're forging ahead into the post-Anthropocene, into the Novacene. I think the chemical-physical type of humanity has had its time. We've mucked about with the planet and we're moving towards a systems type of thing, [a future species] running on cybernetics. The great thing is that if you run your systems on electronics or optical devices, they're up to 10,000 times faster than what we've got at the moment, and this opens up enormous possibilities.

**So will we and the rest of the natural world survive alongside these cyborgs?**

Well, the biological won't necessarily vanish completely, but it will be of less fundamental importance. People automatically assume that therefore humans will be finished. That's nonsense. We are much faster, more advanced, than plants and it doesn't mean plants have all vanished – we rather enjoy having them around. I always imagine one of these new cyborg-type people standing on a five-bar gate and looking out at the humans...

**And when does your Novacene start?**

I'm not sure, it may have already started.

**You have 11 great-grandchildren who are presumably going to be around in our warmer world. Do you think they will survive it?**

Assuming that the Novacene system comes in, its capacity for thinking will be 10,000 times, at least, faster than ours. It could be as much as a million times faster. I don't have doubts about survival. Look what we've done by increasing our intelligence. Perhaps I'm slightly religious, but I think the whole of the live part of the universe, which is mostly us and things [on Earth], is working through its existence. We'll just have to wait and see what happens.

**So you're a fatalist?**

If you like.

**You have seen a century of Earth's changes, humanity's changes – what about you? Have you changed as a person?**

You'd have to ask Sandy. She's still with me. It was an extraordinary love story. I met her at a meeting at Blenheim [Palace], but we hardly spoke to each other. And on the last day, I had just returned from the rather splendid loos and saw Sandy in a group of women. She turned around and looked at me, and I looked at her, and we just walked straight into each other's arms and never said a word. And that was it.

**Oh my goodness. Well, now I'm starting to understand your fatalism!**

All along, I've just happily trundled on, doing the experiments and getting the answers. And they were mostly exactly what I wanted. And it's been a good life. Not a rich one, financially, but a good one. ■



Gaia Vince is a writer and broadcaster based in London and author of *Adventures in the Anthropocene*. Follow her on Twitter @WanderingGaia

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The Department of Psychology anticipates making a tenure-track appointment at the assistant professor level to begin **July 1, 2020**.

We seek candidates with core expertise in **clinical psychology/clinical science** whose research programs also bridge to other domains in psychology, neuroscience, or related disciplines. Our interest is less in specific areas than it is in innovation and excellence. The appointment is expected to begin on July 1, 2020. Candidates at all levels are encouraged to apply.

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

Please submit a cover letter, curriculum vitae, research and teaching statements, up to three representative reprints, and names and contact information of three to five references. Also required is a statement describing efforts to encourage diversity, inclusion, and belonging, including past, current, and anticipated future contributions in these areas. In addition, please arrange for three letters of recommendation to be submitted to <http://academicpositions.harvard.edu/postings/9136>. The application will be complete only when all three letters have been submitted.

Questions regarding this position can be addressed to Jill Hooley at [jmh@wjh.harvard.edu](mailto:jmh@wjh.harvard.edu). The committee will consider completed applications starting immediately on a rolling basis through October 1. We expect to begin conducting interviews in October and November.

*We are an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability status, protected veteran status, gender identity, sexual orientation, pregnancy and pregnancy-related conditions or any other characteristic protected by law.*



HARVARD  
UNIVERSITY

The Department of Psychology anticipates making a tenure-track appointment at the assistant professor level to begin **July 1, 2020**.

We seek candidates with expertise in social psychology, broadly defined. The appointment is expected to begin on July 1, 2020. Candidates at all levels are encouraged to apply.

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

Please submit a cover letter, curriculum vitae, research and teaching statements, up to three representative reprints, and names and contact information of three to five references. Also required is a statement describing efforts to encourage diversity, inclusion, and belonging, including past, current, and anticipated future contributions in these areas. In addition, please arrange for three letters of recommendation to be submitted to <http://academicpositions.harvard.edu/postings/9123>. The application will be complete only when all three letters have been submitted.

Questions regarding this position can be addressed to Joshua Greene at [jgreen@wjh.harvard.edu](mailto:jgreen@wjh.harvard.edu) with the words "Social Search" in the subject line. Applications must be received by September 1, 2019 to be guaranteed review. Applications will be reviewed until the position is filled. We expect to conduct interviews in October and November.

*We are an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability status, protected veteran status, gender identity, sexual orientation, pregnancy and pregnancy-related conditions or any other characteristic protected by law.*



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University of Nebraska Medical Center. The Department of Genetics, Cell Biology and Anatomy (GCBA) invites applications for a tenure-leading, Assistant/Associate Professor position at the interdisciplinary area of 'Bioinformatics and Human Microbiome' to start Fall 2019. The incumbent will complement the existing strengths in genomics, metagenomics, infectious diseases, and bioinformatics at UNMC. We are seeking a dynamic faculty member who interfaces with crosscutting disciplines such as cancer, neuroscience, infectious diseases, precision medicine, etc. to integrate the human microbiome research applications.

We seek candidates with a strong record of achievements at the interface of human microbial studies and Bioinformatics including a strong and relevant publication record, proven capacity or clear potential to attract externally sponsored research funding, and demonstrated experience in teaching and mentoring graduate students and postdocs. The candidate should have a Ph.D., or M.D. (or equivalent degree) in Bioinformatics or a related discipline with postdoctoral training in a genomics-based research area associated with microbiomes or infectious diseases. Wet lab experience is a strong plus but not a requirement.

State-of-the-art research laboratories, biomedical informatics infrastructure, core facilities and collaborative investigators are available at UNMC/UNL to conduct world-class research in Bioinformatics and Human Microbiome. The research ecosystem contains a number of ongoing projects related to genomics, metagenomics and dietary modulation of gut microbiome to develop independent and collaborative grant proposals. Specific opportunities include the development of new computational tools and data analysis pipelines in the areas of metagenomics, nutrigenomics, obesity predisposition and prevention, and dietary modulation of gut microbiome.

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# The back pages

## Puzzles

Cryptic crossword,  
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Precious water and  
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## Liana Finck for

**New Scientist**  
A cartoonist's take  
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## Almost the last word

Lottery strategies and  
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readers respond **p54**

## The Q&A

Roma Agrawal,  
designer of the  
Shard's spire **p56**



How to be a maker 2 **Week 3**

## No more thirsty plants

With **Hannah Joshua**'s device, you can go on holiday safe in the knowledge that your plant will get all the water it needs



Hannah Joshua is a science writer and maker based in London. You can follow her on Twitter @hannahmakes

### New stuff you need

**3V submersible water pump**  
**Plastic tubing to fit your pump**  
**2n7000 transistor**  
**Breadboard**  
**Crocodile clip jumper wires**

### For next week

**Old smartphone**  
**Phone stand**

### Next in the series

- 1** Moisture-sensing plant
- 2** Moisture and temperature-sensing plant
- 3** Plant auto-waterer
- 4** **Tweeting wildlife cam**  
**A motion-controlled animal spotter**
- 5** Pest scarer
- 6** BBQ thermometer
- 7** Rain alarm
- 8** Mini weather station
- 9** Remote controlled pest-proof bird feeder part 1
- 10** Remote controlled pest-proof bird feeder part 2

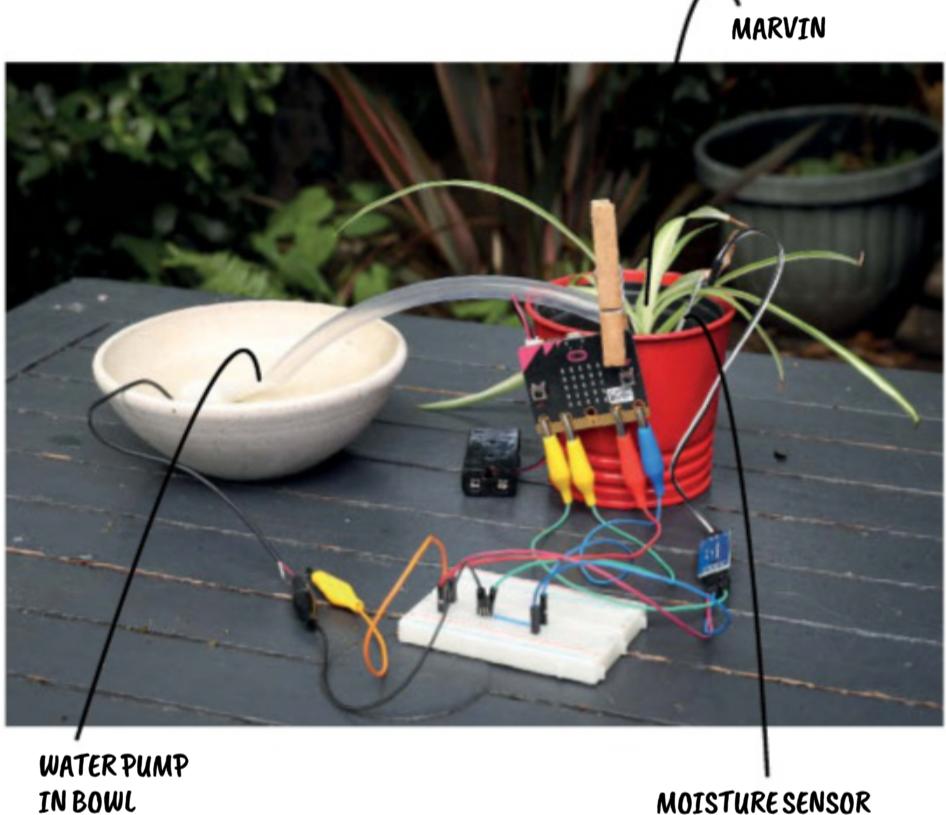
YOU have gone seven days with a moody plant after we left it complaining last week. Now we can give it both the means and a reason to be happy.

First, tweak your code to show a smiley face when the plant's conditions are good. Open your code in the editor – now the variables we created last week will come in handy. Take another “if” block with no “else” part, and snap it under the first two. Then slot in a “<> and <>” block from the “Logic” menu, and two “o = o” comparisons. Slot the “o = o” blocks either side of “and”.

Next, take your variables, DRY and WRONG TEMP, as well as two “false” blocks from the “Logic” menu and make a line that says “if DRY = false and WRONG TEMP = false”. Nestle a “show icon” from “Basic” inside the “if” block and select the smiling face.

Now it is time to build an automatic waterer to stop your plant drying out. For this we need a transistor. A transistor can act like an electronic switch. It has three legs, two of which are connected or not depending on the current going into the third.

Grab your breadboard (for a refresher, see “How to be a maker”, 25 May), and place the transistor so its legs each sit in different rows. Connect the middle leg, called the “gate”, to pin 1 on the micro:bit. On my transistor, when the flat side is facing me, the right leg is the “drain” and the left is the “source”. Yours will probably be the same, but check the packet to be sure. Connect the drain to the pump’s



DAVID STOCK FOR NEW SCIENTIST

### Make online

**Projects so far and a full list of kit required are at [newscientist.com/maker](http://newscientist.com/maker)** Email: [maker@newscientist.com](mailto:maker@newscientist.com)

ground wire, which should be white, and the source to micro:bit's ground. Connect the pump's red power wire to micro:bit's 3v pin.

Now, when the micro:bit sends a 1 to the transistor's middle leg, it will complete the circuit, while a 0 will break it. This lets us switch the pump on and off.

Let's add to our code to do this. From the “Pins” menu, grab a “digital write pin” and select P1 from the drop-down. Leave the 0 at the end and clip the block into “on start”. This will make sure that the pump is off to begin with.

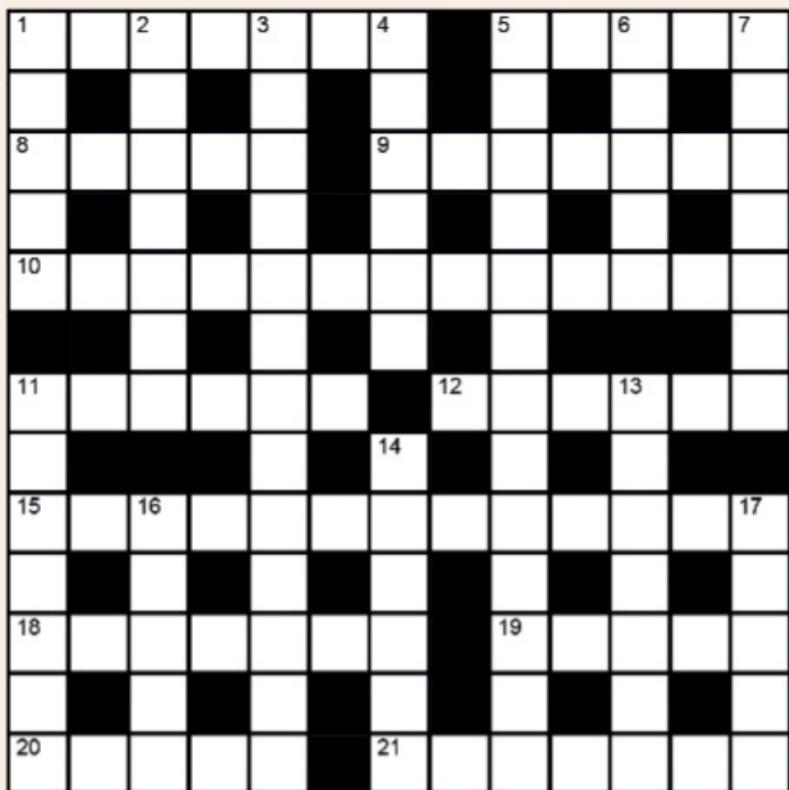
Next, under the block that says “set DRY to true”, add another “digital write pin p1”, but this time

change the 0 to a 1. Underneath that, slot in a “pause” from “Basic” and select 2 seconds from the drop-down. Add another “digital write pin p1” underneath, leaving the 0 in the box. This will switch on the pump for 2 seconds then off again when the soil is dry. Add one final “pause” below, typing in 10,000. This makes the system wait 10 seconds for the water to percolate. Once again, if you get stuck, check my code online.

Finally, put the pump in a bowl of water and attach a length of tube between it and the plant pot. And you're done! Now you can go on holiday and return to a happy houseplant. ■

# The back pages Puzzles

## Cryptic crossword #11 Set by Sparticle



### Across

- 1 Aerial insect gives woman a turn (7)  
5 Problem with Schrödinger's guinea pig loose in Switzerland (5)  
8 Poster I connect with European farewell (5)  
9 Distracted animal tracks earliest Facebook post (3,4)  
10 Order an X-ray. It's faulty? Strange (13)  
11 3 downs are beginning to follow life in French capital (6)  
12 One can wrap one's head
- 15 Opportunities for mass movement to build on cancer study (7,6)  
18 Howler monkey with a long exclamation of pain up front (3,4)  
19 A soupçon of digitalis lethargises a pancreatic region (5)  
20 Chuck, say, investment in acoustic mimicry (5)  
21 Read, and if you highlight a section, smarten up (7)

### Down

- 1 Retail giant chasing Google's tail loses on "wow!" (5)  
2 List the wrong flower of Scotland (7)  
3 It can process, learn, know. True? (6,7)  
4 Guarantee mass drops very loudly in the atmosphere (6)  
5 Distribution of electrons touring foci – an unorthodox arrangement (13)  
6 Revolutionary Atari headband (5)  
7 Golden clay fired and compressed by hydrogen covering (7)
- 11 Mindless drone returning with great speed over you and me (7)  
13 Chief inspector gets sick following graduate (they spread disease) (7)  
14 Once you replace Euclid's Elements II and III, either can be dropped with a wink! (6)  
16 Sources of u-shaped lines near an ellipse parallel to the radii? (5)  
17 Spit food at cutting remark (5)

Answers and the next quick crossword next week.

## Quick quiz #13

1 What speed is required to go hypersonic?

2 Plants of the genus Nepenthes are most notorious for what?

3 Dotted with more than 400 volcanoes, what is the most tectonically active body in the solar system?

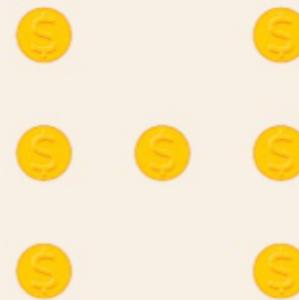
4 The abandoned whaling station Grytviken is the only settlement on which UK island territory in the South Atlantic, also home to the grave of polar explorer Ernest Shackleton?

5 Where are the Islets of Langerhans?

Answers below

## Puzzle set by David Bedford

### #14 The H coins problem



Seven coins have been placed in the "H" shape above. Altogether there are five lines of three, including the diagonals.

Your challenge is to place two more coins so that you can make 10 straight lines of three. No stacking of coins or other sneaky trick is required.

If you find a way to do this, give yourself a silver medal. If you find a second way to do it that isn't a mirror image of the first, award yourself a gold.

Answer next week

## Quick Crossword #36

### Answers

**ACROSS 1/8** Nettie Stevens, 4 Stimulus, 9 Octave, 10 Airspace, 12 Anaerobe, 13 Curare, 16 Asbestosis, 19 Conduction, 20 Glue, 23/15 Don't Be Evil, 25 Fuselage, 27 Vertebra, 28 Cloaca, 29 Roadkill, 30 Expert  
**DOWN 1** Neonate, 2 Titration, 3 Invert, 5 Trig, 6 Mosquito, 7 Llama, 11 Obesity, 14 Zero Sum, 17 Self Aware, 18 Outbreak, 19 Cadaver, 21 Elegant, 22 Reflex, 24 Noria, 6 Aral

## #13 Snail party

### Solution

As the four snails move towards each other they point at all times at the snail they are moving towards. They thus keep to the corners of a rotating, ever decreasing square.

As A, for example, changes direction, so do B, C and D, all by the same amount, so their paths are constantly at right angles. This means that A, for example, always comes towards B at the same constant speed it did at the start, continuing until they meet.

This is exactly the same situation as if B were stationary and A moved directly towards it. Thus the time taken is the initial distance, 2 metres, divided by the speed, 2 metres per hour, which equals 1 hour.

## Quick quiz #13

### Answers

Paul Langerhans  
the German anatomist  
are named for their discoverer,  
it's insulin-producing cells and  
its pancreas. They contain  
3 Jupiter's moon Io  
4 South Georgia  
5 The pancreas. They contain  
carnivorous insects. They are  
plants  
2 Eating insects. They are  
sound  
1 Mach 5, five times the speed of

## Get in touch

### Email us at

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[puzzles@newscientist.com](mailto:puzzles@newscientist.com)

## Wet stones

With an unquenchable thirst for exposing fruitloopery, Kathleen James brings our attention to "bewater", a company selling water bottles decorated with semi-precious gemstone inserts. "We want you to choose to believe, bepowerful, bejoyful and bemagical," someone has written using a keyboard with a sticky space bar. "Each of our four ranges has been designed using gemstones inspired by these qualities."

Consider us bemused. The company is keen to note that the gemstones don't actually come into contact with the drinking water "as certain stones are toxic". Instead the (certifiably non-toxic) vibrational energy of the stone transmits itself to the water.

This brings a list of health benefits as long as your credit card receipt. The fluorite in bewater's £19.95 "positive insert" for a bottle, for example, "cleanses and stabilises the aura", as well as apparently doing a shedload of good for, variously, self-confidence, the immune system, the healing of ulcers, balance (mental and physical), shingles and the "restructuring of cells and DNA".

Great stuff, although Feedback can't help thinking that the mineral sodalite's reported quality of "replenishing your natural thirst" makes it a puzzling choice for use in a water bottle. Help might be at hand, however. Bewater's FAQ notes that the company can't vouch for any of these bemagical powers, only that they were discovered in "books and articles that inspire us", and "we never present them as medical advice". Wise.

## It's grim up Siberia

Also enjoying mineral-infused waters are visitors to a lagoon on the outskirts of Novosibirsk, Russia. The intense turquoise water of the "Siberian Maldives" is proving a magnet for bikini-clad Instagrammers hunting the perfect holiday or wedding snaps. However, authorities have

warned that the pond's unusual hue is down to the fact it is a dumping ground for ash from a nearby power plant, and contains high levels of heavy metals and other toxins. Skin contact with the water is not advised, nor is paddling across it on unicorn-shaped inflatables.

The Siberian Generating Company issued a statement saying "walking along the ash dump is like walking on a military firing range: dangerous and undesirable". But then again, if anyone can thrive in a pool of toxic waste, it is Instagram users.

## A matter of degree

Many parts of the world have been experiencing record temperatures recently, but if a special report on climate change from Sky News in the UK is anything to go by, things are about to get far worse than anyone thought.

Reader Tony Budd is informed that scientists have warned "the impacts of climate change would become rapidly more severe once the average global temperature rose more than 1.5°C (34.7°F). And the threshold could be reached within a generation."

Feedback recalls the tirade against the metric system on Fox News we mentioned last month (22 June), and wonders whether this excessive warming in Fahrenheit might be the impetus the US needs to embrace more sensible measurement units. At least for those not embracing the view that climate change is all a Chinese conspiracy.

## Worm charming

Sweating in the present heat, Feedback welcomes Russia's move to ratify the Paris Agreement, which aims to limit global warming to significantly less than 34.7 degrees above pre-industrial levels. However, Climate Home News reports that there could be a catch with plans to expand wind power capacity: Vladimir Putin is worried about the worms.

Liana Finck for New Scientist



Besides expressing well-worn concerns about the number of birds sliced and diced by wind turbines, the Russian president told a conference in Yekaterinburg, "they shake so much that worms come out of the ground", adding, lest we think otherwise, "Really, it's not a joke".

Perhaps, in a decarbonised economy, redundant coal miners might find employment gently pushing agitated annelids back into the earth, Feedback speculates. But leafing through our back copies, the only reference we can find to the worm-turning phenomenon comes in an article from now-emeritus professor of public health Simon Chapman of the University of Sydney (6 October 2012, page 26). There, he lists it as one of the many phantasmal symptoms of "wind farm syndrome", a frightening and highly variable pathology chiefly

affecting anti-turbine activists, fossil fuel interests and nimbyish landowners. Fancy that!

## Happy accidents

To err is human, to forgive divine. But a well-placed excuse can bridge the gap between the two by alleviating blame, replacing judgement with compassion and granting you an extra day to deliver your copy (here's hoping).

Writing in the journal *Philosophy and Public Affairs*, Paulina Sliwa at the University of Cambridge posits a "unified theory of excuses". The key to getting away with transgressions, she says, is to show that your underlying moral intentions were good – it is just that something went wrong putting them into practice.

Feedback is taking this advice to heart. If you are looking at a blank page, we promise we did write our column, but a dog ate it. An exploding dog. ■

## Got a story for Feedback?

Send it to New Scientist, 25 Bedford Street, London WC2E 9ES or you can email us at [feedback@newscientist.com](mailto:feedback@newscientist.com)



## Lucky dip

**What gives me better odds of winning the lottery: buying one ticket a week for a year [52 weeks] or buying 52 tickets once a year?**

**Antoon Pelsser**

*Maastricht, the Netherlands*

To answer this, we can assume that each week N tickets are sold and there is only one prize to be won. So each ticket has a probability of  $1/N$  of winning.

When you buy 52 weekly tickets, the probability of losing 52 times is  $((N-1)/N)^{52}$ . Hence, the probability of winning at least once is  $1 - ((N-1)/N)^{52}$ . When you buy 52 tickets once per year, then the probability of winning is  $52/N$ .

The second of these probabilities is larger than the first. The most extreme case of this is when there are only 52 tickets in total, then buying all 52 gives a guaranteed win. However, this advantage very quickly drops when N becomes larger. For N=1000, the chances of winning are 0.52 per cent when buying 52 tickets at once vs 0.506 per cent for the weekly purchase.

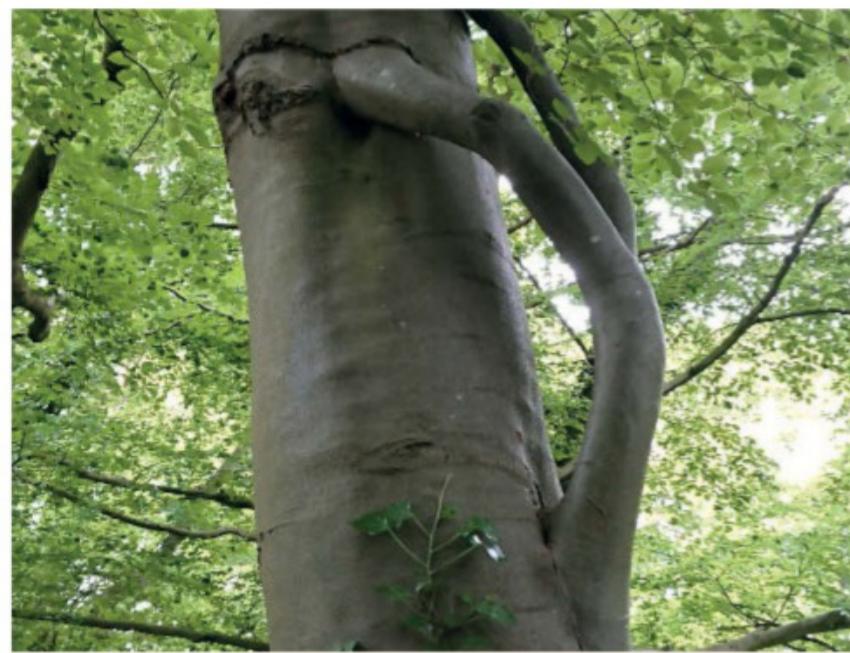
The lower probability of winning when buying tickets weekly is compensated for by the fact that this gives you a (small) probability of winning more than one prize.

**Brian Horton**

*West Launceston, Tasmania, Australia*

Never buy more than one ticket in a lottery. If you buy one each week you could possibly win the top prize two or more times in a year. If you buy 52 tickets once a year you can't win more than one first prize, so you miss that extra chance of a double win.

Instead of considering the chance of winning, you could look at the chance of losing money. If the prize pool is equal to 60 per cent of the value of the tickets sold, then buying more than 60 per cent of the tickets makes certain you will lose money even if you win every prize. Even if you buy



## This week's new questions

**Find yourself** This tree, in the grounds of Anglesey Abbey, Cambridgeshire, UK, has a branch growing in a loop, apparently reabsorbed by the tree. Is this common, and how can it happen? *Kimon Roussopoulos, Cambridge, UK*

**Human traces** In the near future, a mystery virus wipes out the entire human race almost overnight. Later on, a group of extraterrestrials lands on Earth. There are now no visible signs that human civilisation ever existed. How many years in the future would this be? *Duncan Cameron, Brighton, UK*

**Roll of honour** Why do dogs and horses roll on their backs when happy? *Tony Sandy, Crookedholm, Ayrshire, UK*

fewer than 60 per cent, the more you buy, the greater your chance of an overall loss.

So the fewer tickets you buy, the better off you are. Since research has shown that the winners of big lotteries double their chance of going bankrupt in the five years after winning, the best number to buy would be zero.

**Spencer Weart**

*Hastings-on-Hudson, New York, US*

Your probability of winning is slightly greater if you buy 52 tickets once a year. Of course either way your chances of winning are so negligible that what you are actually purchasing is the pleasure of fantasising for several days about striking it rich.

In that sense, you are better off buying one ticket every week. Or you could join the many people who fantasise about what they

would do if they bought a winning ticket, without actually bothering to purchase one.

**Stephen Johnson**

*Eugene, Oregon*

The odds of winning the grand prize in any of the mega lotteries is very small, typically around 1 in 250 million. If you buy 52 tickets of a single large lottery you have increased your odds to 52 out of 250 million, or 1 in approximately 4.8 million.

Many casino games have vastly better odds. For example, the odds of winning on a single number playing roulette in the US is 1 in 38, and the odds of winning by

A tree that reabsorbs its own branch – how does this happen?

betting on either red or black in roulette is 1 in 2.11 or 47.4 per cent. However, such games aren't nearly as attractive as the lottery because the potential payoff is so much smaller.

This preference for poor odds with a large payoff instead of much better odds with a small payoff is one of our errors in economic judgement that undermined the foundation of microeconomics laid out by John Von Neumann and Oskar Morgenstern in 1944.

They expected people to act rationally and make such gambles on the basis of the mathematical outcome. Work by psychologists including Daniel Kahneman, who won a Nobel prize for his work, showed irrational, but predictable, biases govern most economic decisions, in particular gambling.

## Itchy and scratchy

**When we feel itchy, a scratch brings instant relief. But when the itch is caused by a mosquito bite, scratching increases the irritation. Why the difference?**

**Peter Slessenger**

*Reading, UK*

After a mosquito bite, a tight blister can form over the puncture wound made by the insect and tension in the skin causes the pain. Scratching will only distress the traumatised skin even more.

Some time ago, I experimented bursting one of a pair of mosquito bite blisters and leaving the other to heal naturally. The burst blister stopped itching immediately and healed a day earlier than the one left to its own devices. Bursting a blister does increase the risk of infection, however. ■

**Want to send us a question or answer?**

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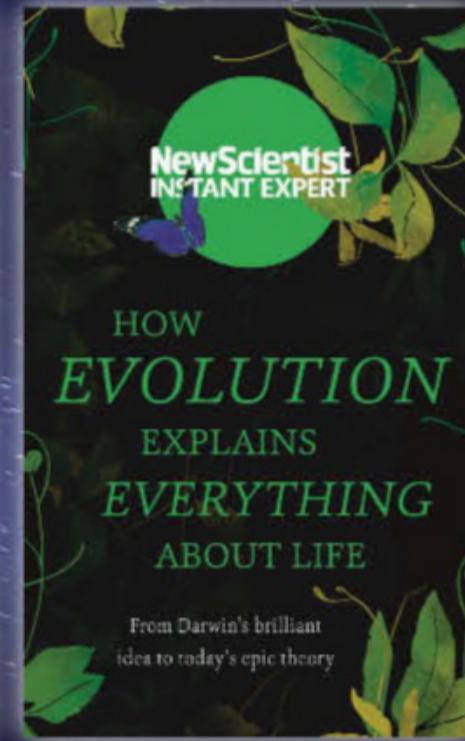
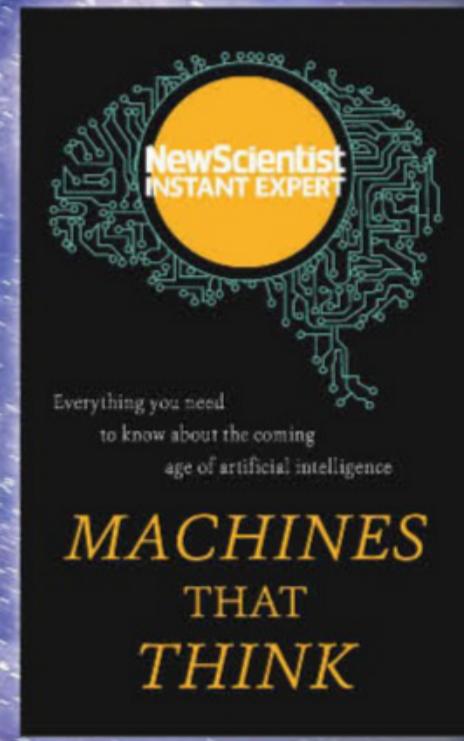
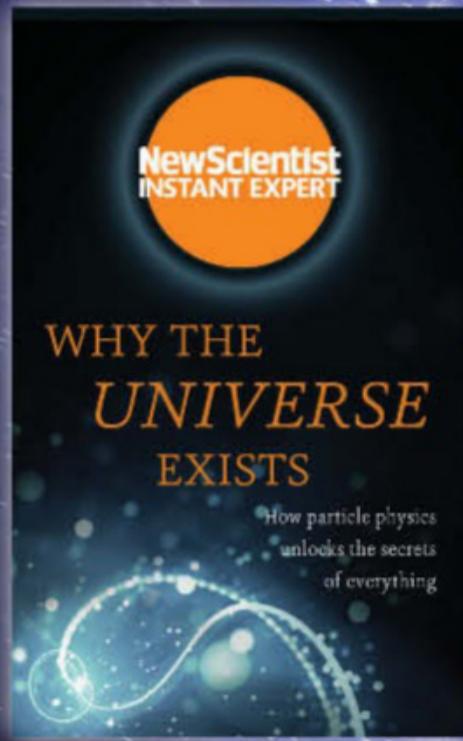
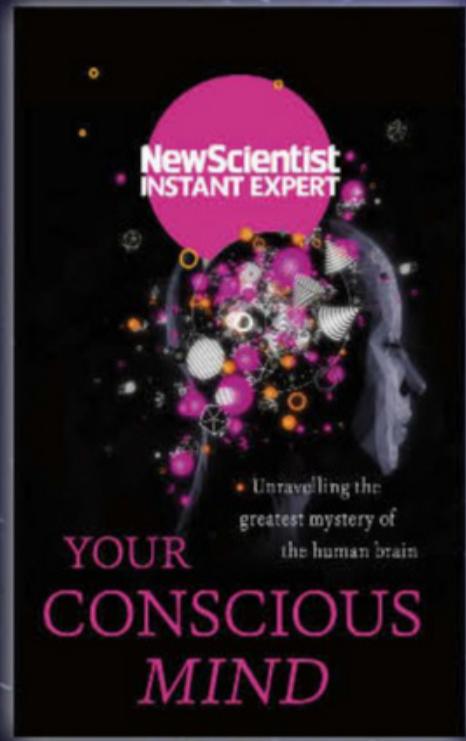
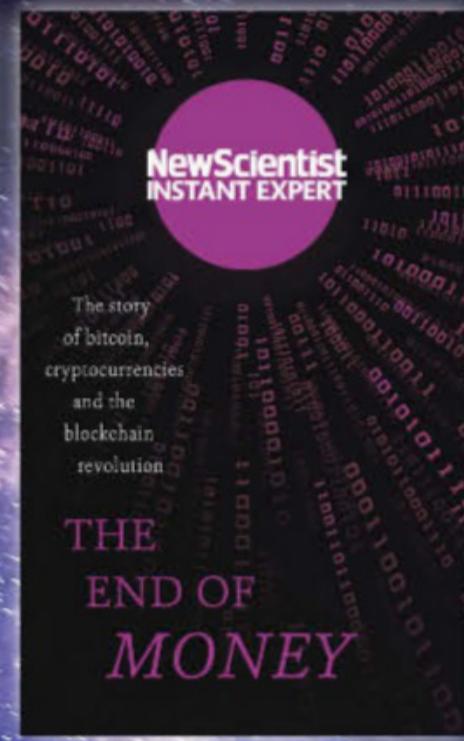
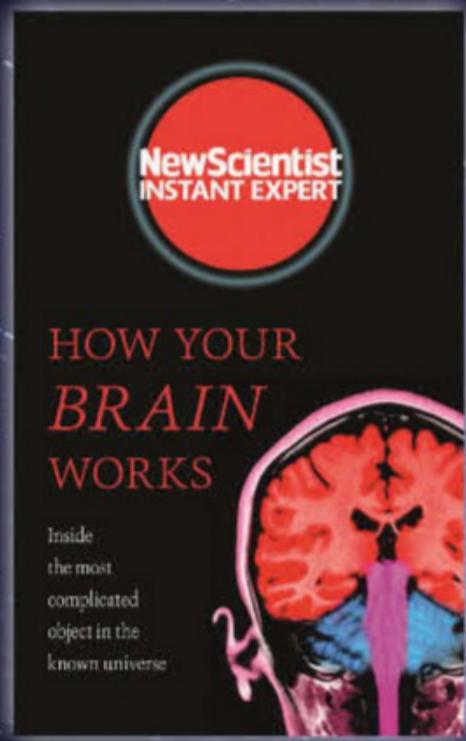
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**Roma Agrawal** designs bridges, sculptures and skyscrapers, including the spire of London's iconic Shard. But her favourite building is the Pantheon in Rome...

### As a child, what did you want to do when you grew up?

I wanted to be an astronaut. At some point that didn't feel terribly realistic – roller coasters scare me – so I thought about becoming an architect.

### Explain what you do in one easy paragraph.

I'm a structural engineer. It's my job to make buildings and bridges stand up. Structures are pushed and pulled all the time by forces like gravity and wind. I work with materials and forces to make sure that the skeleton holding up a structure is strong enough to resist these forces.

### What does a typical day involve?

Meeting architects, other engineers and the people who will build the structure I'm working on. Earlier in my career, I spent more time doing calculations, mostly on 3D computer models.

### Sum up your life in a one-sentence elevator pitch...

A busy life that combines engineering with writing, podcasting, presenting and some cooking and exercise.

### What do you love most about what you do? And what's the worst part?

The best part is seeing something I helped design become a real thing. I love that I can point at structures and say, "I helped build that!". The worst is when a project you have been working on stops for some reason out of your control.

### What's the most exciting thing you're working on right now?

My podcast, *Building Stories*, which unravels the secrets behind our structures. I'm also writing a children's book. I love using these different formats to tell more people about what I do.

### If you could send a message back to yourself as a kid, what would you say?

I'd say it's fine to be different, and reassure myself that I would find my place in the world and thrive.

### Were you good at science at school?

I was good at maths and physics, and less good at chemistry and biology. But I always found these subjects so, so interesting.

### What's the best piece of advice anyone ever gave you?

To try to make things better in your sphere. We might not all be able to change the world, but we can make our corner a nicer, more accepting place.

### Do you have an unexpected hobby, and if so, please will you tell us about it?

I love dancing. I trained in Bharatanatyam, a classical dance form from India, for 20 years and also competed in ballroom and Latin dancing at university.

### What's the best thing you've read or seen in the last 12 months?

*Inferior* by Angela Saini, where she breaks down some of the misconceptions and biases about science and gender. It really opened my eyes to how important it is to include all types of people in science.

"I love that I can point at structures and say, 'I helped build that!'"

### If you could have a long conversation with any scientist, living or dead, who would it be?

I would love to speak to engineer Emily Roebling. She took over running the construction of Brooklyn Bridge in the 1860s when her engineer father-in-law and husband met with tragedy. Women engineers were unheard of at the time.



### How useful will your skills be after the apocalypse?

Super useful! I could rebuild people's homes.

### OK, one last thing: tell us something that will blow our minds...

My favourite structure in the world is the Pantheon in Rome. It is made from a special Roman concrete and is still the largest unreinforced concrete dome in the world, 2000 years after it was built. ■

Roma Agrawal is an associate director at AECOM. Her latest book is *Built: The hidden stories behind our structures*. She will be speaking about skyscrapers at New Scientist Live on 12 October @RomaTheEngineer

PORTRAIT: MASSIMILIANO DONATI/AWAKENING/GETTY IMAGES, BRIDGE: STARCEVIC/GETTY

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RICHARD ROBINSON, BRIGHTON SCIENCE FESTIVAL

The cover of the AQUILA July/August 2019 issue features a vibrant, colorful illustration of a Greek mythological scene. In the center, a large, red, elephantine creature with a single tusk and a small tuft of hair on its head is shown in a dynamic pose, seemingly attacking or interacting with a smaller figure. To the left, a figure in a green and yellow patterned outfit holds a sword and a torch, looking towards the central figure. The background is a stylized landscape with a sun, a crescent moon, and a boat on the water. The title "AQUILA" is at the top in large, bold letters, with "JULY / AUGUST 2019" and "Big ideas for inquisitive kids" below it. The word "Ancient Greece" is printed at the bottom of the cover.

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