# New Scientist

**WEEKLY** May 27 - June 2, 2017

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We put 15 common kitchen tips to the test

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Mystery Greek ape could be the ancestor of us all

**CONSCIOUS QUANTUMNESS**
How to probe the mind-matter connection

**NOWHERE TO HIDE** Invisible nuclear subs still leave a trace

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How a tiny bit of missing energy became the biggest problem in the cosmos

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# Baja whale-watching expedition

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## EXHILARATING WHALE WATCHING

Between December and April, grey whales migrate to the warm, calm waters of the Baja California Peninsula to calve and to nurture their young. Sail through this magical area to spot an abundance of marine life, including majestic grey whales, on small expedition vessel the Searcher.

## LEARN ABOUT MARINE CONSERVATION

Enjoy the company of marine expert Jo Ruxton on board during the voyage. After a long career with conservation organisation WWF and the BBC Natural History Unit, Jo is currently leading the campaign to protect the world's oceans from plastic pollution. Quiz her on the science behind protecting oceanic ecosystems.

## GET CLOSE TO BREATHTAKING MARINE WILDLIFE

From the decks of the Searcher, or in a smaller boat known as a panga, experience unparalleled whale watching from the waters. Be guided by the passion and knowledge of Art Taylor, owner and captain of the vessel, who has been navigating the peninsula for more than 30 years.

We've teamed up with Steppes Travel to offer readers a chance to get close to marine wildlife, with naturalists for company.

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PHONLAMAI PHOTO/SHUTTERSTOCK

# Back to the future

Tech matters in the UK election, but new ideas are in short supply

"THE Britain that is going to be forged in the white heat of this revolution will be no place for restrictive practices or for outdated measures." So said Harold Wilson in 1963, urging Britons to embrace science and technology to ensure "the future greatness of our country"; his message helped the Labour party win the 1964 general election.

Half a century on, and the country once again needs reassuring of its potential for greatness. And most of the parties vying to form the next government accept that embracing science and technology could once again be key to that greatness as they consider the shape of the post-Brexit economy.

A pity, then, that the rival party leaders haven't expressed that half as powerfully as Wilson did. Instead, they have made mostly uninspired pledges along party lines. The Conservatives, for example, say they will make the country into "the world's most dynamic digital economy" with investment in infrastructure, skills and start-ups. Labour says it will look into the potential for "new jobs and new forms of work – but also new risks of inequality and job insecurity". Both have pledged to uphold incoming laws on data protection and increase R&D spending. Neither expresses the passion one might hope for, given the promise and challenges of technology (see page 20).

Except when it comes to amassing power, that is. "Some people say that it is not for government to regulate when it comes to technology and the internet. We disagree," says the Tory manifesto. "Our starting point is that online rules should reflect those that govern our lives offline."

Fair enough, but the reflection so far has been so simple-minded as to be at best counterproductive, and at worst suspect, introducing prudish censorship and mass surveillance. Action might well be needed to curb the excesses of social media and tech giants, but restrictive practices and outdated measures have no place in forging Britain's future greatness. ■

# Domestic science

WHEN did you last conduct a complex chemical experiment? For most of us, the answer is probably whenever you last spent any time in a kitchen. Cookery boils down to applied organic chemistry, with a sprinkling of combustion physics and a dollop of materials science thrown in (see page 32). But the feats of chemical engineering that cooks perform every mealtime – whether in a billycan over a fire, or a *sous vide* in a fancy restaurant – are more often appreciated with the senses rather than the mind.

That's been changing since the advent of molecular gastronomy, which has brought cultural cachet to the kinds of work industrial food scientists do all the time – albeit that many foodies would still rather their food came *au naturel* than highly engineered.

The next big thing in dining is set to be cross-sensory dining: altering diners' perceptions of how food smells and tastes by changing factors like its colour, the lighting and the tableware. You could think of it as putting the art of food presentation, long practised by restauranteurs, on a more neuroscientific basis, much as molecular gastronomy riffs off the chemical basis of cooking. If it catches on, we may soon learn that a feast for the senses is really a feast for the mind too. ■

# Cholera crisis in Yemen

A CHOLERA outbreak in Yemen has killed 332 people in four weeks and left some 32,000 ill, the World Health Organization reported on 22 May.

The disease, which is caused by ingesting food or water contaminated with *Vibrio cholerae* bacteria, has spread faster than any previous outbreak in Yemen. It has now reached 19 of Yemen's 22 governorates, and could affect as many as 300,000 people over the next six months, the WHO says.

When medical care is in place, cholera is easily treated. Oral rehydration solution or intravenous fluid is given to replace lost water and electrolytes. But in Yemen, two years of civil war have crippled an already overstretched healthcare system.

Doctors in the country haven't been paid since September, and less than half the hospitals and medical clinics are still running. There is also a shortage of rehydration fluids for treating people with cholera.

The rapid spread of cholera-causing bacteria is largely due to the collapse of sanitation infrastructure, the WHO says. Rubbish collection services have ceased and sewage pipes have been ruptured by air strikes, allowing faecal matter to leak into water supplies used for drinking and irrigating food crops. Water treatment plants have also shut down.

In response to the crisis, the WHO has delivered 48 tonnes of intravenous fluids to Yemen. Wells and other water sources are also being chlorinated to kill cholera-causing bacteria.

KHALED ABDULLAH/REUTERS

Civil war has trashed healthcare

## US budget cuts

PRESIDENT Donald Trump's administration plans to gut funding for healthcare and medical research, according to a 2018 budget published online and rapidly withdrawn on Monday.

Despite a campaign pledge not to touch Medicaid, which provides healthcare cover for millions of US people on low incomes or with a disability, Trump's budget includes a $610 billion cut to the programme over 10 years. That's on top of the more than $800 billion in cuts included in the American Health Care Act passed by the US House of Representatives.

**"Trump's budget cuts $610 billion from Medicaid, on top of the $800 billion already proposed"**

Food stamps are also on the chopping block. The Supplemental Nutrition Assistance Program, which helps low-income people buy food, is slated for a $193 billion funding cut over the next decade.

Medical research could take a hit, too. The budget calls for slashing $5.8 billion in funding for the National Institutes of Health and cutting $1 billion from the US Centers for Disease Control and Prevention, the country's health protection agency.

It also includes deep cuts to programmes designed to prevent substance abuse, while the US is in the midst of an opioid epidemic.

If enacted, the proposed budget would withhold all federal funds from facilities that provide abortions.

Many other scientific organisations stand to lose part of their funding. The Environmental Protection Agency is facing a suggested 31.4 per cent reduction in government funding. NASA is set to lose out on $200 million – just under 1 per cent of the organisation's current budget.

Brian Schatz, Hawaii state senator and Democrat, described the cuts as "cruel". Early responses from both Democratic and Republican members of Congress suggest that this budget is unlikely to pass in its current form.

## Go for the rematch

HUMANITY is lost. DeepMind's artificial intelligence AlphaGo has defeated Ke Jie, the world's number one player, in the first of three games of Go played in Wuzhen, China.

The AI won by half a point – the smallest possible margin of victory – in a match lasting 4 hours and 15 minutes. Although the scoreline looks close, AlphaGo was in the lead from relatively early on in the game. Because the AI favours moves that are more likely to guarantee victory, it doesn't usually trounce opponents.

In a press conference after the match, Ke said AlphaGo had learned from its recent victories against Go champions. "In the past it had some weaknesses, but now I feel that its understanding of the Go game and its judgements are beyond our ability," he told the audience.

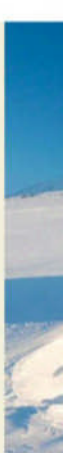
AlphaGo will play Ke again on Thursday and then Saturday. It will also take on a team of five top-ranked Go players.

## Doomsday vault not watertight

THE doomsday vault that is supposed to protect the world's most valuable seeds against any kind of disaster has sprung a leak.

The Norwegian government is altering the entrance to the Svalbard Global Seed Vault after unusually heavy rain and melting permafrost entered the entrance tunnel and froze on the floor. The water didn't get near the seed storage areas deep within the mountainside, but the alterations will ensure the entrance is more secure. The measures include building waterproof walls, digging drainage ditches and moving a power transformer whose heat might be helping to melt permafrost.

The vault is located on an island in the Svalbard archipelago, far to the north of Norway. It is less than a decade old, but has already proved useful, for example in providing seeds to drylands researchers unable to access a seed storage facility in war-torn Aleppo, Syria.



## Tabby's star dims

THE weirdest star in our galaxy is acting up again. On 19 May, Tabby's star began to dim, carrying on its history of strange dips in brightness. Astronomers are scrambling to decipher the mysterious signal from the star, which is 1300 light years away in the constellation Cygnus.

**"Some have suggested the dimming could be caused by an orbiting alien megastructure"**

In 2015, astronomers led by Yale University's Tabetha Boyajian saw light from the star, officially called KIC 8462852, suddenly and repeatedly dip in brightness by up to 22 per cent. Then, in 2016, a review of old photographic plates revealed that it dimmed by 14 per cent between 1890 and 1989.

There are many potential explanations for the strange behaviour of Tabby's star, such as its interior dynamics or it being orbited by asteroids and debris. Some astronomers have suggested the dimming could be caused by an orbiting alien megastructure.

The latest loss of brightness has prompted a swift repositioning of telescopes to catch the dimming in action. If we're lucky, new observations may help us figure out what's making this happen – but it's probably not aliens.

KERSTIN LANGENBERGER/IMAGE BROKER/ALAMY

Secure the doors

XAVIER ROSSI/GAMMA-RAPHO VIA GETTY

Niger's elephants could benefit

## Saving our heritage

THREE sites of outstanding biodiversity could soon be granted Natural World Heritage status, and so receive new protection.

"We're hoping we will see these three sites on the World Heritage List come mid-July," says Peter Shadie, senior adviser on world heritage to the International Union for Conservation of Nature.

One site is China's Qinghai Hoh Xil –the world's largest, highest and youngest plateau. It is the sole home of the endangered Tibetan antelope – only 40,000 are left Other endemic species here include wild yaks, gazelles and snow leopards. "It's an extraordinary place," says Shadie.

**"Los Alerces is one of the world's most spectacular sites, hosting a 2600-year-old Patagonian cypress"**

Another site, Argentina's Los Alerces National Park, hosts endangered Patagonian cypresses, the second longest-lived trees on Earth. One is 2600 years old. "Scenically, it's one of the most spectacular places in the world, combining high mountain peaks with lush forests and clear streams," says Shadie.

The third site will extend the reach of Niger's W National Park by 1.5 million hectares – a seven-fold increase. Listed since 1996, the park is home to threatened species including cheetahs and elephants. "Most species require large ranges, so extending the park creates one large, intact ecosystem across national borders, providing corridors and connectivity that will help these species."

## Erasing emissions

EU NATIONS that appear keen to boost their climate credentials by switching to "green" biomass are accused of working behind the scenes to expunge the carbon emitted by burning wood in power stations from national emissions statistics.

On 19 June, EU environment ministers will set new rules to account for carbon produced from forest loss. Countries with plans to replace coal and nuclear power with wood are lobbying for rules that will obscure the emissions that are a likely result, says Hannah Mowat of FERN, a European NGO working to save the continent's forests. "France, Austria, Sweden and Finland are fighting tooth and nail to weaken the EU's rules," Mowat says. "This is because they all plan to significantly increase the amount of trees they cut in the next decade... and they don't want to count the emissions."

## 60 SECONDS

### Emergency spacewalk

Two astronauts ventured outside the International Space Station on an unplanned two-hour spacewalk. The aim was to repair a vital data relay box that controls solar arrays, radiators and cooling on the station. NASA said the five-person crew was not in danger, but had to rely on backup systems until the fix was made.

### Why diets don't work

An internal "thermostat" may be the reason diets don't work. A set of neurons in the brain stops mice from burning calories when they are not eating enough. This might prevent people from burning fat while on a diet (*eLife*, doi.org/b7gk).

### IQ genes discovered

Intelligence is in your genes, at least to a small degree. Research on around 60,000 adults and 20,000 children has identified 52 genes linked to IQ. Together, the genes only account for about 5 per cent of the variation in intelligence, though (*Nature Genetics*, doi.org/b7gm).

### Radon threat in Ireland

Nearly half a million Irish citizens may be exposed to potentially harmful radiation from radon gas in their homes. Radon trickles up from soil as a byproduct of rock decay. Some 460,000 citizens – 10 per cent of the population of the Republic of Ireland – face exposure above the safety threshold of 200 becquerels per cubic metre of air, raising their risk of lung cancer (*Science of the Total Environment*, DOI: 10.1016/j.sciotenv.2017.05.071).

### Brain chips

Computer chips made of memristors that simultaneously store and process data could be much quicker than current processors. Engineers at the University of Michigan wrote an algorithm that takes advantage of these brain-like devices to achieve superfast image recognition (*Nature Nanotechnology*, doi.org/b7gr).

# Did we split from chimps in Europe?

The ancestor of all early humans may have been an eastern European

Colin Barras

THE last common ancestor we share with chimps might have lived in the east Mediterranean – not in East Africa as is generally assumed.

This bold conclusion comes from a study of Greek and Bulgarian fossils, suggesting that the most mysterious of all ancient European apes was actually a human ancestor, or hominin. However, other researchers remain unconvinced by the claim.

Go back 12 or more million years and Europe was an ape's paradise. But, some 10 million years ago, environmental conditions there changed and apes became largely confined to Africa, where they eventually split into gorillas, chimpanzees and humans.

At least, that's what most researchers think happened. But, in 2012, Nikolai Spassov at the National Museum of Natural History in Sofia, Bulgaria, and his colleagues reported the discovery of an ape tooth from Bulgaria that was just 7 million years old. It was, they said, the youngest European ape fossil yet found.

Spassov and his colleagues – including Madelaine Böhme at the University of Tübingen in Germany and David Begun at the University of Toronto, Canada – now think the tooth belongs to an ape called *Graecopithecus*, which clung on in Europe long after other apes had disappeared from the continent. What's more, the team says, *Graecopithecus* was no ordinary ape – it was a hominin.

Other than the Bulgarian tooth, *Graecopithecus* is known from just one fossil jawbone found near Athens in 1944. With so little fossil material, *Graecopithecus* is the most poorly known of all European apes. This is not helped by the Greek jawbone, nicknamed El Graeco, having a heavily worn surface.

Now Spassov and his colleagues have used a micro-CT scanner to peer into the jawbone of El Graeco, and found that the roots of one of the premolars are "fused" together in an unusual way. "This condition is so far only known to occur regularly in hominins – pre-humans and humans," Spassov says. "It is extremely rare in recent chimps." There are also hints from the jaw that *Graecopithecus* had relatively small canines. Together, the two features suggest *Graecopithecus* may have been a hominin (*PLoS One*, doi.org/b7gb).

The team has also investigated the local geology and found that *Graecopithecus* lived in exactly the sort of dry, savannah-like environment traditionally thought to have driven early hominin evolution (*PLoS One*, doi.org/b7gc).

Furthermore, geological dating techniques suggest it was alive between 7.25 and 7.18 million years ago – which means *Graecopithecus* slightly predates the oldest potential hominin found in Africa: *Sahelanthropus* is between 7 and 6 million years old.

**"Our last common ancestor with chimps may have lived in what is now Greece and Bulgaria, not Africa"**

Putting the pieces of the puzzle together, the team thinks hominins might have split from the chimp evolutionary lineage in the eastern Mediterranean a little earlier than 7.25 million years ago. In other words, our last common ancestor with chimps may have been an eastern European.

David Alba at the Catalan Institute of Palaeontology in Barcelona, Spain, says there is value to the new work: it provides convincing anatomical evidence that *Graecopithecus* is different from other ancient apes found in Europe – something that wasn't clear from earlier studies.

But he is less convinced by the idea that the tooth roots alone can confirm that *Graecopithecus* is a hominin. He says study co-author David Begun has been arguing for 20 years that the great apes first appeared in Europe. "It is not surprising at all that Begun is now arguing that hominins as well originated in Europe."

Sergio Almécija at George Washington University in Washington DC says it is important to bear in mind that primates seem prone to evolving similar features independently. "Single characters are not reliable to make big evolutionary [claims]," he says.

Ultimately, however, the early human fossil record is so poorly known that it's impossible to definitively dismiss the new claims, says Alba. "Of course, it is possible that hominins first evolved in Europe. However, evidence favouring this view is anecdotal at best," he says. Likewise, *Graecopithecus* might be a hominin, he says, but that can only be confirmed if more fossils are found.

Spassov is optimistic. "We are working on that," he says. ■

PAINTING BY CHICAGO-BASED ARTIST VELIZAR SIMEONOVSKI ACCORDING TO SCIENTIFIC INSTRUCTIONS OF MADELAINE BÖHME AND NIKOLAI SPASSOV

One day this will be a resort

# Minesweeping turtle bots learn to crawl

WHEN it comes to detecting landmines, being slow is an advantage. Swarms of robotic sea turtles teaching themselves to crawl in the Arizona desert could one day be used to help clear landmines in war zones.

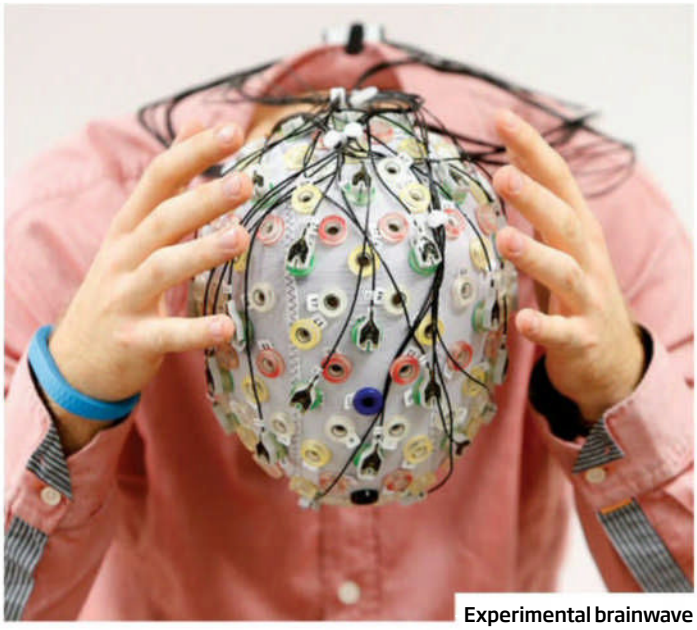
The military already has minesweeping robots, but their bulk makes them costly and difficult to deploy – something the turtle bots could help resolve.

The robotic turtles, which are about the size of a small drone, are laser-cut from two sheets of cardboard before being folded together origami-style and fitted with an inexpensive computer chip and motors that move their fins. Each robot only takes 2 to 3 hours to put together and costs around $80, so losing one in a landmine blast isn't necessarily a huge setback, says Heni Ben Amor, joint leader of the project at Arizona State University.

Ben Amor thinks that swarms of up to 100 turtle bots, which move at about 5 centimetres per second, could be deployed to scour desert sands for landmines, alerting humans when they find one and tagging it for removal.

Creating autonomous robots suited to different deserts can be tricky because each of these terrains has a particular type of sand. If you train a turtle bot to crawl in one desert, it could end up going nowhere if it tries to move in the same way in a desert with different-shaped sand grains. Rain and changing humidity can also change the desert surface and make it impossible for robots to move.

To get around this problem, Ben Amor programmed his turtle bots with an algorithm that lets them adapt their crawling technique each time they're faced with a new surface. Drop a turtle bot on unfamiliar sand and after a couple of hours it will have altered its fin movements to let it crawl more efficiently. Ben Amor will present his research at two robotics conferences in July. Matt Reynolds ■



MICHAELA REHLE/REUTERS

Experimental brainwave

# Quantum test could show if minds are matter

THE boundary between mind and matter could be tested using a new twist on a well-known experiment in quantum physics.

For years, experiments known as Bell tests have confirmed the weirdness of quantum mechanics – specifically the "spooky action at a distance" that so irked Einstein.

Now, a Bell test has been proposed using something unprecedented: human consciousness. If the results differ from those of standard Bell tests, it could hint that our minds are immaterial.

Spooky action at a distance was Einstein's phrase for a quantum effect called entanglement. When two particles are entangled, measuring the state of one seems to instantly influence the other, even if they are light years apart.

But any signal passing between them would have to travel faster than the speed of light, breaking the cosmic speed limit. To Einstein, this implied that quantum theory was incomplete, and that a deeper theory was needed to explain the particles' behaviour. We have been trying to find this deeper theory ever since.

In 1964, physicist John Bell paved the way for testing whether the particles do in fact influence each other. He devised an experiment that involves sending a pair of entangled particles to locations A and B. At each point, there is a device that measures, say, the spin of the particle.

**"It would be the first time we as scientists can put our hands on this problem of consciousness"**

Random number generators choose the setting on the device in such a way that it's impossible for device A to know of B's setting and vice versa at the time of measurement.

In all actual Bell tests so far, the measurements correlated far more than they would if Einstein had been right, indicating that spooky action at a distance exists.

However, some physicists have argued that even random number generators may not be truly random. They could be governed by some underlying physics that we don't yet understand.

Now, Lucien Hardy at the Perimeter Institute in Canada suggests that the measurements at A and B can be controlled by something that could potentially be separate from the material world: the human mind.

In the 17th century, French philosopher René Descartes proposed a mind-matter duality, where the mind is outside regular physics and intervenes on the physical world, says Hardy.

In the new experiment, A and B would be 100 kilometres apart. At each location, about 100 people would wear EEG headsets that read their brain activity. These signals would then be used to switch the settings on the measuring device at each location (arXiv.org/abs/1705.04620).

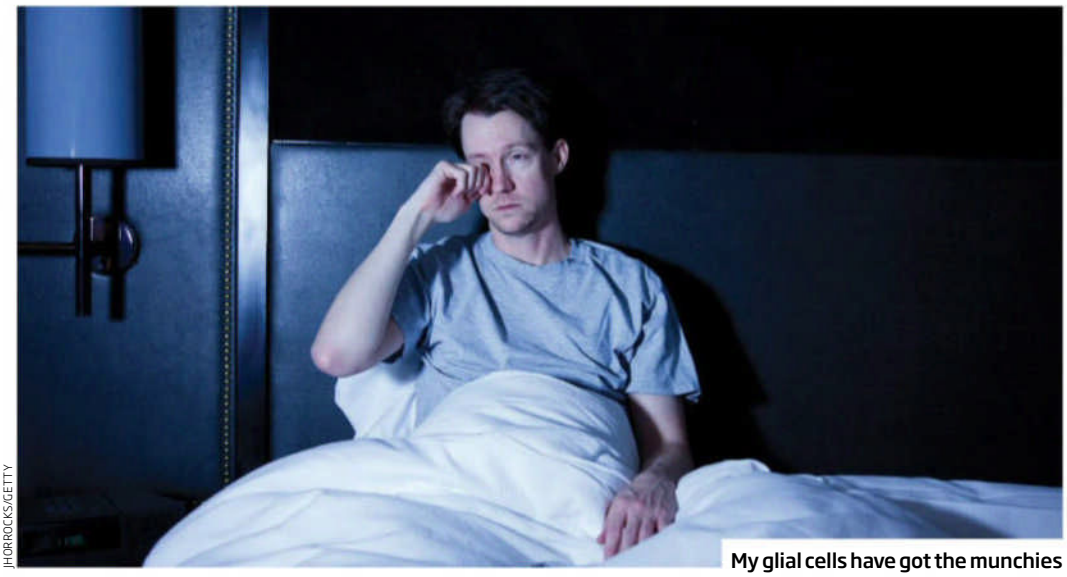
If the correlation between readings differs from earlier Bell tests, implying a violation of quantum theory, it would hint that the measurements are being controlled by processes outside the purview of standard physics.

"I can't imagine a more striking experimental result in physics than that," Hardy says. "We'd want to debate as to what that meant."

Such a finding would stir up debate about the existence of free will. Even if physics oversaw the material world, the human mind not being made of that same matter might mean that we could overcome physics with free will.

Nicolas Gisin at the University of Geneva in Switzerland thinks Hardy's proposal makes plenty of sense, but he is sceptical about using unstructured EEG signals. He would prefer an experiment where conscious intent is used to perform the switching – but that would be tougher to carry out.

"The reward is enormous. It would be the first time we as scientists can put our hands on this mind-body [problem] or problem of consciousness," says Gisin. **Anil Ananthaswamy** ■



J HORROCKS/GETTY

My glial cells have got the munchies

# Brain starts to eat itself after chronic sleep loss

BURNING the midnight oil may well burn out your brain. The brain cells that destroy and digest worn-out cells and debris go into overdrive in mice that are chronically sleep-deprived.

In the short term, this might be beneficial – clearing potentially harmful debris and rebuilding worn circuitry might protect healthy brain connections. But it may cause harm in the long term, and could explain why a chronic lack of sleep puts people at risk of Alzheimer's disease and other neurological disorders, says Michele Bellesi of the Marche Polytechnic University in Italy.

Bellesi reached this conclusion after studying the effects of sleep deprivation in mice. His team compared the brains of mice that had either been allowed to sleep for as long as they wanted or had been kept awake for a further eight hours. Another group of mice were kept awake for five days in a row – mimicking the effects of chronic sleep loss.

The team specifically looked at glial cells, which form the brain's housekeeping system. Earlier research had found that a gene that regulates the activity of these cells is more active after a period of sleep deprivation.

One type of glial cell, called an astrocyte, prunes unnecessary synapses in the brain to remodel its wiring. Another type, called a microglial cell, prowls the brain for damaged cells and debris.

Bellisi's team found that after an undisturbed sleep, astrocytes appeared to be active in around 6 per cent of the synapses in the brains of the well-rested mice. But astrocytes seemed to be more active in sleep-deprived mice – those that had lost eight hours of sleep showed astrocyte activity in around 8 per cent of their synapses, while the cells were active in 13.5 per cent of the synapses of the chronically sleep-deprived animals.

**"We show that portions of synapses are literally eaten by astrocytes because of sleep loss"**

This suggests that sleep loss can trigger astrocytes to start breaking down more of the brain's connections and their debris. "We show for the first time that portions of synapses are literally eaten by astrocytes because of sleep loss," says Bellesi.

For all we know, this may be a good thing. Much of the remodelling was of the largest synapses, which are more mature and used more intensively. "They are like old pieces of furniture, and so probably need more attention and cleaning," says Bellesi.

But the team also found that microglial cells were more active after chronic sleep deprivation (*Journal of Neuroscience*, 10.1523/JNEUROSCI.3981-16.2017).

This is a more worrying find, says Bellesi; excessive microglial activity has been linked to a range of brain disorders. "We already know that sustained microglial activation has been observed in Alzheimer's and other forms of neurodegeneration," he says.

The finding could explain why a lack of sleep seems to make people more vulnerable to developing such dementias, says Agnès Nadjar of the University of Bordeaux in France.

It's not yet clear whether getting more sleep could protect the brain or rescue it from the effects of a few sleepless nights. The researchers plan to investigate how long the effects of sleep deprivation last. **Andy Coghlan** ■

# Citizens hand over data to improve city life

**ACTIVISM has never been so easy. Urban residents will soon be sharing their personal data – not with the usual social media giants, but with a scheme that aims to make their cities better places to live.**

**The three-year European Union-funded project, dubbed the Decentralised Citizen Owned Data Ecosystem (DECODE), will involve four pilot schemes that will begin in Barcelona and Amsterdam at the end of 2017. In each city, 1000 people will get an app through which they can share data about themselves to help firms or government groups create products or services to improve the city, such as better play areas in parks.**

**In general, people have little control over their data online, says Tom Symons, at innovation charity Nesta, who is leading the work on DECODE.**

**But with the project, each citizen will choose how much personal data is uploaded to its platform and how it should be used. For example, a person may decide that location-tracking data about parks they visit can be used by the city council but not by firms. Individuals' data-sharing choices will be kept on the blockchain: a digital ledger that securely stores data across a network of computers.**

**Symons says publicly available data such as social media posts could be combined with location data to better understand how people feel about different parts of the city. This could help pinpoint places where people feel unsafe or provide insight into how they use public spaces and transport.**

**As part of the project, the DECODE team also plans to launch a website or app that will let people get involved in local politics and share possessions. Residents will be able to use this platform to comment on city legislation, put forward their own ideas and vote on proposals. People might also use the platform to offer to lend items such as spare power tools or even their car, says Symons.** Matt Reynolds ■

FIELD NOTES Serengeti, Tanzania

# Drought is hitting Serengeti wildlife

Adam Popescu

THE wildebeest look tired. Skittish at the slightest sound, their hooves pound the dusty plain until they kick up a cloud that obscures the hundreds of animals in the herd. Under the dust, the short grass is yellow and grey, if it's there at all. How do these animals find sustenance amid this sparseness, I wonder? Where is the water?

"Drought," answers Ngiimba, my Maasai guide. "More than a year now. Killed over 50 per cent of livestock."

I'm in Tanzania's Serengeti National Park, a sprawling wilderness the size of Belgium. The Serengeti's great annual migration sees as many as 2 million wildebeest, zebras and gazelles travel thousands of kilometres between Tanzania and Kenya. And though there is wildlife seemingly everywhere – lions, cheetahs, elephants – Ngiimba's words hint at trouble. It's supposed to be the rainy season, but not a drop has fallen in my 10 days here.

The relationship to water stretches far beyond the savannah, and affects humans as much as wild animals. The water shortages are causing humans to compete with wildlife for resources and push into their territory. It is not uncommon for locals to lead their flocks onto protected lands to graze. Increasingly, people find that their crops and livestock are dying, leading to a food shortage that could become a humanitarian crisis.

"The biggest problem is that people and wildlife don't recover," warns Friederike Otto at the University of Oxford. "The soil cannot recover, so deep soil moisture cannot rebuild." That means a bad cycle is poised to get worse. The only major river in the area – the Mara – could dry up, further stunting grassland growth and imperilling resources for ungulates.

When rainfall does hit the parched earth, the potential for flash floods increases, and these can make it near impossible for herds to cross rivers. Sparse rain also means wildlife must scatter over a wider area in search of water, which increases animals' odds of straying into developed areas, where fencing can block their way. If the bodies of water in the area disappear entirely, 30 per cent of the wildebeest migrating through could die within two weeks.

North of the border, in Kenya, there's talk of damming the Mara, which would "decimate the migration", says David Blanton, co-founder of non-profit initiative Serengeti Watch. His organisation helps train locals in conservation and journalism, encouraging them to become invested in protecting their environment. "This place has to be saved by the people who own it and live next to it," he says.

It's sobering stuff. East Africa's population has increased by 74 per cent between 1988 and 2008, and could further double by 2050. Poaching and the bushmeat trade will skyrocket, and this land may soon be unrecognisable.

"We have to bridge the gap between scientists and politicians," says Eivin Røskaft, a conservation biologist who heads the European Union-funded AfricanBioServices project. "As long as tourists come to give money, we can use that argument for politicians. Otherwise, it's really hard to find good arguments why they should save nature."

A third of Tanzania's land is protected, but Røskaft says factors such as the population growth and rising demand for natural resources threaten not only wildebeest migration, but all wildlife in the area. "If there's no will from the West, these trends will continue," he says. ■

GINA BENDER

Wildlife could be decimated

## Electrical tweak lets worm grow two heads

**CUT off the head of a planarian flatworm and a new one will grow in its place. The worm is one of many creatures that have some kind of memory for lost limbs, enabling them to regenerate what was there before.**

**Now it seems that this memory can be altered by meddling with the electrical activity of the animals' cells. Michael Levin at Tufts University in Medford, Massachusetts, and his colleagues have used anaesthetic to shift the bioelectric current at the site of a cut, changing the type of appendage regenerated – allowing a head to be regrown in place of a tail.**

**Charged ions constantly move in and out of cells, giving the cells an electrical charge. The patterns of electrical activity are thought to influence how embryos develop, but it is unclear how they work in adults.**

**Levin's team has found that after changing the electrical current of the worms' cells, about 70 per cent of worms regrew a second tail or head instead of the "correct" body part after the original was cut off. This suggests that an animal's body plan is not just down to its genes and environment – electricity plays a role, too. "It's pretty profound," says Levin.**

**The effect continued when the worms were cut again, and with the same 70:30 preference for the "wrong" body part, even with no further treatment. By altering the bioelectric code, the animal's body plan can be rewritten, Levin says.**

**"An animal's body plan is not just down to its genes and environment. Electricity plays a role, too"**

**The findings suggest electrical changes alter the way genes work, says Voot Yin at the MDI Biological Laboratory in Bar Harbor, Maine. To investigate the implications for humans, the next step would be to test it in a mammal that can regenerate to the same extent as us, he says, such as mice.**

**But the approach might also trigger the growth of other tissues at the mouse's paw, such as a tail. "It is likely to trigger more unexpected changes," says Yin.** Jessica Hamzelou ■

# Narwhals may help monitor ice sheet

Adam Popescu

AN ICONIC whale species will soon be spearheading climate change science. Narwhals have started hanging out near melting ice, and researchers studying the Greenland ice sheet have spotted an opportunity.

Rising seas may be the worst threat from global warming, and the Greenland ice sheet could have a huge effect. Eight per cent of the world's fresh water is trapped in it. Researchers estimate that sea levels will rise 6 to 7 metres if it all melts.

It is hard to measure how fast glaciers flowing off Greenland are melting under the sea, which could indicate how solid the ice sheet is. This is where the narwhals come in.

Warmer air is melting the sheet from above, and warmer seawater speeds up melting below the sea surface – a one-two punch that accelerates overall glacier loss.

When run-off from ice melt hits the sea and glaciers calve off icebergs, it stirs up the ocean ecosystem and brings nutrients to the surface, increasing the narwhals' food supply. Kristin Laidre, an ecologist at the University of Washington, has found that the unicorn-like whales are spending so much time around melting ice that this seems to have become their preferred habitat (*Biology Letters*, doi.org/b7cg).

She says we can make use of their new habits to collect hard-to-get data on ice melt. The idea is that whales could be fitted with thermometers, allowing the first effective measurement of underwater glacial melt, which has been hard to study accurately. "It's like narwhals are oceanographers," she says.

The sensors would transmit their data to US polar-orbiting satellites as part of NASA's Oceans Melting Greenland (OMG) project.

It's not the first time Laidre has employed narwhals as research assistants. In 2010, she used them to measure temperatures in Baffin Bay, Canada, and hopes to do the same off Greenland.

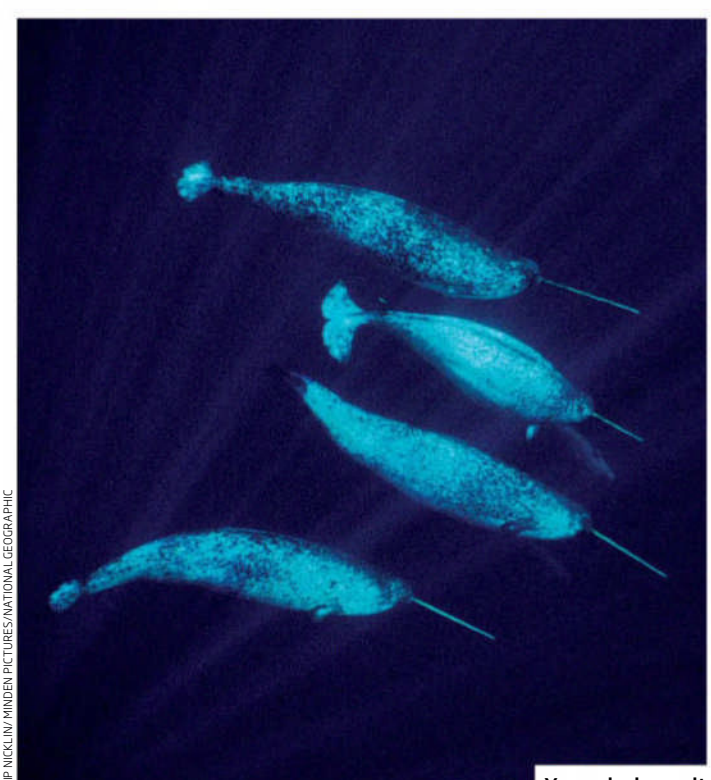
"Based on narwhal locations, we can measure the temperature of fjords, how it varies and how it potentially impacts glaciers," Laidre says.

Her new work with OMG is scheduled to begin in summer 2018. While she will focus on temperature, the project's overarching goal is to study the changing glaciers and the Greenland ice sheet as a whole, and plan for what is arguably the gravest ecological challenge of this century.

To do that, OMG uses a NASA plane to measure Greenland's coastal glaciers and track their seasonal growth and shrinkage. Each summer, 250 expendable probes will be dropped into the Atlantic to measure the temperature and salinity of ocean water. These findings, along with observations of the sea made from ships and planes, will help predict sea-level rise around the world more accurately.

**"Based on narwhal locations we can measure the temperature of fjords and how it impacts glaciers"**

Animals including Antarctic seals and elephant seals off the coast of California have previously been tagged to provide information on the oceans. Depending on the size of tag the animal can carry, researchers can measure temperature, salinity and depth. ■



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Yum, glacier melt

# Blood stem cells made in the lab for first time

**PEOPLE with blood diseases and leukaemia could one day be treated with their own cells, rather than with bone marrow transplants. That's the prospect in sight after two studies have created blood-making stem cells in the lab.**

**"This is a very big deal," says Carolina Guibentif at the University of Cambridge, who was not involved in the research. "If you can develop [these cells] in the lab in a safe way and in high enough numbers, you wouldn't be dependent on donors."**

**George Daley at Harvard Medical School and his colleagues set out to create blood stem cells from human pluripotent stem cells – which can form almost any type of body cell. By studying the genes involved in blood production, the researchers found five proteins that work together to encourage the pluripotent stem cells to become blood stem cells. When they put these human cells into mice, they went on to produce new red and white blood cells and platelets (*Nature*, doi.org/b7bt). "It's very cool," says Daley. "We're very excited about the results."**

**A separate team has achieved a similar feat with stem cells taken from adult mice. Raphael Lis at Weill Cornell Medicine in New York and his colleagues started with cells taken from the animals' lungs. The team identified four genes that could encourage the lung cells to form blood stem cells (*Nature*, doi.org/b7bs).**

**Taken together, the two sets of results are a breakthrough, says Guibentif. "This is something people have been trying to achieve for a long time," she says.**

**Daley hopes lab-made stem cells will eventually create blood for transfusion. This would be more reliable than donor supply and would also carry no risk of disease. "When new pathogens like Zika pop up, you have to make sure that blood is safe," says Daley. "We'd be able to have more quality control."** Jessica Hamzelou ■

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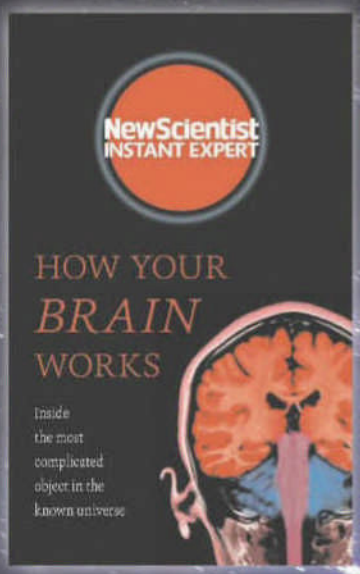


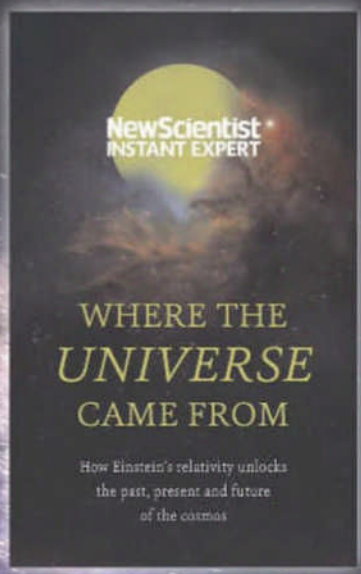


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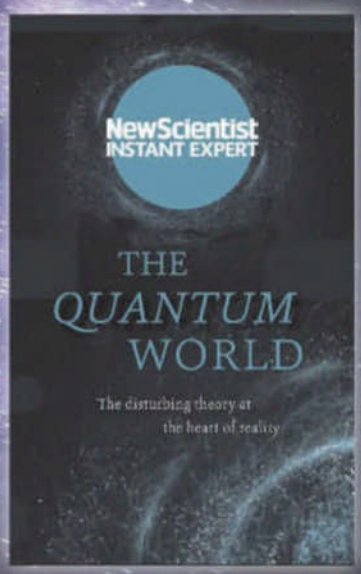


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# Big cities' flood risk to double by 2050

Chelsea Whyte

BY MID-CENTURY, severe coastal floods could be hitting twice as often as they do now – even if the seas rise less than we think they will. The weather events in question are so extreme that we currently expect them only once in 50 years.

Sea levels are actually projected to go up by 10 to 20 centimetres over the next few decades. With just a 5-centimetre rise by 2050, however, wave-exposed cities like Mumbai and Kochi in India, and Abidjan in Ivory Coast, would see much more frequent floods, according to Sean Vitousek of the University of Illinois at Chicago and his colleagues.

If the sea-level rise were 10 centimetres, extra floods would also hit Shanghai, London and New York, for example.

Seas are currently going up by about 3 to 4 millimetres a year across the globe, says Vitousek. "It doesn't take a ton of sea-level rise to significantly change the frequency at which you have flooding," he says.

Extremely high water levels are sometimes caused by storm surges and low-pressure atmospheric systems, when the easing of pressure on the sea allows the waters to rise. But normal tides and waves also play a part in flooding, and Vitousek's team took all those factors into account in their model (*Scientific Reports*, doi.org/b7dm).

Sea-level rise affects different parts of the world in different ways. The ice sheets in Antarctica and Greenland are so massive that their gravity attracts ocean water. As the sheets melt, that water will go elsewhere.

"If you lose Greenland, you'll have more water in the ocean, which will elevate sea level everywhere. But the effect will be stronger further from Greenland," says Anders Levermann of the Potsdam Institute for Climate Impact Research in Germany.

"In Greenland or Antarctica, the water levels may even drop. The tropics always lose because they're in the middle."

DINODIA PHOTO/GETTY

Get used to it

Over the next few decades, an increase of 10 to 20 centimetres is inevitable, says Levermann. Even with large reductions in emissions, the die has already been cast for the near future. Vitousek says possible responses are to retreat from coastlines or to invest in engineering solutions, such as building up natural beaches or creating artificial ones, or building sea walls that provide shoreline protection.

"No one has to be afraid of sea-level rise, if you're not stupid," says Levermann.

"It's low enough that we can respond. It's nothing to be surprised about, unless you have an administration that says it's not happening. Then you have to be afraid." ■

# Space-time warp could leave memories

**SPACE-TIME can be permanently warped by the gravitational waves that constantly ripple through it. The distortion, called gravitational wave memory, could allow us to detect waves previously beyond our reach – offering hope of finding some of the universe's most exotic objects.**

Gravitational waves are created by massive objects moving through space-time. In 2015, the LIGO collaboration first detected a gravitational wave caused by two black holes spiralling towards one another and merging. Since then, theorists have been hard at work studying what such waves from other events and objects would look like.

Some of the most exotic objects in physics, such as evaporating black holes, cosmic strings and even possible extra dimensions, would induce gravitational waves at much higher frequencies than we can currently detect. But there is still hope that these elusive objects could leave an observable signal, say Lucy McNeill and her colleagues Eric Thrane and Paul Lasky at Monash University in Melbourne, Australia.

If two people were floating near, say, a pair of merging black holes, the space between them would grow and shrink as space-time was stretched and distorted by gravitational waves. Once the black holes merged and the waves ceased, this oscillation would stop – but the two people would be at a different distance apart to when they started. Memory of the waves would leave them slightly further apart or closer together.

This permanent distortion of space-time creates a signal 10 to 100 times weaker and with a frequency much lower than the original one from the oscillating gravitational wave (*Physical Review Letters*, doi.org/b7dr).

**"Gravitational wave memory offers hope of finding some of the universe's most exotic objects"**

This means that the kinds of event where LIGO can now spot gravitational waves will produce a memory signal at a frequency too low for the observatory to pick up.

But if there are astrophysical events that produce gravitational waves at frequencies too high for LIGO to spot, their memory signals might fall easily into the observatory's detection range, thus allowing us to pick them up. McNeill and her colleagues call these "orphan" signals because the parent wave is not detectable.

These memory signals could allow researchers to find high-frequency sources without looking for the sources themselves. "Who knows what we may find?" says Thrane.

Leah Crane ■

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SAYAKA WAKAYAMA ET AL

Astronauts before they were born

# Healthy pups bred from space sperm

Alice Klein

WE HAVE lift-off. Freeze-dried mouse sperm that spent nine months in space has successfully impregnated female mice and created healthy offspring.

Despite growing discussion around space colonisation, there are still big questions about the viability of human reproduction off Earth. Scientists say the high levels of radiation and low gravity could hinder conception or lead to abnormal development.

Experiments have shown that fish and salamanders reproduce normally on space stations, but research in mammals is scarce. A handful of studies in the 1980s found that male rats produced less sperm in space, but sperm quality was not assessed.

To address this, Teruhiko Wakayama at the University of Yamanashi in Japan and his colleagues sent freeze-dried sperm from 12 male mice to the International Space Station (ISS) in August 2013. The samples were kept in a -95°C freezer for nine months, before being flown back.

Wakayama and his team then analysed the sperm's DNA. They found that it was severed in several places – probably due to exposure to cosmic radiation. Radiation levels on the ISS are 100 times greater than on Earth because the station is not protected by the planet's atmosphere and magnetic field.

However, this damage did not seem to affect fertility or the health of offspring. Female mice implanted with the sperm via IVF had the same birth rate as those impregnated with freeze-dried sperm that had not been exposed to space. The pups appeared healthy, and gene sequencing confirmed that they did not have any significant defects (*PNAS*, DOI: 10.1073/pnas.1701425114).

**"Mammalian eggs can repair damaged DNA. Essentially, the female fixes up the male's mess"**

The radiation damage in the DNA may have been repaired when the sperm cells were combined with the eggs, says Andrew Wyrobek at Lawrence Berkeley National Laboratory in California. Mammalian eggs are known to have a strong capacity for repairing damaged DNA, he says. "Essentially, the female fixes up the male's mess."

To test the effects of space radiation on sperm-egg pairings, Wakayama's team has now received approval to send frozen mouse embryos to the ISS. There, astronauts will thaw and culture them until they reach maturity. Then they will be returned to Earth and implanted in female mice to see if they produce healthy offspring.

This experiment will also probe the effects of low gravity on early embryo viability. Previous studies have found that mouse and zebrafish embryos do not develop properly in simulated microgravity. So, even if embryos can successfully form in high-radiation space environments, their growth may be hampered by the reduced gravity.

However, we won't know for sure without experiments in space, says Wakayama. Eventually, he would like to test whether live mice can mate normally on the ISS, because this would give the best insights into whether humans could safely conceive in space. "Nobody has tried it and we really want to know." ■

# Our brains trust made-up vision over what's real

**SEEING shouldn't always be believing. We all have blind spots in our vision, but we don't notice them because our brains fill in the gaps with made-up information. Now subtle tests show that we trust this "fake vision" more than the real thing.**

**If the brain works like this in other ways, it suggests that we should be less trusting of the evidence from our senses, says Christoph Teufel of Cardiff University, UK, who wasn't involved in the study. "Perception is not providing us with a true representation of the world," he says.**

**The blind spot is caused by a patch at the back of each eye where there are no light-sensitive cells.**

**We normally don't notice blind spots, because our two eyes can fill in for each other. When vision is obscured, the brain makes up what's in the missing area by assuming that whatever is in the regions around the spot continues inwards.**

**Now Benedikt Ehinger of the University of Osnabrück in Germany and his colleagues have asked 100 people to look at a picture of a circle of vertical stripes, which contained a small patch of horizontal stripes.**

**The circle was positioned so that with one eye obscured, the patch of horizontal stripes fell within the other eye's blind spot. As a result, the circle appeared to have no patch and the vertical stripes were continuous.**

**Next to this was another circle of vertical stripes without a patch of horizontal stripes. People were asked to choose which circle seemed most likely to have continuous stripes.**

**Ehinger's team thought that people would choose the circle without a patch more often, as they could really see all the information in those.**

**In fact, people chose the circle with a filled-in patch 65 per cent of the time. "We never expected this," says Ehinger. "The brain trusts its own generated information more than what it sees outside in the world."**

Clare Wilson ■

# Where did we come from?
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## Flushing fallopian tubes with poppy seed oil helps fertility

A 100-year-old medical technique used in fertility scans has turned out to help women get pregnant.

When a woman has trouble conceiving, a common cause is blockages in the fallopian tubes that prevent eggs travelling from her ovaries to her uterus. To search for obstructions, doctors sometimes put a liquid containing a dye into the uterus. The dye can be seen on X-ray scans as the liquid flows from the uterus into the fallopian tubes, revealing whether they are blocked.

To find out if the procedure itself might affect fertility, Ben Mol at the University of Adelaide, Australia, and his colleagues compared the use of poppy seed oil with water in 1119 women. Each woman was randomly given the dye dissolved in oil or water, before having an X-ray.

Of the women who received the oil, 40 per cent got pregnant over the next six months, compared with 29 per cent of those who got water (*NEJM*, doi.org/b7dq). There could be something in poppy seed oil that has a specific benefit, or it could just be that oil is better than water at dissolving any debris or mucus in the tubes, says Mol.

"The size of the effect is impressive compared with other fertility interventions," says Tim Child of Oxford Fertility, UK. Child says his fertility centre will now consider using oil to flush the fallopian tubes without the subsequent X-rays. "It looks like it's not just an investigation, it's a treatment," he says.

## Dust gives away tangled black holes

The hunt for a key stage in the formation of the biggest type of supermassive black hole has begun in earnest, with the discovery of merging pairs of these objects.

A targeted search method has turned up five new pairs. Until now, only nine pairs had been detected – all serendipitously.

"Our model of the universe tells us they should be there, but we have failed miserably to find them," says Sara Ellison at the University of Victoria, Canada.

When two galaxies collide, their central supermassive black holes circle each other until they eventually merge into an even bigger supermassive black hole.

The galactic collision stirs up enough gas and dust to feed the black holes, creating two so-called active galactic nuclei (AGN) and a much heavier final black hole.

To find these duos, Ellison and her team sifted through data from two sky surveys to find AGN that look like they are colliding and also glow with infrared light, a hint that there is a lot of dust (arxiv.org/abs/1705.05465).

As well as boosting the number of pairs of supermassive black holes, this method may help us understand how gas and dust flows onto both individual black holes to feed their growth spurts.

## Can landfill sites save rare vultures?

THE endangered Egyptian vulture could bounce back thanks to the presence of landfills.

In some areas, the vulture's population has fallen by 25 per cent over 20 years because of various threats.

But in central Catalonia in Spain, the species is doing better, says Joan Real at the University of Barcelona. Real's team monitored the birds from 1988 to 2014. In that time, their population leaped from one to 25 breeding pairs.

Landfill sites seemed to make the difference: surprisingly, vultures preferred scavenging at those than at conservation sites where food is left out for wildlife (*Ibis*, doi.org/b694).

"In a landfill, you would find all sorts of nasty things," says Chris Bowden at the International Union for Conservation of Nature. "It makes you wonder what really makes them so attractive to these birds."

## AI videos can make you say anything

ARTIFICIAL intelligence can put words right into your mouth. A new system turns a still image of a person and an audio clip into a doctored video of the person speaking the words in the audio. The software could soon mean that realistic fake videos are only a single click away.

It works by first identifying facial features using algorithms. As the audio clip plays, the system then manipulates the mouth of the person in the still image so it looks as if they are speaking. Little preprocessing is required, so all of this can be done in real time.

In the future, the system could allow audio from news clips to be automatically translated into another language and the images updated to fit.

## Titan's riverbeds mimic Mars

RIVERS run through Titan, and they take a different path to those on Earth or ancient Mars. Comparing their riverbeds leaves Earth the odd one out.

Titan, Saturn's largest moon, has methane rivers and clouds, and mountains and valleys – so it superficially resembles Earth. But how those features came to be is poorly understood.

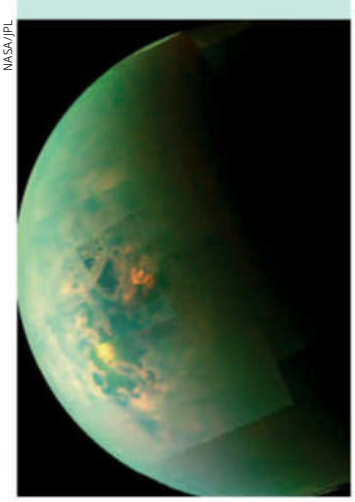
Artificial satellites orbit both Mars and Earth, constantly taking high-resolution pictures. But Titan is harder to observe.

To compare them, Benjamin Black at the City University of New York and his team reduced the resolution of sharp images of Mars and Earth to match ones of Titan from the Cassini probe.

Unlike Earth, neither Titan nor Mars has plate tectonics, but they both have longer range features that span at least one-fortieth of each world's girth.

On Mars, large-scale terrain seems to have been created first and then directed the flow of ancient rivers.

On Titan, the largest features may be made by changes in the thickness of its ice shell due to tidal forces from Saturn. Such changes may help explain how Titan gets its constantly replenished methane (*Science*, doi.org/b682).



NASA/JPL

## Hopping parrots might offer window into origin of bird flight

HOP, skip, jump… fly? Over short distances, some birds save energy by jumping at the most efficient angles and adding wingbeats for greater distance. This skill may have helped bird ancestors first get off the ground, too.

To examine the biomechanics of these short trips, Diana Chin and David Lentink at Stanford University, trained Pacific parrotlets to fly between perches for a food reward. The perches were equipped with sensors to measure the forces generated by the birds' legs and wings.

The team found that at the shortest distances, the birds hopped between branches, but as the distances increased, they added occasional wingbeats.

The data collected by the perches showed that the extra effort of adding a wingbeat was small compared with the gain in distance, making it an energy efficient strategy – something that would have benefited early birds.

"We saw that as a model of how early birds, who couldn't fly well, developed their flights to get further and further," says Chin.

That's perfectly feasible, says Bret Tobalske at the University of Montana in Missoula. "The authors do a nice job of pointing out how limited use of the wing would prolong range in hopping, and potentially improve the energetics of foraging," he says.

The model shows that as large early birds evolved to be smaller, they would have been able to generate more support for their body weight with each wingbeat this way (*Science Advances*, doi.org/b693).

## Bacteria made into living photographs

BLIND gut bacteria have received the gift of colour vision – of sorts. The organisms can use their new skill to make living photocopies of pictures shone onto their colony.

Christopher Voigt at the Massachusetts Institute of Technology began producing bacterial "photocopies" 12 years ago. At that point, however, they could generate only black-and-white images.

To enable *Escherichia coli* bacteria to register colour, Voigt's team inserted genes into them that respond exclusively to either red, green or blue light. When activated by the relevant light colour, these genes feed signals to other added genes that then produce visible pigment of an identical colour.

When a colourful image is shone onto a thin, film-like bacterial colony, the cells change colour to match the light striking them (*Nature Chemical Biology*, DOI: 10.1038/nchembio.2390).

The technology could have practical applications. For example, it might allow engineers to use light to gain finer control of the bacteria grown in fermenters, which churn out vital drugs, antibodies and materials.

CHASE DEKKER WILD LIFE IMAGES

## Rivers stay cool thanks to beavers

THAT'S dam cool. Beaver dams could lower maximum water temperatures in streams – keeping fish safe from dangerous highs.

Previous studies suggested that these dams warm the water, for example, by expanding its surface area and cutting its flow speed. But the opposite may in fact be the case, says Nicholas Weber at Eco Logical Research Inc in the US.

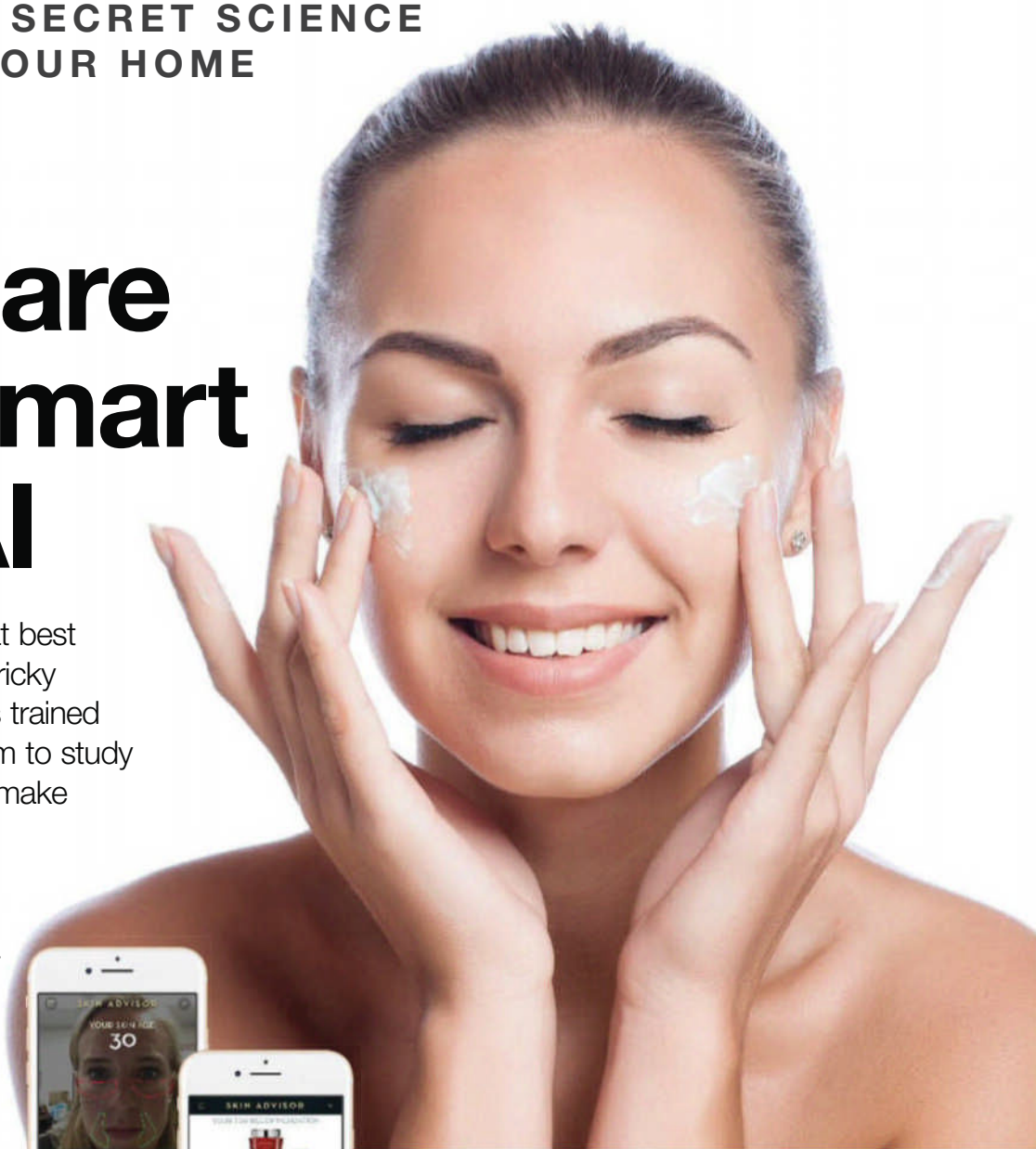
Weber's team monitored stream temperatures at 23 sites along 34 kilometres of Bridge Creek in Oregon for eight years. The number of beaver dams there increased over this period from 24 to 120. The team looked at temperature differences between an upstream site with no beaver activity and downstream areas before and after the dam proliferation. By the end of the eight years, maximum daily temperatures downstream had dropped by 2.6°C on average, though it's not clear how the dams lead to this (*PLoS One*, doi.org/b692).

"These results suggest that beaver relocation projects could be used to mitigate the impact of human-induced thermal degradation that may threaten sensitive cold-water fish species," says Weber.

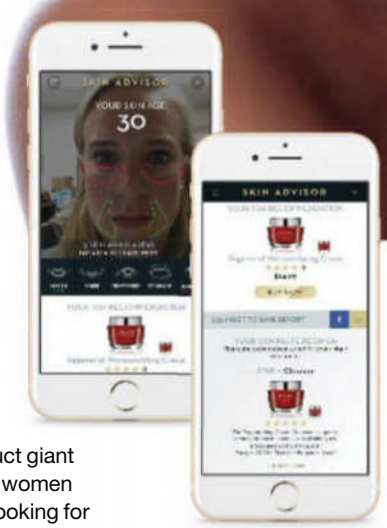
THE SECRET SCIENCE
IN YOUR HOME

# Skin care gets smart with AI

Choosing the cream that best matches your skin is a tricky business. Now Olay has trained a deep learning algorithm to study your face and help you make the best decision



WHEN it comes to choice, more is not always better. The all too familiar conundrum of choosing between dozens of chocolate cookies or hundreds of toothpastes can sometimes induce a kind of decision paralysis, a phenomenon that psychologists call the paradox of choice.




## Skin care conundrum

It's a problem often seen in the confused faces of customers surrounded by hundreds of products in the skin care section of department stores.

A 2013 survey by consumer product giant Procter & Gamble found one third of women were unable to find what they were looking for in facial skin care aisles. Almost two-thirds say they have unused facial products at home.

"There's been an explosion of skin care brands and products in the past 10 years or so," says Dr Frauke Neuser, principal scientist for P&G brand Olay. "One result is that women are shopping in places where they can get advice. However, that can be intimidating for those who might not want to buy a $150 skin cream recommended for them."

**The algorithm calculates your skin age using only a picture of your face**

P&G says it has the solution. Its web-based Olay Skin Advisor analyzes make-up-free selfies uploaded by users to estimate skin age and make personalized product suggestions. It is believed to be the first artificial intelligence-based skin care advice tool.

It's the result of decades of endeavor. P&G scientists have been studying skin for over 60 years and developing improved image capture and analysis technology for almost three decades (see box). That includes a 2015 clinical study comparing the facial skin of 330 women of different ethnicities. These included a subset judged to look 10 years younger than they actually are and who proved to have a common pattern of gene expression.

Inspired by this study, P&G scientists wondered whether artificial intelligence could replace the subjective human judgements of age with something more objective.

The idea of machines that can perceive the world, learn from examples and understand humans has been around since the 1950s. It is however only in recent years that major strides in building such machines have been made thanks to key advances.

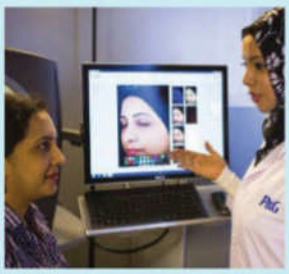
These include the rapid growth in large datasets that include images and the ability

## A HISTORY IN IMAGING

THE use of deep learning in the Olay Skin Advisor may seem bold, but it is no leap in the dark. In fact P&G has been breaking new ground in skin imaging and analysis for 30 years.

These innovations were initially designed to assist product development, before later being used in devices that assess skin age by analysing features such texture, tone and radiance in images.

During the 1990s, for example, it developed software to correct color variations caused by changes in lighting and camera response by



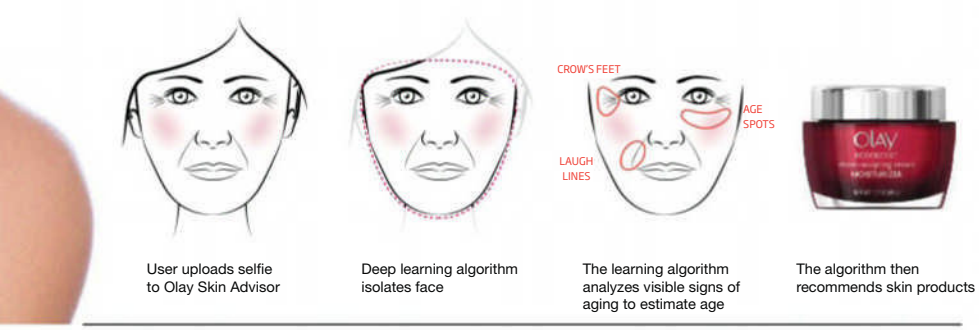
comparing them with reference colors incorporated into images. It also standardized facial positioning using "ghost images" from earlier capture sessions to precisely line subjects up in subsequent ones.

In 2001, P&G licensed its imaging know how to Canfield Scientific as the basis for its in-store, feature-based skin analysis devices, and later to create VISIA, a similar system for medical professionals.

In 2006, P&G automated the assessment of the molecular basis of skin color using digital cameras and custom software to create maps of melanin and hemoglobin.

"Adopting deep learning algorithms hasn't been as difficult as it might have been, thanks to Olay's rich heritage in image acquisition and analysis," says Dr Paul Matts, Olay Research Fellow.

DEEP LEARNING + SKIN AGE ANALYSIS = BETTER CHOICES




User uploads selfie to Olay Skin Advisor

Deep learning algorithm isolates face

The learning algorithm analyzes visible signs of aging to estimate age

The algorithm then recommends skin products

to store such vast amounts of data. Also important has been a shift to using computer chips known as graphics processing units (GPUs) originally developed for video gaming. These offer enhanced power over normal chips for certain tasks. "There's a natural fit between the workloads of deep learning models and gaming. Both involve doing very large batches of computations, and doing so in parallel," says Thomas Bradley, Director of Developer Technology at NVIDIA, which created the GPUs used to train and run the Olay Skin Advisor deep learning algorithm.

**"Deep learning mimics the way the human brain learns to estimate people's ages"**

That algorithm, the result of experimenting with different types of image recognition software, is the outcome. It was developed by the P&G bioinformatics group with artificial neural networks, programs inspired by the way human brains process information. They allow so-called deep learning by a machine

### Deep learning models

"Human brains learn to estimate people's ages by building a model that associates features we see in faces with the ages we know those people are," says Dr Jun Xu, a P&G computational biologist and lead developer of the Olay Skin Advisor's VizID™ algorithm. "Deep learning mimics this process."

Deep learning models are made up of hierarchies of filters called "layers" designed to detect the presence or absence of features.

Each pixel in an image has red, green and blue colour values. By analysing these, a layer can, for example, look for the edge of a feature or the edge of a color patch. It then passes its finding on to the next layer, which might look at what shapes are formed by those edges. Early layers look at smaller areas and later ones assess larger ones.

By going through 20 such layers, VizID™ builds skin age predictions. By comparing these repeatedly with known real ages, it can tweak the weightings it gives to different elements to improve its accuracy. Olay researchers used 50,000 selfies of women of different ages and ethnicities to "train" their model. This included feeding these images back through the algorithm 250 more times, each time with a slight change to lighting, resolution or positioning, for example. This ensures the model learns to predict the right age despite these image variations (a technique called data augmentation).

Once trained, the model was tested with a new set of 630 selfies of women aged 18-65. The Olay Skin Advisor's average age difference was 3.8 years. This compared to an average of 7.3 years for a group of dermatologists.

By retracing the model's calculations, the Olay team found it assigned most weight to eye wrinkles, pigmented age spots and "laughter lines" running between the corners of the mouth and the edge of the nose. These are among key features that humans also use to estimate age.

Launched last year, Olay Skin Advisor gives users an estimate of their skin age and tells them which of their forehead, cheeks, mouth, and eye areas are in best shape, as well as which could benefit most from improvement. Based on this and questionnaire answers, it gives personalized product recommendations.

More than 1 million women have already used the web-based tool. The images they uploaded are helping further improve its accuracy. A survey of users carried out by P&G found 94 per cent agreed that the products recommended by the algorithm were right for them and 88 per cent were still using the same products four weeks later.

"We're not doing this because deep learning is cool," says Neuser. "Ultimately the proof is in the pudding. If women buy the recommended products, see results, and keep using those products, then we can say that Olay Skin Advisor is a success." ■

**Try the Olay Skin Advisor at:**
www.skinadvisor.olay.com
**More at:** www.us.pg.com

# Technology for tomorrow: A manifesto for change

From fake news to artificial intelligence, our world is defined by technological change. But the political response is too often characterised by ignorance, incompetence and illiberality: failing to address challenges such as cybersecurity; letting giant companies wreak havoc on social norms; and using high-tech snooping to restrict our freedom rather than enhance it.

So what should politicians do to make sure technology truly benefits the public? We asked the experts and came up with six pledges we'd like to see them make

## 1. Enforce the right to an explanation

COMPUTER says no. Algorithms decide everything from what ads we are served online to whether we are eligible for a loan, affecting many aspects of our daily lives. That's led to mounting concern about their opacity: how do they arrive at the decisions they do?

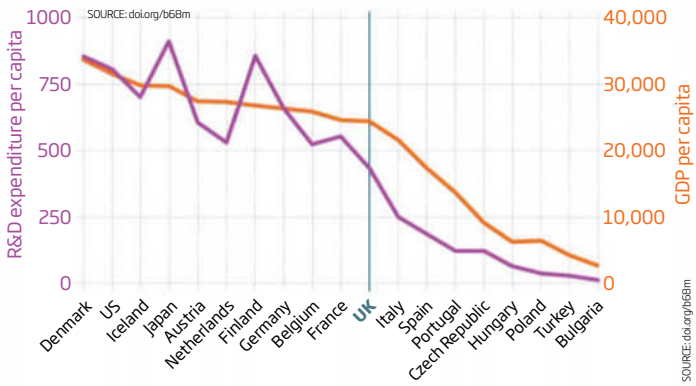
The problem is that algorithms aren't objective, but can be led astray – for example, because they're poorly designed or trained on an unsuitable data set. In the US, algos are used to inform sentencing by calculating the probability of a defendant reoffending – a process that has turned out to be biased against black people. But we have no way to peer into their icy minds to understand when, whether and why their decisions are unfair.

The EU's antidote is to give people a "right to explanation" as to why an algorithm made a particular decision about them. Though the spirit of these rules is worthy, Sandra Wachter and colleagues at the Oxford Internet Institute in the UK have suggested that the wording means it might not be legally enforceable. What does an explanation of an algorithm look like – and who could understand it?

Nonetheless, we can look for undesirable outcomes, and Joshua Loftus at the University of Cambridge has developed tools to test whether algorithms are biased. So politicians must keep the right enshrined and back it up with workable mechanisms. A watchdog should be established with robust powers to investigate the algorithms used by private firms. And parties should promise to make data science a regulated profession, to ensure that those designing algorithms also know their ethics. **Joshua Howgego**

PHONLAMAI PHOTO/SHUTTERSTOCK

The UK spends less on R&D than other rich countries




SOURCE: doi.org/b68m

## 2. Own the next killer app

MANY urbanites harbour little fondness for the days before Uber, when you couldn't always get a cab and drivers only accepted cash. But the convenient ride-hailing app has created its own problems – including slashing taxi drivers' wages in cities where it has been adopted, while the employment status of its own drivers is hotly disputed. Its contempt for regulators and competitors has drawn fire, too.

All this for a private service that relies on public infrastructure and in some respects replicates public transport. But it took Silicon Valley's technological wizardry to make it happen, right? Wrong, says University College London economist Mariana Mazzucato. It's often public money that creates crucial technologies in the first place – from semiconductors to the internet to search engines.

Uber's founder Travis Kalanik didn't invent GPS: the US Department of Defense did. But he did grasp that many places are underserved by public transport, and smartphones with GPS could help fill the gap. The Valley, in turn, provided the funds needed for Uber to grow rapidly – and the attitude that "moving fast and breaking things" was a good, and perhaps the best, way to proceed.

But what if governments didn't passively wait for Silicon Valley mavens, but anticipated how such new technology could help fix and fill gaps in public services, rather than breaking them? If that were possible, governments could ensure the resulting innovation gives back to society, not just to private firms. That doesn't have to mean public ownership – but it could mean a greater public say in how innovations reshape society.

Governments already fund research and development, as Mazzucato points out. But "everyone forgets about the D" in R&D, says Jen Rae of innovation charity Nesta. "Countries like Finland and Sweden devote a larger piece of the pie to development." That's where the ways people want to use a technology are identified, markets created and societies changed. Increasing R&D spending could prove be good for citizens' purses and wallets, too (see graph, above).

The UK has seen a big increase in grassroots organisations that try to anticipate public desires by looking at social challenges, from air pollution levels to lack of engagement with political systems. Fund these better, and maybe the next killer app could work within civic society rather than disrupting it. **Sally Adee**

## 3. Put workers before robots

IF ROBOTS aren't already lining up to take your job, they will be soon. A much-cited study from the University of Oxford found that 47 per cent of US jobs are at risk of being automated over the next 20 years. Other studies have come up with lower, but still large, estimates. Automation is set to affect everyone from cashiers to credit analysts: even if your job can't be fully automated, there's a good chance parts of it can be. That means everyone's working life is set to change.

Instead of letting automation push people into low-skilled jobs or the gig economy, automation can and should be made to work for everyone. There are already suggestions for how this could be done. Bill Gates has suggested a robot tax, for instance, which firms would shell out when they supplant humans with machines.

But the EU rejected a robot tax proposal in February, and such simplistic measures don't get to the heart of the problem. What we need is a larger reassessment of our relationship with work, says Anthony Painter at the RSA think tank. Work isn't just about money. It gives us a sense of purpose and identity, which is why using technology to track workers to enforce optimal performance is so dehumanising.

That's partly why a universal basic income – a guaranteed small monthly income from the state – has been gaining interest; it lets people pursue their own priorities, including caring for relatives or running their own business. We have preliminary evidence that this can work.

Now is the time to begin testing measures that can channel the impact of automation in a beneficial direction. This could include prohibiting certain jobs from being automated, such as those in healthcare, as well as plans to work out what levels of basic income and taxation would be appropriate. **Matt Reynolds**

XINHUA NEWS AGENCY/REX/SHUTTERSTOCK

**Beneficial automation?**

## 4. Create a digital Geneva Convention

IT WAS Web War 1. Government websites disappeared, as well as those of national newspapers and banks. All because Estonia had removed a Soviet-era war memorial. Russia retaliated by taking down the country's entire digital civilian infrastructure.

Since then, government-sponsored cyberattacks have become increasingly confused with general hacking. The internet is a NATO- designated war zone.

Since the second world war the Geneva Convention has outlined rules of traditional war that minimise its impact on civilians and try to maintain a basic level of humanity. These can't and don't stop devastation, but provide a code of conduct that nations can later refer back to.

"The Geneva Convention tells governments how to protect civilians in times of war. Today, we have a situation in which governments are waging war on

each other's civilians in times of peace," says Microsoft president Brad Smith.

Earlier this year he began to advocate for a digital Geneva Convention that sets ground rules for cyberwarfare. With hospitals, power stations, electricity grids and water supplies connected to the internet, it's time. Nations that sign up would agree not to hack critical infrastructure. Just as bombing a hospital is a war crime, hacking one should be too.

Neither should nations hoard software vulnerabilities to exploit. "Software weaknesses are never just for the good guys," says Joe Sturonas of security firm PKWARE. Instead, vulnerabilities should be reported and fixed to avoid situations like the recent global ransomware attack that took out hospitals in the UK.

**"Today, governments are waging cyberwar on each other's civilians in times of peace"**

Finally, nations shouldn't attempt to influence the democratic process in other countries through data leaks or proliferating online propaganda. **Timothy Revell**

## 5. Enshrine digital human rights

THE UN Universal Declaration of Human Rights and the European Convention on Human Rights (ECHR) were written more than 60 years ago. It's time they were brought to bear on the sweeping changes that technology has brought to our ways of life.

Some might scoff at putting digital rights on the same footing as access to clean water. But as the gap between digital and physical has disappeared, loopholes have opened up in established rights. For example, the ECHR grants the right to a private life: citizens cannot be searched without probable cause. In the digital realm, that means no indiscriminate collection of data.

But how such rights are protected is largely a matter of state interpretation. Where the physical and virtual intersect, analogues should be enshrined in law, says Estelle Masse from digital rights group Access Now, starting with the following.

*The right to internet access.* This doesn't mean the state becomes a service provider or pays your bill, but that it ensures access and regulates minimum standards.

*The right to a digital private life.* Your online activity reveals more about you than a search of your home, so unreasonable digital searches need to be explicitly barred. This includes the right to encrypt your data.

*The right to control your own data.* People should have to explicitly grant permission to the firms that use it, and clearly and succinctly describe the purposes for which it will be used. It should also be easy for citizens to revoke these permissions and have their files wiped. **Timothy Revell**

JOSH EDELSON/AFP/GETTY

Needs to share

## 6. Cut the data giants back down to size

WINNER takes all. That's what often happens when a new frontier opens up to commerce – whether spice routes, oil fields or telephony. Companies like the East India Company, Standard Oil and AT&T grew to enormous sizes, buying up competitors or driving them to the wall, while amassing geopolitical power to rival that of nation states.

Sound familiar? Google, Facebook and Amazon dominate different sectors – search, social media and shopping – but are converging on complete control of personal and civic information. Competitors struggle to catch up: today's titans are shielded by the very data they hoard, which allows them to spot and exploit new opportunities before anyone else secures a foothold.

Is that what we really want? In previous eras, competition authorities stepped in to break over-mighty giants into smaller firms. But their mandate is to

# The parties respond

Their proposals reveal more than technological plans, says **Sumit Paul-Choudhury**

WE INVITED three major UK political parties to comment on our six pledges. The first to reply was Labour, which told us it will raise the UK's investment in R&D to 3 per cent of GDP, in line with other industrialised nations.

Its spokesman added that deputy leader Tom Watson has set up an independent commission on the future of work, looking at the impact of new technology and automation. That's due to report back later this year. In its manifesto, Labour promises to "clamp down" on gig economy platforms that shirk their responsibilities as employers – but doesn't specify how.

Beyond universal superfast broadband and giving young people the right to delete anything they posted online before they turned 18, Labour's manifesto is a bit thin on substantial technology policies. One notable inclusion is a promise to "reintroduce effective judicial oversight" of government snooping, which was largely legalised last year under the Investigatory Powers Act.

The Liberal Democrats responded with a digital bill of rights, which threatens prison for those whose companies illegally sell personal data and promises to give people more power over their information online. It would also "protect against internet giants and ISPs restricting competition".

**"The Conservative manifesto has some of the strongest statements on digital policy ever made"**

The ruling Conservative party, expected to win comfortably, didn't respond – but its manifesto includes some of the strongest statements on digital policy made by any democratic government. It effectively vows to retain EU laws that give citizens control over their data – again, allowing them to expunge any gathered before they were 18. And it pledges a Data Use and Ethics Commission to advise regulators and politicians.

The manifesto also promises to make the internet safer from cyber risks. It doesn't say how, but Theresa May, as home secretary and then prime minister, instigated and pushed through laws widely criticised – including

protect customers against market failure – a hard argument to make when the services on offer are free. It's also hard to define a market when a firm offers everything from search engines to driverless cars.

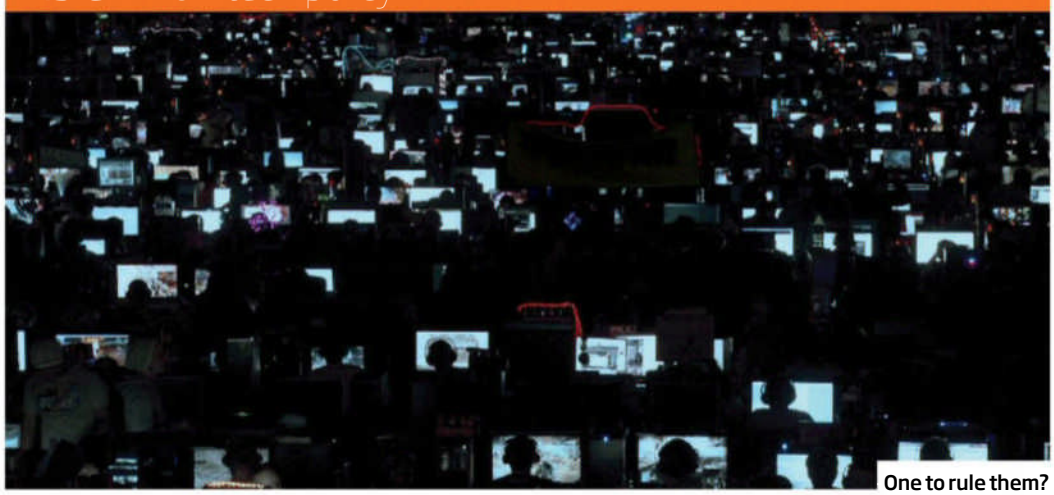
So perhaps we should look at the problem a different way. We might be concerned that a given company owns too much data. But how much is too much? A first step in deciding would be to create or empower bodies that could insist on meaningful disclosure of the amount and kinds of data that companies have gathered, and how they use it. The recent spat over Facebook's assimilation of WhatsApp data suggests there's scope to give information commissioners real teeth.

Since data can be endlessly reused, there's not necessarily any need to break up big companies: instead, certain classes of data could be made available to other organisations – much of it was, after all, originally donated with very specific purposes in mind, rather than for any and every future purpose that the tech giants dream up. That would provide a way to let competitors develop past infancy – and ensure that new winners join the old ones. **Sumit Paul-Choudhury**

by *New Scientist* – as illiberal and technologically illiterate. Both the Investigatory Powers and Digital Economy Acts give government sweeping powers, while arguably exposing users to greater risk – by outlawing encryption, say.

Digital platforms may also be obliged to protect "vulnerable" users from "hate speech, pornography or other sources of harm" by a new regulatory framework. Again, details are vague. While forcing companies to purge or block internet vitriol and extreme content may prove popular, the Tories' approach – which to date has more closely resembled broad censorship than targeted harm reduction – will worry free-speech advocates. ■

INSIGHT UK tech policy



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One to rule them?

# Why the UK needs a chief technology officer

**Niall Firth**

YOU only have to stick a UK politician on a TV sofa to chat about technology to see how well it is understood at a senior level. At best, you get empty platitudes about the importance of science, technology, engineering and maths (STEM) subjects in school. For anything more, it quickly becomes apparent that they either don't understand the subject or don't see the bigger picture, as amply illustrated by home secretary Amber Rudd's plan to ban all encryption. Or by the suite of ill-advised surveillance laws.

Who is advising policymakers on technology? Other, forward-thinking countries have chief technology officers. Shouldn't we?

The position has existed – technically – but in a department whose primary function is getting Westminster's digital infrastructure – including Wi-Fi coverage – up to speed.

There are numerous officers and advisors whose responsibilities include the word "technology". But the approach is divided over departments, without coordination or accountability, when it comes to big strategic decisions on the UK's line on issues where tech meets society. For example, Facebook and Google profiting from ever bigger chunks of our personal data, black-box algorithms making vital decisions with no oversight, and automation threatening jobs.

Peter Wells, head of policy at the Open Data Institute thinks it's high time we had one place for the buck to stop. He believes the government needs a real position to coordinate tech policymaking, particularly with regards to data. "We certainly need a chief data officer with clout now, both to do the strategic stuff and with the ability to say no to bad stuff," he says.

**"You've got to change a culture that is almost anti-technological in its thinking"**

It certainly seems to have paid off in Estonia where Taavi Kotka, a tech entrepreneur drafted into a senior political post launched the country's much-feted e-residency programme, and helped to make Estonia the most technologically advanced nation in the world. Now his successor is preparing the country's workforce and laws for labour automation and the rise of autonomous cars.

Too bad this solution will probably not scale to a country the size of the UK. "Just having someone with that job title isn't the answer," says Mike Bracken, a former executive director of digital in the Cabinet Office.

Instead of focusing on a single post, he thinks we should get the whole of the government up to speed – not just its infrastructure but its politicians' grasp of the deeper issues of technology and society. "You've got to change a culture that is almost anti-technological in its thinking."

While in the heart of government, Bracken found that decisions around big topics such as encryption were made without consulting anyone who grasped the basics. "These issues are central to how we run the country," he says. "You need people who actually understand the details in power."

Innovation charity Nesta is about to publish figures showing that just 7 per cent of candidates in the upcoming UK general election have a STEM background. The charity points to the lack of tech issues on party manifestos as indicative of how the political elite view such subjects now. It also points out that "automation" was mentioned just once in Parliament last term.

This is the situation that really needs addressing. "Never mind one CTO, put 100 in there and then see what happens," says Bracken. ■


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## Reaching into the past

IN THE jungle of northern Tanzania, high in the Usambara mountains, stands a research centre frozen in time. The Amani Hill Research Station is a remnant of the country's colonial past, founded under German rule in 1902 and brought to renown by British scientists in the mid-20th century.

After the second world war, the scientific station became famous for its malaria research. Today, that legacy is forgotten.

The nearly abandoned lab is now tended to by John Mganga, a 67-year-old retired assistant, seen here tidying a shelf. Mganga also keeps up the entomological collection (below) with butterflies and other insects caught in the surrounding national park. The Usambara mountains are legendary for their biodiversity, which is on display in the Amani collections. Although the lab sees few visitors, 34 staff remain to look after the space.

Since the 1970s, the laboratory has remained largely unchanged, left with the instruments and specimens of an era gone by.

Russian photographer Evgenia Arbugaeva visited the lab – her first trip to Africa – after anthropologists at the University of Oslo, Norway, told her about their work studying postcolonial scientific stations. Chelsea Whyte

**Photographer**

**© Evgenia Arbugaeva, from the series Amani, 2015**

Courtesy of The Photographers' Gallery

# Our leaking universe

*The steady drip of energy through the fabric of space-time could be ripping the universe apart, finds Joshua Sokol*

IF PHYSICISTS went in for commandments, the first would surely be: thou shalt not get something from nothing. Also known as the principle of energy conservation, this universal accounting law makes it impossible for energy to be magicked either into or out of existence.

Whenever a suspicious transaction seems to take place in physics, a careful audit with the principle of energy conservation usually reveals the source of the error – some overlooked entry in the ledger that, once taken into account, helps balance the books.

This time-honoured technique has allowed us to predict planets and discover particles. But now it appears to be under attack. Look out into the depths of the universe today, and you see a vast quantity of energy. It is so vast, in fact, that it accounts for over two-thirds of all the energy there is. And this mysterious stash is growing continuously – energy laundering on the grandest of cosmic scales.

Working out where this so-called dark energy comes from is probably the biggest problem in physics. We have long been frustrated in finding a solution, but now two groups of physicists think they have it. If they are right, we may have found dark energy's source in the imperfect joins of the universe where different theories of reality meet. Follow the trail back, and we could even arrive at a better theory of reality.

We've known about the invisible elephant in the universe for some time. In 1998, astronomers observing distant supernovae noticed that they were even dimmer than expected. We expected their light to fade as it travelled towards us across an expanding universe, but these new results suggested there was a foot on the accelerator.

Dark energy is the mysterious substance conjured up to explain what is pushing the universe apart ever faster. And as the latest data from sources like the Planck space telescope reveal, it is spread evenly throughout the universe at a density equivalent to around half a dozen protons in every cubic metre of space.

> "Dark energy may be a cosmic accounting error, rather than an unknown substance"

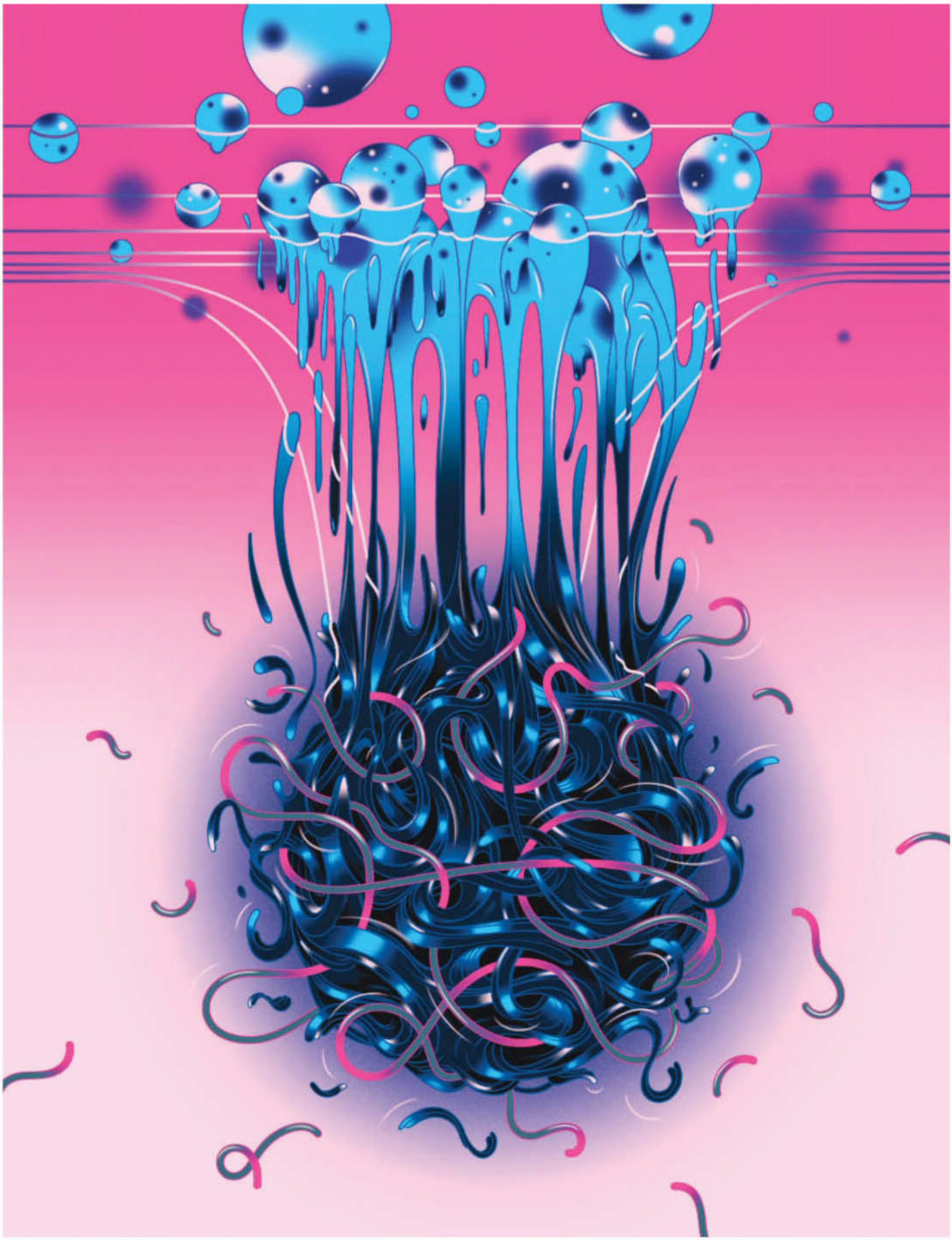
The simplest way to explain this all-pervasive energy is to think of empty space as not being empty after all. On very small scales, quantum mechanics says that any vacuum is filled with the wriggling of quantum fields. But calculations following that approach give us a dark energy density that is 120 orders of magnitude larger than the one astronomers measure from the accelerating expansion of the universe. Almost laughably wrong.

Some researchers, however, haven't given up on making these two numbers square. According to a new paper by Qingdi Wang, a student of theoretical physicist Bill Unruh at the University of British Columbia in Canada, these jiggling fields would tend to cancel each other out on larger scales, drastically deflating the prediction.

But frustration at the inability to make progress has now led some to suggest that it's all down to a cosmic accounting error. The idea is that dark energy is not actually a substance held in the universe's vaults – it's something that appears on the books purely because there's something else we've overlooked.

Energy conservation is such a basic principle that any apparent violation should give pause for thought. The seminal work of mathematician Emmy Noether in the early 20th century showed that energy conservation was an expression of something even more fundamental: the idea that the laws of physics are immutable over time. And indeed, it is a principle that has paved the way for centuries of discovery ("What has conservation of energy ever done for us?", see page 31).

When it comes to dark energy, cosmologists ›



ANDREW ARCHER

already had a vague idea where the accounting error might lie. According to Einstein's equations of general relativity, energy is absorbed and released all the time by the bending and stretching of the fabric of space-time. When photons seem to lose energy as they travel across an expanding universe, for example, that energy is all assumed to go into the universe's geometry. On the scale of the cosmos as a whole, energy is always appearing to be either created or destroyed.

Similarly, dark energy isn't adding or subtracting anything from the universe's overall budget. From afar, cosmologists are confident that everything balances out between the universe's stuff and the warped space-time holding it. But up close, the exact nature of the transaction bestowing space with extra energy remains mysterious. "The question is 'Where is it coming from?'" says Spiros Michalakis at the California Institute of Technology in Pasadena.

## Secret source

For Thibaut Josset of Aix-Marseille University in France, the processes responsible for that transaction lie in the jagged edges where quantum mechanics and general relativity meet. For decades, we have been looking for a unified theory of quantum gravity, one capable of explaining microscopic quantum processes alongside the large-scale workings of gravity. Thus far, no such theory exists.

One key difference between general relativity and quantum mechanics lies in the way they see the universe's fundamental structure. In Einstein's view, which works perfectly for objects on the scale of planets, stars and galaxies, the four dimensions of space and time are smooth and continuous. But quantum mechanics, which seems to govern reality at small scales, implies that deep down, space, like everything else, must be made up of discrete units that we still don't know how to describe.

Such a grainy structure would have repercussions for the objects that inhabit it. Relativity dictates that particles with mass bloat or compress the space around them depending on how much mass they have. The process is often equated to a taut sheet bending under the influence of a bowling ball rolling around on top of it. But what if up close, the sheet's surface was stippled?

In such a situation, Josset and his colleagues argue, particles are likely to feel that graininess as a form of friction, shedding energy into the stitching of space.

*"Tiny violations of energy conservation build up during the universe's history"*

If their model holds, the matter in the universe has been losing energy continuously since a fraction of a second after the big bang.

Adding up the little losses of energy between then and now gives an estimate for dark energy's strength closer to reality than the 120 orders of magnitude overestimate, although still quite a way off. "We are only seven orders of magnitude away," says Josset's colleague Alejandro Perez of the National Autonomous University in Mexico, noting that they plan to keep refining their estimate.

"The magic of this thing is that very tiny violations of energy conservation, that are very, very hard to detect in normal, local experiments, build up during the very long history of the universe," says Perez. Add them all up, and you could have enough to explain away dark energy. In other words, it is the tiniest drip-drip of energy – the smallest of leaks in space-time – that is causing this biggest of problems to accumulate.

The leak would have to be so small as to have gone unnoticed so far. At the Large Hadron Collider and elsewhere, experimental physicists are on the lookout for apparent violations of conservation of energy, as spotting one might indicate the existence of

new particles. So far they haven't found any good leads, and the chances are they won't with current particle colliders. But the amount of energy non-conservation these experiments allow is still enough to hide the observed strength of dark energy, Perez says, something like the mass of a proton going missing every year from a cube of water 10 kilometres across.

While physicists have long known about general relativity's ability to transfer energy in and out of the space-time curvature on a grand scale, they have struggled to make it work on the scales Josset describes. What has stood in their way, says Sabine Hossenfelder, a theoretical physicist at the Frankfurt Institute for Advanced Studies in Germany, is that Einstein's equations are ruthless about energy conservation when you zoom in on small regions of space. Any quantum jiggery-pokery would invalidate the mathematics.

That is, until Josset's colleagues suggested using a less restricted view that Einstein himself had worked on. This workaround allowing Josset to relax its restrictions on energy conservation.

"I'm annoyed I didn't think of it earlier," says Hossenfelder.

But one of Josset's assumptions remains contentious. The idea that space-time is ultimately made up of grains, while popular, is far from proven. Identifying the source of dark energy in the interplay between quantum theory and general relativity may require a different approach. Natacha Altamirano of the Perimeter Institute in Waterloo, Canada, has come at the problem from a different angle. Or rather from the largest possible scale, to examine how quantum mechanics and general relativity play off each other across the entirety of the universe.

Altamirano's work considers what would happen to a particle traversing the smooth hills and valleys described by Einstein's theory, but within a universe itself following the fuzzy rules of quantum mechanics.

Considering a quantum universe is a familiar gambit in theories of quantum cosmology, which try to explain the universe's earliest instants back when it was still tiny and ruled by wild fluctuations. If the whole universe was quantum, then, much like an electron orbiting an atom, the cosmos could theoretically exist as a superposition of many different possible sizes and states at once.

In practice, the universe's choices are a lot more limited. The reason lies in Heisenberg's uncertainty principle, which governs the precision with which we can know the value of any quantum variable. Measure the position of a particle very accurately, for example, and you can't closely measure its momentum, and vice versa. As photons travel from one galaxy to another, they lose energy. And in the language of the uncertainty principle, that's a lot like taking a cosmological measurement.

All those unintentional measurements of the universe force the quantum uncertainty to go somewhere else. And one of the ways that can manifest itself is in the form of information loss elsewhere: a little more uncertainty in the rate the universe is accelerating, for example. That change, in turn, would have consequences for all other variables that depend on that rate, further changing the acceleration of the universe in a perpetual feedback loop.

Unless you accounted for it, all that noise would add up to a mysterious dark energy-like term popping out of the void. "If I decide to describe my universe with a theory of general relativity that conserves energy, I would see this extra fluid," says Altamirano. As to whether the dark energy density that emerges from such a model might turn out to match reality in a way that rivals Josset's, Altamirano is still working on generating such a figure. "I can't tell how possible that is," she says.

Josset's and Altamirano's approaches come at a time when dark energy has repeatedly foiled theorists' attempts to nail it down. Not everyone is convinced the pair are barking up the right tree, though. For Antonio Padilla at the University of Nottingham, UK, the sheer difference in scales makes it unlikely that quantum gravity effects on the smallest imaginable sizes can explain dark energy, which is manifest across billions of light years.

*"Finding dark energy may involve treating the universe as a quantum object"*

They can't both be right, either. Because the two approaches use different mathematical language to discuss how gravity and the quantum world interact, they produce different answers for what happens to cosmology. Altamirano's model produces something like dark energy, but it's a kinder, gentler version. As the universe expands, it dilutes in space, whereas the dark energy density predicted by Josset's model remains a constant, in keeping with observations.

Ironing out such wrinkles to everyone's satisfaction would probably need a fully formed theory of quantum gravity – or at least some as-yet unimagined experimental test that would allow us to look at the universe's very earliest moments. Until then, dark energy will continue to accumulate interest in the distant reaches of the cosmos – a silent rebuke to the idea that we have our cosmic accounting practices in hand. ■

Joshua Sokol is a freelance writer based in Boston

## WHAT HAS CONSERVATION OF ENERGY EVER DONE FOR US?

**Everywhere we look, energy seems to be created or destroyed. Falling objects gain speed; tides rise and fall; digested food seems to practically disappear.**

**But each time we've pulled these apparent mysteries apart, believing that the energy must be conserved rather than made or eradicated, we've revealed new science. Objects raised above Earth's surface acquire gravitational potential energy; seas and oceans are affected by the pull of the moon; food is converted into body fat.**

**Similar reasoning, applied to blocks sliding across a surface, allowed Leonardo da Vinci to discover friction. The 19th-century French astronomer Urbain Le Verrier combined it with data demonstrating irregularities in the motion of the planets to predict the existence of Neptune. Physicists like James Joule made use of it to prove that heat was simply another form of energy. And Albert Einstein's $E=mc^2$ shows that the colossal energy generated by an atomic blast has been stored up as mass all along. Even the mystery of dark energy might one day be explained away by applying the principle (see main story).**

**Perhaps the most remarkable example concerns the neutrino. In 1930, physicists knew that radioactive atoms could emit electrons, but energy seemed to vanish during this process. That led Wolfgang Pauli, clinging to the law of conservation of energy like a lifeboat, to propose that a small and unseen extra particle was ferrying it away.**

**"I have done something very bad today by proposing a particle that cannot be detected," Pauli wrote. "It is something no theorist should ever do." But a quarter of a century later, the particle, a neutrino, was discovered – exactly as Pauli, and the energy conservation principle, had predicted.**

# THE PROOF IS IN THE PUDDING

Think you've got cooking down to a science? Sam Wong sifts top tips to separate must-do from myth

EMILE LOREAUX/PICTURETANK

**MENTION the words "science" and "cooking" in the same sentence and the phrase "molecular gastronomy" springs to mind. Scientific techniques have added zest to high-end cuisine, but you don't have to be using liquid nitrogen, spherification and the like to benefit. Home cooks can learn a lot from science, especially when it comes to knowing which bits of kitchen folklore are worth swallowing.**

**It turns out that many top tips make little difference, while others undermine flavour or even increase the risk of food poisoning. We've sifted through some of the most commonly promoted techniques, chewed over the science and put the tips to the test to figure out which should be saved and which should be thrown away.**

## SEAR MEAT TO LOCK IN JUICES

Many chefs say to sear meat first at a high heat to trap moisture. But if you cook identical steaks to the same internal temperature, one that is roasted then seared is often juicier than one that is seared then roasted.

Why? Higher heat makes the muscle fibres contract more, forcing liquid out. A cold steak takes longer to sear in a hot pan than a steak that has been warmed in the oven, so loses more liquid.

To retain moisture, the most important step is to rest the meat after cooking. As muscle fibres cool, they widen, holding on to more juice.

Searing does boost flavour by browning the outside. This is caused by Maillard reactions: as sugars and amino acids react, usually under heat, they produce a huge range of flavour compounds that contribute to the distinctive tastes of everything from roast beef to popcorn. It is Maillard reactions that turn bread into toast and provide the savoury crunch of roast potatoes. But they also produce acrylamide – particularly in starchy foods cooked at high temperatures. In the body, acrylamide is converted into glycidamide, which can bind to DNA and cause mutations. In animal studies, consuming acrylamide has been shown to cause cancers.

There is less certainty about its effects on us, and whether the amounts we consume are dangerous. Still, to be safe, the UK's Food Standards Agency says to limit acrylamide exposure by aiming for golden, rather than brown, with foods like roast potatoes and toast.

## COOK PASTA AT A ROLLING BOIL

Many Italian chefs say you must add pasta to a big pot of water at a vigorous boil. This is because it will return to the boil quicker and the extra room stops the pasta sticking together.

It's true that adding a set amount of pasta to a smaller pot will lower the water temperature more than adding it to a bigger pot. But returning to a boil takes the same amount of energy and may even be quicker in a smaller pot because it has less surface area.

As for sticking, this only happens during the first minute or so of cooking, when surface starch granules swell and pop. Stir the pasta for the first minute and you can happily leave it to cook in your small pot. In fact, you can turn the heat off and leave the lid on and it will cook just fine, as starch gelatinises at about 82°C, well below water's 100°C boiling point.

## RISOTTO: NEVER STOP STIRRING

To make risotto, you must add stock slowly and stir constantly, right? Traditionalists are adamant that doing so ensures even cooking and the perfect creamy consistency.

This creaminess comes from dissolving starch. Rice contains two forms: amylose, made of long, straight chains packed tightly together, and amylopectin, which has a branching structure. Constant stirring and the slow addition of stock are supposed to help dislodge amylopectin – by rubbing rice grains against each other and pushing liquid through gaps in the branches. The amylose stays tightly packed, so the rice retains some bite.

But chef J. Kenji Lopez-Alt, author of *The Food Lab: Better home cooking through science*, points out that most of the starch that thickens risotto comes from fine particles on the grains' surface and it is the addition of liquid, not stirring, that mostly affects its release. (If you rinse the rice before you cook it, the starch comes off and you get a risotto with little creaminess.) Lopez-Alt found that vigorous stirring for a couple of minutes at the end of cooking gives equally creamy results.

Still, traditionalists have a point, says Matt Hartings, who teaches a chemistry of cooking course at the American University in Washington DC. The higher the ratio of released starch to liquid in the pot, the thicker the risotto will be. Adding stock gradually gives you more control over that ratio. "But if you control your ingredients just right from the outset, a no-stir method should give you the creaminess that you're looking for," he says.

## AVOID CERTAIN OILS FOR FRYING

Don't fry in olive oil. This common advice is based on its low smoke point of around 165 to 190°C. When the oil is heated to this temperature, fat molecules get oxidised, producing aldehydes and other compounds that can be toxic and give an acrid flavour. ›

MARCUS NILSSON/GALLERYSTOCK

But studies have found that both extra virgin and ordinary olive oils hold up well at high heat, producing fewer toxic aldehydes than other oils. That may be because the unsaturated fat in olive oil is more resistant to oxidation than the types in nut or sunflower oils.

Still, this consternation over cooking oils may be a storm in a teacup: just don't reuse the oil too much, says Selina Wang of the Olive Center at the University of California, Davis. "Most cooking oils are safe for cooking at high temperature until the oil gets very oxidised and starts breaking down."

Butter too has a low smoke point, around 190°C. To avoid burning, some chefs say to add oil too. But it's the milk proteins in butter that cause the smoke, and these will remain. If you skim them off to make clarified butter or ghee, you can heat it to 250°C without it smoking, though you may sacrifice some flavour.

## SOME DIRT WON'T HURT

A bit of dirt won't do you any harm, will it? Well, soil can carry harmful bacteria such as *E. coli*, outbreaks of which can be deadly. In fact, bugs on fruit and vegetables can be even more harmful than those found on raw meat. That's why public health bodies recommend washing fruit and veg to remove soil, especially if you're eating them raw. But don't wash uncooked meat: you risk splashing bacteria around and cooking will kill bugs.

## PLASTIC IS SAFER THAN WOOD

Plastic chopping boards are meant to be superior because bacteria can get into wooden ones and linger.

To test this, US food safety researcher Dean Cliver contaminated chopping boards with germs such as *E. coli* and *salmonella*. He found that 99.9 per cent died within 3 minutes on wood, but none died on plastic. When contaminated boards were left overnight, bacteria multiplied on plastic ones but couldn't be recovered from wooden ones the next day.

One problem with plastic boards is that it's easier for knives to leave grooves where bacteria can thrive. Hardwood boards are generally tougher, and their porous structure means bacteria sink below the surface, where they get trapped, have little room to multiply and eventually die off. That said, when any chopping board gets too many grooves, food safety specialists recommend replacing it.

Plastic boards should be quite safe after a run through the dishwasher as they can be sanitised at high temperatures. However you clean your board, let it dry thoroughly as bacteria need moisture to grow.

Regardless of material, to avoid cross-contamination it's best to use different boards for raw meats and any food that won't require more cooking, such as raw salad ingredients.

MICHAEL GRAYSON/GETTY

## PERFECT POACHED EGGS

**There are plenty of tricks for poaching eggs: the cling-film method, silicon cups and the vortex to name a few. It is true that adding vinegar or salt to the water will help the whites coagulate at a lower temperature. Egg proteins mostly have negative charge, so adding positively charged particles can help them get close to each other and bond.**

**But the best advice is to use fresh eggs. As an egg ages, carbon dioxide escapes through the shell and is replaced by air. The pH of the egg white increases, destabilising links between its albumin and lysozyme proteins. These proteins then dissolve, making the egg white runny. "Loose whites" put into hot water drift around, rather than clinging to the yolk. You can test the freshness of an egg in water: old eggs are more buoyant because of the air they've absorbed.**

**If you've only got old eggs, chef Heston Blumenthal has a trick to give you tidy whites. Break the egg into a wire mesh strainer. Liquid whites will pass through, leaving you with solid whites that won't dangle off during cooking.**

## YOLK SPOILS THE WHIP

Egg whites' ability to be whipped into an airy foam is a wonder of kitchen chemistry. They are about 90 per cent water and 10 per cent protein. Some of the amino acids that make up these proteins are hydrophilic, meaning they are attracted to water. Others are hydrophobic. The proteins start curled up, with the hydrophobic regions tucked inside. As the beating causes them to unfurl, they form clumps with the hydrophobic bits sandwiched against each other and the hydrophilic parts pointing out towards the water. The resulting network of proteins around each air bubble gets stronger and stiffer as you keep beating.

Recipes warn us that a trace of yolk or grease will ruin a whole batch. That's because fats can bond to the amino acids, stopping them from interacting with each other to create the strong network. But you needn't despair: one drop of yolk in 100 grams of egg white just means it will take longer to reach stiff peaks. Three drops, you've got problems. The same goes for working in a bowl with oily residue.

In your meringue-making, you might have experienced liquid leaching out of the foam that won't mix back in. This can happen when the proteins clump together too strongly, collapsing the foam and leaking water. Adding lemon juice or cream of tartar should help. These acids lower the pH, affecting how much the amino acids want to avoid or contact water.

Egg whites aren't the only option for foamy meringues. It was recently discovered that the liquid from tins of chickpeas, known as aquafaba, whips up just as well.

## MARINATE MEAT FOR FLAVOUR

You need to marinate meat at least overnight, right? Maybe not. Only salt, small sugar molecules and some acids

**"There's little benefit to hours of marinating. Many flavour molecules just coat the surface"**

are able to penetrate more than a few millimetres. Aromatics and flavour molecules won't do much besides coating the surface, so there's little benefit to hours of marinating. Acids like lemon juice denature proteins and can leave your meat mushy. So instead of giving meat a soak, it may be better to simply rub spices on the outside.

What about brining turkeys? When meat cooks, muscle fibres contract, squeezing out liquid (See "Sear meat to lock in juices", page 33). Salt dissolves some muscle proteins, such as myosin, which loosens the fibres, letting them take on more water and ensuring they don't contract quite as much when they cook. The trouble is, that just leaves you with a bird pumped full of water. Dry salting can create a concentrated brine that gets absorbed into the meat, letting it hold on to more of its original moisture without diluting the flavour.

## NO MORE TEARS

**As you chop onions, they release enzymes that lead to the production of syn-propanethial-S-oxide, the volatile compound that makes you weep. There are countless tips for avoiding this chemical assault. We put some to the test.**

- **Freeze the onion for 10 minutes**
The cold is supposed to reduce the activity of the enzymes.
**Verdict:** Quite effective.

- **Peel and soak the onion in water for 10 minutes** The eye-stinging compound is water-soluble.
**Verdict:** The volatile chemical isn't released until the onion is chopped, so this did little to help. It also made the onion slippery, so harder to chop cleanly and safely.

- **Chew gum while you chop**
This is supposed to help by forcing you to breathe through your mouth.
**Verdict:** The tear-producing glands that get irritated are in your eyes, so it's unlikely to help. For us, it made no difference.

- **Wear glasses, contacts or goggles**
This blocks syn-propanethial-S-oxide from getting into your eyes.
**Verdict:** Goggles work, though perhaps not for impressing dates.

SUPERSTOCK

## HOT PAN FOR PERFECT YORKIES

There are two rules for Yorkshire puddings: the pan must be smoking hot before the batter goes in and you shouldn't open the oven door or the cold air will make them collapse.

It took an American to challenge the accepted wisdom on this British creation. While researching the best Yorkshire puddings, chef J. Kenji Lopez-Alt found that a preheated pan makes little difference for small puddings in a muffin tin. (The advice is probably aimed at larger tins, which are harder to heat up.) And opening the oven door made no difference.

Much more important is letting the batter rest. Lopez-Alt found this affects how much the puddings rise, with ideal results from batter made a day earlier. During cooking, proteins and starches break down and get rearranged into new compounds. These give the batter colour and flavour, and allow elastic-like gluten to develop from the flour, which results in larger air bubbles when baked. Making the batter in advance gives this process a head start.

These reactions occur slowly in the fridge or at room temperature, and speed up during baking. The pudding will rise more if the batter starts at room temperature. Cooking from cold will give you more cup-shaped puds as the edges heat faster than the middle.

## SOUFFLÉ IS A RECIPE FOR FAILURE

The word soufflé needn't inspire terror. Soufflés are like meringues: you beat air into the egg white, fold it into your flavoursome mixture, then watch it rise as air bubbles expand in the oven.

According to Harold McGee, a food writer who focuses on the chemistry of cooking, expanding air accounts for only a quarter of the rise. The rest comes from evaporating water. When the soufflé cools, the volume of gas in the bubbles decreases, and the water vapour condenses – this is why soufflés collapse if left before serving. Cooking your soufflé at a lower temperature for longer will lead to a less pronounced rise, but may help it resist collapse by enabling heat to penetrate and firm up the centre. It's also important to grease the dishes: if the mix sticks to the side, it might rise too little or unevenly. ›

## TOMATO CATCH-UP

**You say tomato, I say: "Not in the fridge!" Chilling unripe tomatoes reduces production of enzymes that generate taste and aroma compounds, and many don't recover when back at room temperature. That is why supermarket tomatoes can be flavourless: they were probably picked some time ago and kept cold to extend their shelf life.**

**But what about tomatoes that are already ripe? According to Trevor Suslow and Marita Cantwell at the University of California, Davis, the ideal temperature for firm, ripe tomatoes is 7 to 10°C. Unfortunately, most of us don't have a storage space in that range. So what's better, the fridge or a warm kitchen?**

**In blind tests done by chef Daniel Gritzer, tasters noticed little difference between tomatoes stored at room temperature and ones that were refrigerated for two days. However, warmer parts of the fridge – the top shelf and near the door – are probably best.**

PAULINE DANIEL/PICTURETANK

## CHILL YOUR EGGS

Where should you keep eggs? Storing them in the fridge was once advised to reduce risk of bacterial growth. In the UK in the 1970s and 80s, there was an increase in salmonella in chickens. The bacteria didn't make the hens sick, but infected their eggs. "Unless these eggs were fully cooked, until the white and yolk were solid, the bacteria were liable to remain viable and cause disease in humans," says Barbara Lund at the Quadram Institute, a centre for food science and health research in Norwich, UK. No runny yolks, folks.

Since then, the UK has required most hens to be vaccinated against salmonella. It worked. In 1997, there were 33,000 infections with the bacteria. Within five years of the new strategy, that was halved. Today, 90 per cent of eggs sold in the UK, labelled with the Lion Quality mark, are from vaccinated hens. Last year, the Food Standards Agency even declared runny yolks safe for pregnant women.

For the other 10 per cent of eggs sold in the UK – and in countries such as the US, where hens are not vaccinated – refrigeration reduces infection risk.

## LEAVE LEFTOVERS TO COOL

Some people whack warm leftovers straight into the fridge, others leave them to cool to room temperature first. Who's right? The idea behind waiting is to avoid raising the temperature inside the fridge, potentially putting other contents at risk of bacterial growth.

But this is only really a problem if you're cooling something like a vat of piping hot soup. The US Department of Agriculture suggests using small containers that can chill quickly and refrigerating all leftovers immediately.

That's because leaving food out, especially in a warm room, is risky: between 20 and 50°C, many bacteria can double every half hour. Improper cooling practices in restaurants contribute to around 50 outbreaks of food-borne illness a year in the US.

As for what you do with that saved portion of spaghetti, the UK Food Standards Agency recommends eating refrigerated leftovers within two days, since some bugs can continue to grow slowly at fridge temperatures. Frozen leftovers should last up to four months.

Rice, however, should be eaten in one day. That's because *Bacillus cereus*, a bacterium found in uncooked rice that can cause diarrhoea and vomiting, forms spores that can survive cooking. These can produce a toxin that's resistant to heat, so a blast in the microwave won't ensure the rice is safe.

## THOU SHALT NOT REFREEZE

Whether you can safely refreeze food depends on how you defrosted it. It's all about maintaining a safe temperature – below 4.5°C. Above this, bacteria grow.

That's why it's safest to thaw food in the fridge. Provided it hasn't started to spoil, it's then fine to refreeze. Thawing food in the microwave or in water is OK, but it should then be cooked immediately. Thawing food on the worktop is dangerous as bacteria can multiply rapidly at room temperature. This is why you should never refreeze ice cream that has melted. *Listeria monocytogenes* is known to survive for prolonged periods in ice cream, says food scientist Barbara Lund. It can cause serious infection and deaths in vulnerable people, and is known to multiply at temperatures as low as 3°C.

Another reason not to refreeze ice cream is that it just won't be as nice. It's usually churned as it freezes so that it forms small crystals separated by air. Melted and refrozen ice cream will instead form a dense block. ■

**Sam Wong** is a reporter at *New Scientist*

If submarines are trackable then our nuclear strategy is in trouble, says **David Hambling**

# Dead in the water

STEVE KAUFMAN/CORBIS/GETTY

ON 17 April, North Korea's deputy ambassador to the UN gave a tense press conference. The US was insisting that North Korea scale down its nuclear programme, and this, said Kim In-ryong, had created a situation in which "thermonuclear war may break out at any moment".

It was not the first time such warmongering talk had come from North Korean diplomats, but concerns over nuclear war have rarely been higher. Donald Trump has warned of a "major, major conflict" with the country.

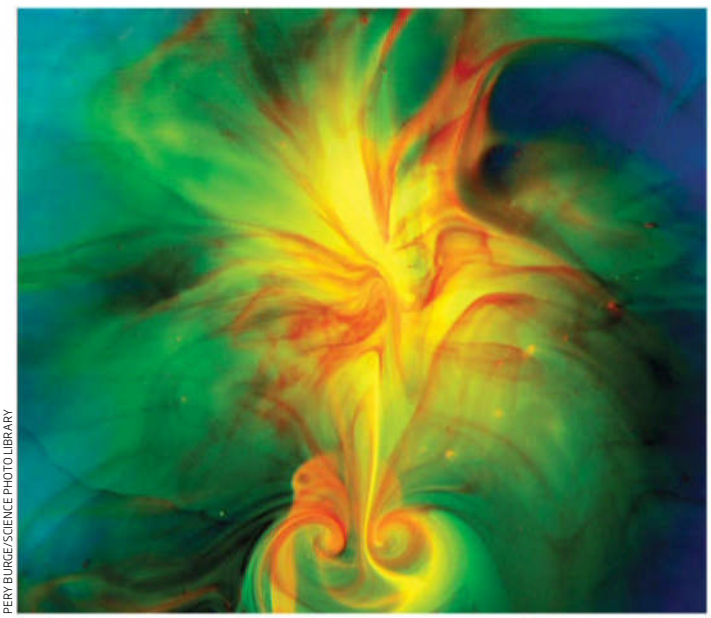
On the face of it, such tensions might seem to bolster the case for maintaining a nuclear deterrent in the West. Recent arguments in the UK in particular about replacing the ageing submarines that carry the country's Trident nuclear missiles are part of that wider debate.

But what if those submarines are lame ducks? A rumour has circulated since the cold war that subs, often considered the epitome of military stealth, can in fact be tracked. If that's true, and there are fresh hints that it could be, it overturns an opinion that has largely held sway among military analysts for nearly 50 years – and changes the terms of debates about nuclear deterrence entirely.

It was the 1960 book *The Strategy of Conflict* by economist Thomas Schelling that put forward the first rigorous analysis of strategies for preventing nuclear war. Schelling used game theory to introduce the idea of a "credible commitment". This principle says the US must be locked into ordering a retaliatory strike if it is hit by a nuclear missile. This guarantee of a counter-strike is supposed to deter the use of nuclear weapons in the first place.

For the commitment to be credible, the ›

**Disappearing act: we've always thought submarines are virtually untraceable**



PERY BURGE/SCIENCE PHOTO LIBRARY

## HOW TO TRACK A SUB

We don't know for sure whether the Russians are able to track submarines by spotting their wakes (see main story). But no matter: there are other ways to find these metal leviathans.

One method emanates from the saltiness of seawater. The sodium and chlorine ions in the water have a charge, and when something disturbs the water the ions move at different rates because of their different masses. This Debye effect, known since the 1930s, sets up a magnetic field. The magnetic signature left by a submarine was thought to be vanishingly faint, but a paper published by the British Defence Research Agency in 1996 suggested they might be detectable. The US Navy has picked up this idea, and since 2009 has commissioned studies from Cortana Corporation to determine its potential in sub detection.

There is another option, which depends on another unique property of the seawater. The ocean contains distinct layers of water, with the warmest and least dense at the top. Ships, whales and submarines disturb these layers, pushing colder water upwards and creating a thermal scar on the surface.

Jordan Peckham at the Memorial University of Newfoundland in Canada and his colleagues have looked at inexpensive ways to spot home-made submarines that are packed with cocaine for smuggling trips to other countries. In 2013, they showed that a commercial infrared imager could detect the thermal trail of these "narcosubs" a few metres beneath the surface. It also works in practice: the US Coast Guard uses P-3 Orion aircraft equipped with thermal imagers to spot the drug-laden subs too.

Seeing submarines at depths of several hundred metres is another matter. But nuclear submarines need to dissipate megawatts of heat from their reactors. Seawater is used for cooling, and subs leave a slowly rising plume of heated water behind them. A Soviet study during the cold war estimated a nuclear submarine would leave a trail on the surface that differs by just 5 millikelvin from the background temperature, but which may persist for some hours.

Is that detectable? Commercial imagers can detect only a 20 mK difference at present, but better imagers are in the pipeline. "I can design a camera that can see 1 to 5 mK pretty easily" using emerging technology, says Ron Driggers, CEO of St Johns Optical Systems.

nuclear missiles must be constantly available at a moment's notice. This led the US to introduce a "nuclear triad", in which nuclear missiles are kept at military bases, on aircraft and on submarines. The thinking goes that no state could disable them all at once, and render themselves immune to retaliation. In theory, Shelling's principles still apply today.

## Ear on the deep

Submarines are the critical leg of the triad because they are supposedly well nigh impossible to pinpoint. So much so that the UK doesn't bother with the other legs at all, keeping all its missiles aboard submarines. "The maritime element remains the most survivable part of any nuclear triad – a fact unlikely to change in the immediate future," says Peter Roberts at the UK's Royal United Services Institute (RUSI), a defence think tank. Disappearing into the vast ocean, "submarines on patrol are remarkably difficult to find".

That's not to say subs are undetectable. Sonar can reveal a sub if it is within about 15 kilometres, depending on the ocean conditions. Starting in the 1950s, the US also used an array of hydrophones to listen for Soviet submarines. This exploited a layer of water about 1 kilometre down where sound carries especially well, and allowed subs to be heard hundreds of kilometres away. That still left a lot of ocean to hide in, though.

The USSR explored an alternative way to find subs during the cold war when it was lagging behind with sonar technology. This involved identifying the wake of disturbed water submarines leave behind them, which would create a pattern that rises to the ocean's surface. According to the cold war historian and ex-US Navy analyst Norman Polmar, a task force was set up in the early 1960s within the Soviet Union's council of science to look into whether it was possible. The Soviets later claimed to be able to track wakes with ship-based radar, with aircraft and even from satellites. Their own submarines were fitted with comb-shaped SOKS or *Snegir* (meaning "bullfinch") sensors, which supposedly allowed them to secretly tail NATO submarines for days at a time.

Scientists in the West were sceptical of all this. Submarines certainly leave a trail of turbulent water immediately behind them, but according to the accepted understanding of turbulence it ought to disperse and merge with other currents within minutes. Think sloshing your hand around in a bath tub. The

turbulent flow you produce breaks down into smaller and smaller streams, eventually fading into nothing.

But is that true under all circumstances? Turbulence is one of the trickiest unsolved problems in physics. When a thick fluid like honey flows, we know where we are. But with less-viscous fluids like water, the movements can become unpredictable. We have equations that describe this turbulent flow, but they can't be solved exactly, meaning that we're not certain they capture what is happening.

In 1963, Carl Gibson, an oceanographer at the University of California, San Diego, looked at turbulence in wind tunnels, water tunnels and tidal channels and became convinced that the data didn't fit the expected pattern. Instead, he points to the existence of "fossil turbulence", an idea first mentioned in the 1950s by George Gamow, a Russian physicist living in the US.

Gamow was talking of galaxies being a kind of snapshot of the turbulent gas flows in the young cosmos. But Gibson has extended the idea: "Turbulence always starts with eddies forming at small scale and cascades to larger scales," he says.

This is the reverse of the accepted understanding of turbulence – that energy dissipates from large to small scales, says Colm-cille Caulfield who studies turbulence at the University of Cambridge. But this is a net effect and recent computer modelling studies now suggest "backscattering" of a small amount of energy to larger scales is possible.

Gibson's idea is that those spinning whorls of turbulence you can create with your hands in the bath will combine to produce larger and larger whorls over time. And he does have a little evidence to support these controversial thoughts.

In 2002, he joined an environmental research project studying the impacts of a waste water pipe in Mamala Bay, Hawaii. The team deployed a series of sensors to measure water velocity in three dimensions and Gibson used this to map the turbulence. He says the sensors picked up patterns of turbulence that increased in size as they rose to the surface.

He then analysed satellite photographs of the sea, looking for tiny changes in the brightness of the surface. Despite the pipe being 70 metres underwater, he reported in a 2005 paper that those anomalies were there, and that they matched the patterns of turbulence recorded by the sensors. Signs were visible on the surface as far as 12 kilometres away from the pipe.

This means fossil turbulence is real, says Gibson, and submarines could be tracked via their wakes. True, subs typically cruise at a depth of about 300 metres, but Gibson insists his extrapolation should hold. "The fossil turbulence remnants from a submarine persist for many days," he says. "The Russians have understood this from the beginning, but have considered all their progress to be important state secrets."

Recently there have been hints that the US Navy is also waking up to wakes. It funds firms to carry out research through a government scheme called Small Business Innovation Research. Records from the scheme show that the Navy contracted a firm called Cortana Corporation in Falls Church, Virginia, to develop models of various ways a sub might be detected (see "How to track a sub", left). One of them is how underwater currents and turbulence might manifest themselves on the ocean surface.

The company declined an interview with *New Scientist*. But military analysts are also sounding the alarm. "The Russian interests in this field are real," says Polmar. "Some of their accomplishments are impressive, and a concern to US and British officials."

**"If fossil turbulence is real, submarines could be tracked via their wakes"**

Even if he's wrong, the worries over submarine tracking aren't over. Keir Lieber at Georgetown University's Center for Security Studies in Washington DC points out that a number of technologies, including underwater drones, have evolved to the point at which submarine undetectability is no longer a given.

This casts a shadow over the NATO efforts to create stealth submarines that are invisible to sonar. If Polmar and Gibson are right, then perhaps more focus should be on finding ways of reducing the wake that submarines create. That, it seems, is what the Russians have done. "Many Russian submarines have vortex attenuators on their screws and small vortex-unwinding propellers," says independent naval analyst Jacob Gunnarson in Williamsburg, Virginia.

It's enough to give us pause over UK government plans to upgrade its nuclear deterrent. The planned four new Dreadnought class subs will cost upwards of £31 billion. A government document released in 2016 says: "It is unlikely there will be any radical technological breakthrough which might diminish materially the current advantages of the submarine or make the oceans transparent." That statement now looks just a tiny bit less certain. ■

JAIME SALDARRIAGA/REUTERS

**Not just nukes: drug gangs use home-made "narcosubs" to evade detection**

**David Hambling** is a freelance writer based in London

# Inventive brothers who gave pilots a sixth sense

From helping British fighter pilots triumph in the second world war to the cultural seeding of Silicon Valley, the **Varian brothers** were a creative force to be reckoned with

THE urgent cablegram zipped under the Atlantic towards the US as the second world war started to unfold. British scientists at the University of Bristol, rightly fearing an aerial war with Germany, were desperately searching for ways to put radar technology on board small fighter planes, to give them an edge in the air. What they needed was a small but powerful instrument that could greatly amplify high-frequency radio waves – those into the microwave range – so they could bounce them off things that were hidden by clouds or darkness.

When their cablegram landed on the desk of Russell Varian at Stanford University, their quest came to an end. Announced in the *Palo Alto Times* in 1939 as "an invention so breath-taking in its possibilities, that it may alter the future radio development of aeronautics, as well as telephone, telegraph and television communication", the item in question was the klystron tube, developed and first prototyped in 1937 by Russell and his brother Sigurd.

Press articles celebrating the invention of the klystron had omitted certain key details, because they were classified, but Russell wanted to help the Allies so he got permission from the US government to pass the information on. It led to the British developing the "Sutton tube" klystron, which gave Royal Air Force pilots a significant advantage during Germany's night-bombing raids. The British went on to win the Battle of Britain, thanks in some measure to the Varians' timely creation.

Born around the turn of the 20th century, Russell and Sigurd were ingenious, bold brothers who grew up in California, two of three sons of Irish-immigrant parents. How did they come up with a device as remarkable as the klystron? Thank the mother of invention. Sigurd had been a pilot for Pan American Airways from 1929 to 1935. Flying frequently between the US and Mexico, he knew all too well the risks associated with the crude instrumentation of the day. In stormy weather, flying over mountains or trying to land in thick cloud was treacherous. Surely there must be a way to see through the clouds.

Although bright and gifted at making things, Sigurd lacked Russell's college degrees. He thought Russell would be able to design something that could solve the problem. Growing up, the duo often collaborated on making toys and inventions. Now, that special dynamic was to come to fruition. Russell decided to design a radio wave amplifier that could do what Sigurd dreamed of.

They got a contract at Stanford that provided them with the use of a lab, access to faculty members and $100 for materials and supplies. "Sig loaded his tools in the car, and they left for Stanford immediately, in their excitement forgetting their coats, most of their clothes, and Russell's notebook," recalled Russ's wife, Dorothy, in her 1983 biography of the brothers, *The Inventor and the Pilot*.

**"The klystron was hailed as an invention 'breath-taking in its possibilities'"**

Working with Stanford physicist Bill Hansen – a pioneer of microwave electronics – it took them less than a year, and less than $100, to come up with a working klystron. Russell had had a brainwave. Electrons in a beam travelling from one end of a vacuum tube could be bunched together by alternately decelerating and accelerating them as they flowed. This produced amplified oscillations: pulses of increased energy that could be emitted from the other end of the tube as a powerful radio or microwave signal. The name klystron, provided by a classics professor at Stanford, was adapted from an Ancient Greek verb relating to waves lapping on a shore.

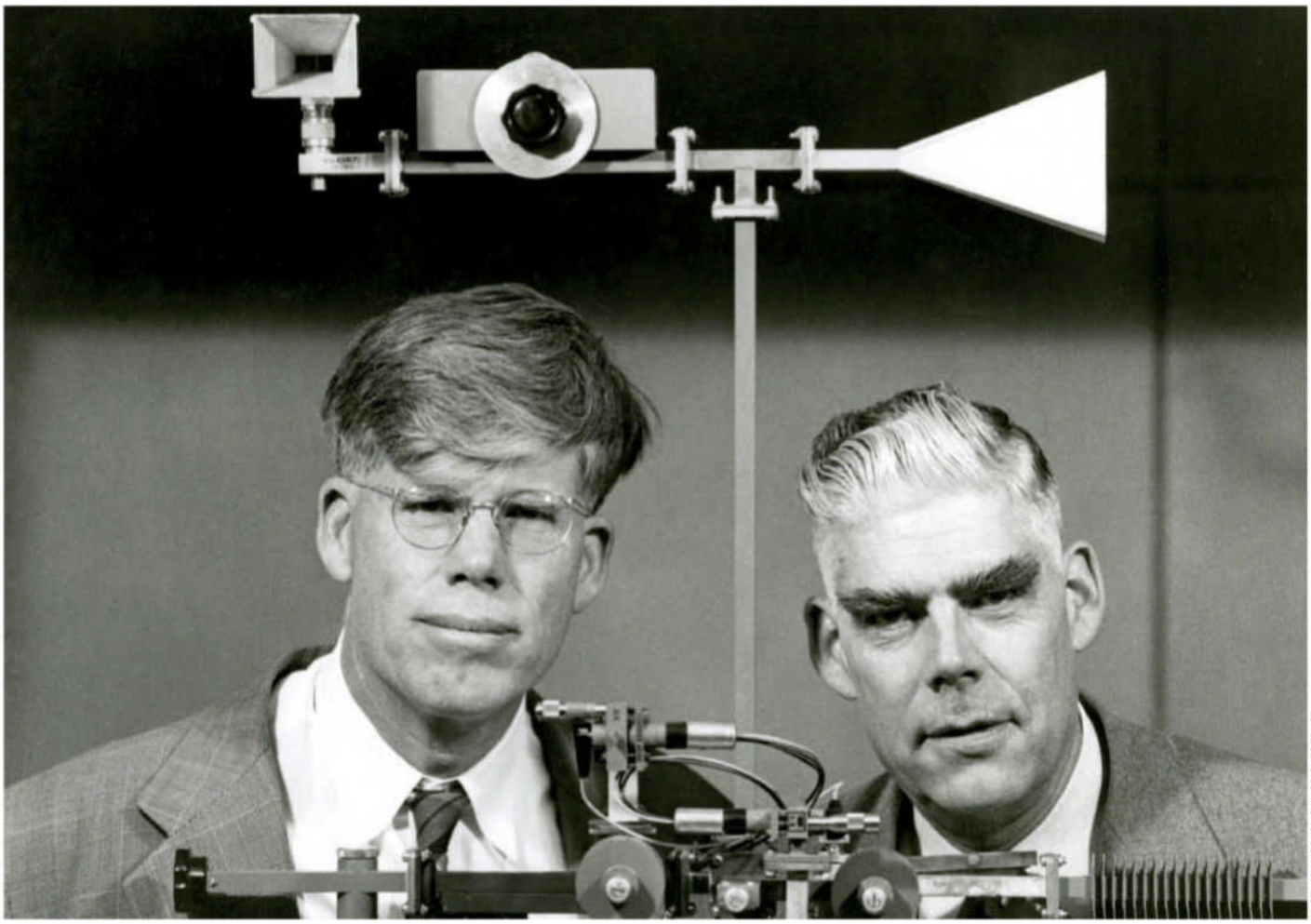
When klystrons were used in a test by the US military, the brothers knew they were on to something big. At a Boston airfield in February 1939, ground-based klystron tubes emitted signals that were detected by incoming aircraft in a daytime "blind landing" simulation – without runway lights or other signals to guide them. The technology would be used extensively for blind landings by the US army.

During the war, the Varians briefly relocated to the east coast of the US, where they worked on klystrons for the Sperry Corporation. Sperry put their designs into practice, but the two dreamed of starting their own laboratory back in California, and come 1946, that's what Russell went back home to do, later followed by Sigurd. Their new associate, Ed Ginzton, who they had met at Sperry, helped them set up their firm in 1948.

It began humbly, with six full-time employees, in what looked like a concrete shack, in San Carlos. They christened it Varian Associates, a name that was intended to emphasise the idea of a cooperative run by scientists and researchers, not corporate executives. And what shaped Varian Associates helped to shape a nascent Silicon Valley – and the echoes remain today.

The Varians' ethos was doubtless a result of their upbringing. Raised in the utopian community of Halcyon, California, their father, John Varian, was a mystic poet and both parents were theosophists. Gatherings at their house included local writers, artists, businesspeople and "dreamers", Russell fondly recalled.

"Varian was the second seminal Silicon



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**Russell and Sigurd Varian with one of their many pieces of cunning technology**

Valley company after Hewlett-Packard," says John McLaughlin of the Silicon Valley Historical Association. In 1953, Varian Associates moved – and became the first firm based in Stanford Industrial Park in Palo Alto. McLaughlin notes that, years later, Steve Jobs's mother worked at Varian, as a bookkeeper.

Russell and Sigurd never thought they'd make big money from building klystrons, expecting to simply license the patents. But Varian Associates' first big contract was to make klystrons for guided missiles. It put the firm on the map. The company was soon making klystrons for many applications – including in ballistic-missile early-warning systems, satellite communications and television transmission equipment. Klystrons are ubiquitous today.

But the Varians were not one-trick ponies. Perhaps inspired by the brothers' Halcyon days, Varian Associates developed a reputation for creativity and the free-flow of ideas. Like Apple and Google today, the company attracted top minds and innovated furiously. Among other things, it went on to pioneer nuclear magnetic resonance technology, which revolutionised molecular research, X-ray accelerators, which have become ubiquitous in cargo screening in ports worldwide, and radiotherapy technology, which treats many thousands of people with cancer every day. One descendant company, Varian Inc, was bought by Agilent Technologies in 2010 for $1.5 billion.

## A bum idea

However, the brothers didn't always get it right. Sigurd once asked Russell if he thought it was worth developing a kind of metal-printing gun to put wires into radio sets, instead of having to do this by hand or with traditional machinery. Russell dismissed it as "a bum idea" – but, as they later marvelled, the information age as we know it was founded perhaps on one technology more than any other: printed circuits. You can't win them all.

Nonetheless, their impact on the world has been huge, even if neither brother would live to see it. Both died suddenly in separate incidents. In 1959, Russell suffered a heart attack in Alaska while travelling with his family and companions. They had been searching for land that could be turned into a new national park when a storm caught their boat in a riptide. Exhausted after rescuing it, Russell collapsed and died.

Two years later, Sigurd was flying into Puerto Vallarta in Mexico, but the airport never received a telegram asking for the landing lights to be switched on. His plane crashed into the sea – tragically ironic, after his pioneering work on technology that allowed for blind landings. It was a premature end to a story of remarkable innovation. ■

By Chris Baraniuk

# Mind is where the heart is

Can we fuse our rational and animalistic sides, asks **Pat Kane**

*The Patterning Instinct: A cultural history of humanity's search for meaning* by Jeremy Lent, Prometheus Books


AS THE daily turbulence of politics, economics, environmental change and religion rages around us, there is an understandable marketplace for books that look at the bigger picture. Jeremy Lent's *The Patterning Instinct* does just that, joining the dots between points in history and culture, identifying echoes and consiliences across the natural and social sciences.

This is more than a scholastic exercise. Our planetary predicament demands the broadest and deepest perspectives, not just to enable masterful armchair contemplation, but also to guide our actions in the middle of what would otherwise be an enervating horror show.

The cover of Lent's intellectual epic shows a line drawing of networks, the dots ostentatiously joined. No doubt this expresses the author's fundamentalism, derived from his scientific and religious readings, about the power of connectedness.

But on the way to a somewhat familiar end point, Lent provides a useful and massively referenced road map of the most enduring structures of meaning in human history.

Humanity's first world-encompassing idea, says Lent, was the hunter-gatherer belief that "everything is connected". There followed an agricultural era during which humanity lived under the "hierarchy of the gods". He then charts what he calls "the divergence".

Lent's shorthand for this pattern is "split cosmos, split human": the assumption that our physical reality, personal or objective, can be controlled by transcendent powers. Whether we call those powers "divine" or "rational" is, to Lent, neither here nor there. The two developed in lockstep: you couldn't have conceived one without the other.

Articulated first by the philosophers of Ancient Greece, this "Western pattern" of meaning gathered force under the rise of Christianity and the innovations of the Enlightenment and continues to hold sway under today's scientific industrialism.

**"This idea could produce a split humanity, one species enhanced and exploring, the other barely surviving"**

Lent traces his splitting thesis all the way to the thrumming fortresses of Silicon Valley. Here, Plato's fantasy – a rational soul subjecting the animalistic body to its will – is not just a moral compass, it's become techno-scientific mission.

Are you extending our cognitive abilities by creating devices that mimic and mesh with our thinking? Are you influencing people's emotions through mood-altering drugs? Are you engineering our bodies to the optimum with gene editing? Then you are in the grip of an ancient idea: that pure rationality stands sovereign over the biological world.

This idea has the potential, already half-realised, Lent says, to produce a split humanity, "one species, genetically and technologically enhanced, exploring entirely new ways of being human; the other species, genetically akin to us, barely surviving within its collapsed infrastructure."

Similar to Yuval Noah Harari's recent, and equally expansive, *Homo Deus*, Lent's book seeks some perspective on our modern juggernaut of radical innovation and global polarisation. To do so, it reaches towards Asian wisdom traditions – an "Eastern pattern" that Lent calls "the harmonic web of life".

But while Harari's no-self Buddhism comes close to exulting in the way humankind will be overtaken by intelligent algorithms, Lent finds a place for connecting, meaning-seeking humans in this complex future.

To carve out this space for ourselves, Lent says we must recast the deep metaphors structuring our attitudes to nature and other humans.

Neo-Confucianism is the candidate that Lent favours to lead this metaphorical revolution. Its core concept is an understanding of the universe as the interrelation of *qi* (spoken as "chi") and *li*. *Qi* is the raw material of the universe – but *li* is "the ever-moving, ever-present set of patterns that flow through everything in nature and in all our perceptions of the world, including our consciousness".

Like his mentor Fritjof Capra, who provides an introduction for the book, Lent seeks corroboration for this spiritual insight in what were once called the "new", non-deterministic sciences – the study of complex adaptive systems in physics and biology, which find curious analogues in certain branches of mathematics.

Lent shows how the tenets of Neo-Confucian thought are homologous with maths, neuroscience and climatology, particularly when those disciplines identify "a complex

OLIVIER AUBERT/PICTURETANK

The revolution starts here: a Confucian temple in Shanghai

of dynamical systems that remain valid across the entire natural world, from systems as vast as global climate to as small as a living cell".

Like Capra, Lent wants to fuse spiritual tradition and the "new" sciences in service of a less rapacious and divisive world. If we could grasp what Lent calls elsewhere "liology", we would attribute our ultimate sources of value not to "a transcendent realm", or to our "moral rationality", but to "humanity's intrinsic connection with the natural world".

There's an obvious, real-world refutation available, of course. It's not hard to find a regime that loudly deploys Confucian values in a modern setting. But does China, which recorded its highest ever figures for coal-fired electricity this April, provide the best exemplar? Lent himself delicately "refrains from making direct inferences regarding modern China" in his study of Neo-Confucianism. He should entertain a little more hope. Although China is producing more energy from coal in absolute terms, the percentage of total energy provided by coal is dropping.

Since 2007, Beijing elites have been hyping East Asia as a land mass uniquely placed to bring about an "ecological civilisation", underpinned by the Confucian belief in harmony with nature. Meanwhile the administrations of US president Donald Trump and UK prime minister Theresa May have each rubbished climate change action and research. They have handed China a golden opportunity: to make good on its soft-power rhetoric and create a sustainable model that, sooner or later, the rest of the world will have to emulate.

Lent uses what he calls "cognitive history" and "archaeology of the mind" to show how such massive shifts in underlying world view can happen, and they involve an evolutionary account of the brain. Again like Harari, Lent dates the advent of our capacity for advanced cognition to a point about 70,000 years ago, when our prefrontal cortex began to expand.

Lent describes the "executive function" of the prefrontal cortex well. "It mediates our ability to plan, conceptualise, symbolise, make rules, and impose meaning on things. It controls our physiological drives and turns our basic feelings into complex emotions. It enables us to be aware of ourselves and others as separate beings, and to turn the past and the future into one narrative." This is the locus of the "patterning instinct".

In many of the neurology-informed history epics, authors are often studiedly neutral about the raw mental ability of humans to forge new paradigms. Few of them dare to connect our cognitive flexibility to any necessary idea of progress, or human flourishing. This is perhaps understandable given what's involved is often a survey of historical carnage. Lent himself is unsparing in his descriptions of the cruelty and brutality meted out by righteous monotheists and dualists, their meaning-patterns justifying colonialism and empire.

**"Cultures shape values, and those values shape history. Our values will shape our future"**

Given all this, you have to admire the way Lent sticks his neck out on behalf of Neo-Confucianism. He goes so far as to propose that its concept of "heart-mind", which seeks to integrate emotion and reason, is analogous to the prefrontal cortex when it functions at its best. And he has a point, citing research that shows that a healthy prefrontal cortex is not about "repressing or overriding emotional states", but about "integrating them into appropriate decisions and actions… our cognition takes place not in the brain but in the felt sensation of the entire body."

*The Patterning Instinct*, oblivious to the science-deniers currently occupying high executive office, ends with a statement of simple confidence: "Cultures shape values, and those values shape history. By the same token, our values will shape our future." One way to equip yourself for this heroic task will be to read this enormous, learned, yet garrulous and helpful book. ■

**Pat Kane** is the author of *The Play Ethic: A manifesto for a different way of living* (Macmillan)

# The view from Apollo

The first moon mission exposed a deep paradox, finds **Doug Millard**

*Apollo 8: The thrilling story of the first mission to the moon* by Jeffrey Kluger, Henry Holt


HERE'S a tricky exam question: "Frank Borman reporting 'Light on. Ignition,' from the Apollo 8 spacecraft is more significant than Neil Armstrong's 'That's one small step…' from Apollo 11. Discuss."

Borman was reporting the firing up of an S-IVB engine that would hurl him and crewmates James Lovell and William Anders out of Earth orbit and towards the moon. This Apollo 8 launch was the moment humanity started its journey to another world. Armstrong's stepping onto the moon signalled its arrival.

Jeffrey Kluger's new account of Apollo 8 is a welcome reminder that surrounding any famous historical event are others that impinge directly on how posterity remembers it. Indeed, focusing largely on the stories of the three Apollo 8 astronauts, he takes us through their formative time on Project Gemini – the testing ground for NASA's plan to go to the moon.

Apollo was a gargantuan national effort by the US. It cost billions and involved thousands of engineers, technicians, scientists, industrialists and managers. There is plenty of Apollo information and narrative out there for the interested reader, but it needs the discerning eye of a Kluger, who knows how to sift through it all to the essential detail and tell it accessibly.

His style never underplays the spectacle and achievement of the moonshots, but he laces his descriptions with reminders that the endeavour was delivered by human ingenuity, labour and passion. For example, writing about the almost-unimaginable strength of the engines that lifted Borman's crew off the launch pad, he invokes a natural context: the engines generated more power than an imaginary hydroelectric turbine fed by all the rivers and streams in the US.

More prosaically, but equally vivid, is his description of a noise the astronauts heard during launch as a "glug-glug-glugging", like water going down a plug hole. It was, in fact, the sound of the rocket's liquid propellants being pumped from tanks to engines.

Despite the intensity of the astronauts' preparations for the mission, their training couldn't alert them to what the experience would really be like. Nor could it give them a hint about what all the monitoring for ill-effects would be like to live with. So great were the space medics' concerns over the expected loss of calcium from the astronauts' bodies, for example, that all their urine and faeces for days before, during and after the mission were collected for analysis. And less a molecule be missed, they showered in distilled water, with the run-off collected for further assessment.

**"NASA stole the race with the launch of Apollo 8, killing off Soviet hopes of landing on the moon first"**

In 1968, NASA was facing huge problems with the Apollo programme. It was still recovering from the fire a year earlier that killed three astronauts on the launch pad. The second uncrewed Saturn V launch (Apollo 6) had been a near disaster and the lunar landing module wasn't ready.

Aware that the Soviets might launch a mission around the moon, perhaps with cosmonauts on board, NASA reconfigured the original Apollo mission to do likewise.

On 21 December, Borman, Lovell and Anders blasted off from Cape Kennedy and became the first humans to orbit the moon. NASA stole the race with Apollo 8. For cosmonaut Alexei Leonov (the first person to walk in space), that killed off Soviet hopes of landing on the moon first.

As Apollo 8 passed over the moon, Anders, scrambling weightlessly to grab a camera with the right lens, captured perhaps a defining image of the space age: Earth rising from behind the lunar horizon. As he said: "We came all this way to explore the moon, and the most important thing is that we discovered the Earth." ■

**Doug Millard** is deputy keeper, technologies and engineering, at the Science Museum, London

Apollo 8's trip brought a fresh perspective to those back home

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NEW SCIENTIST DISCOVERY

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EDITOR'S PICK

## If reality is tough to swallow, swallow harder


*From John Cookson, Bournemouth, Dorset, UK*

Alex Berezow argues that the Left aren't true heirs of the Enlightenment and are just as "deluded" as their opponents (6 May, p 25). The sociologists mentioned in his article make no distinction between opinions formed from the assessment of the scientific evidence and those of people whose beliefs are aligned solely with a conservative world view that accepts no contradictory evidence, no matter how well-founded. If you hold the view that all knowledge is purely a social construct then you are able to equate nonsense with rationality.

For the rest of us, the scientific evidence for anthropogenic climate change, for example, is overwhelming. It is ridiculous to give nonsense supported by prejudice equal status to a vast body of scientific work that has been subjected to rigorous scrutiny.

The fundamental problem for conservatives is that their views are increasingly divorced from anything remotely resembling reality. The answer for them is to deny reality, whether climate change or the effectiveness of vaccination. Ignoring the implications of scientific knowledge and denying the need to act on them is a classic tactic of conservatives trying to support vested interests.

Berezow states that "twisting science into a bludgeon for political opponents is a gross perversion". Science can only be used against conservatives if they ignore or deny the scientific evidence.

If they didn't do this, there would be no basis for conflict with the scientific community. To argue that there is an "institution of science" that will be damaged unless science can be completely divorced from its effects on society refers to an entity that doesn't exist and policies that would be profoundly damaging to the entire future of humanity.

## The fifth dimension is no more 'real' than others

*From Julian Higman, Wantage, Oxfordshire, UK*

Leah Crane suggests gravitational waves could show hints of extra dimensions (6 May, p 8). But dimensions aren't part of the physical world. They are a mental geometric tool created by humans to locate any spot in the physical world in relation to other spots. They don't exist otherwise.

We don't "experience" three spatial dimensions: we don't experience any dimensions at all. We see, hear and feel things all over the place, whether at the far reaches of the universe or in the clutter in our living rooms. To make sense of what is where, we impose our mental "dimensions ruler" on whatever space we are interested in. It is doing this that gives our world a 3D effect.

**"The irony of me seeing this on Twitter when I'm supposed to be writing a novel is not lost on me"**

**Alison Winter** takes a moment out to contemplate deliberate distractions that help concentration (20 May, p 26)

Generally we describe these "three dimensions" as three lines: left/right, ahead/behind and up/down. Of course "up" to someone in England is "down" to someone in Australia.

The fourth dimension is also a ruler. It is the ruler of motion, generally called "time". It, too, is a mental creation.

Gravity is something else entirely, definitely part of the physical world, and it shouldn't be made harder to understand by entangling it with something that is our own mental creation.

*From Frank Newbery, London, UK*

Leah Crane suggests that gravity may be "leaking" from our own observable universe into tiny hidden extra dimensions. But what if these extra dimensions weren't tiny, but invisibly "other" in some way not yet understood? Such dimensions might independently combine to form parallel co-universes not essentially dissimilar to ours.

If so, couldn't gravity from these be "leaking" back into our own universe? This would tend to have a flattening/thickening effect on gravitation in our universe, perhaps accounting for effects that are currently ascribed to "dark matter".

## Defying dementia and dealing with deafness

*From Neil Clutterbuck, Boolarra, Victoria, Australia*

You quote Alzheimer's Research UK saying that £12.9 billion could be saved annually if we delay the average onset of dementia by two years (29 April, p 28). This is interesting to audiologists.

Effective fitting of hearing aids can delay diagnosis of dementia by two years. It's not clear whether undiagnosed hearing loss causes acceleration of dementia, or it exaggerates the symptoms, or they have a common cause.

Performing the Mini-Mental State Exam verbally on someone with impaired hearing may lead to a false positive result. Needless to say, I fitted myself with hearing aids on the first indication of hearing problems.

## The extraterrestrial question is: when?

*From Thos Sumner, Waterloo, Indiana, US*

You report astronomer Avi Loeb saying "extraterrestrial signals should be no harder to find than other astronomical events" (29 April, p 7). But such signals would be many orders of magnitude weaker than those of most other events, although intentionally transmitting aliens could compensate with beam formation and directionality.

One further limitation stands out. The search for extraterrestrial intelligence has been going on for less than a century, but there could be a 100-million-year difference between the evolutions of two signal-emitting species.

## Shouldn't Europa get protection, too?

*From Steve Blyth, Roade, Northamptonshire, UK*

It is good to see pains being taken to protect Saturn's moons from bacterial contamination by burning up Cassini in its atmosphere (22 April, p 8). But the suggested mission to Jupiter's moon Europa involves a craft colliding with this potential harbour of alien life at the end of its assignment (29 April, p 4). Maybe a rethink is in order? ›

## Testing whether artificial intelligence steps up

*From Neil Doherty, Barnsley, South Yorkshire, UK*
I was fascinated by the use of plain English to instruct an artificial intelligence to "climb up the ladder" in its search for treasure in the computer game *Montezuma's Revenge* (29 April, p 12). As a next step, can we envisage the opposite scenario, in which an AI instructs people where to go to retrieve "treasure" in an arena with real-life obstacles?

## Estimating odds against spotting a thylacine

*From Andrew Smith, Leongatha, Victoria, Australia*
I have been chastising friends who believe thylacines may still be running around the Australian bush, quoting the 1 in 1.6 trillion chance that Alice Klein reports (22 April, p 11).

Now environment researcher Bill Laurance believes the chance they still exist on Cape York peninsula is a more likely "1 to 2 per cent" (6 May, p 40).

I would have thought, though, that checking the DNA in scats would be a more efficient and accurate way of verifying them as non-extinct than using 50 camera traps. It might be less convincing to the general public, however, or less lucrative than footage from a camera trap.

## What will plastic-eating caterpillars pollute?

*From Ann Wills, London, UK*
Much as I'm glad of research into stopping plastic waste blighting land and sea, I am concerned that researchers think it may be a good idea for caterpillars to eat plastic (29 April, p 8). Plastic can contain undesirable substances including hormone disruptors. Grubs eating these and being eaten by other creatures could contaminate even more of the food chain.

## Drones won't work very well underground

*From Bob Masta, Ann Arbor, Michigan, US*
So drones could be used to map unsafe mines (22 April, p 16).

But how can they can be remotely controlled once they turn a corner, given that radio waves don't penetrate rock or earth very well?

Cavers have been working on this problem for decades. The best scheme that I have heard so far involves planting walkie-talkie-sized repeaters every 100 metres or so along passages. This achieves data transfer at text-messaging speed – too slow for navigation and control.

## Maybe mitochondria were thermophiles

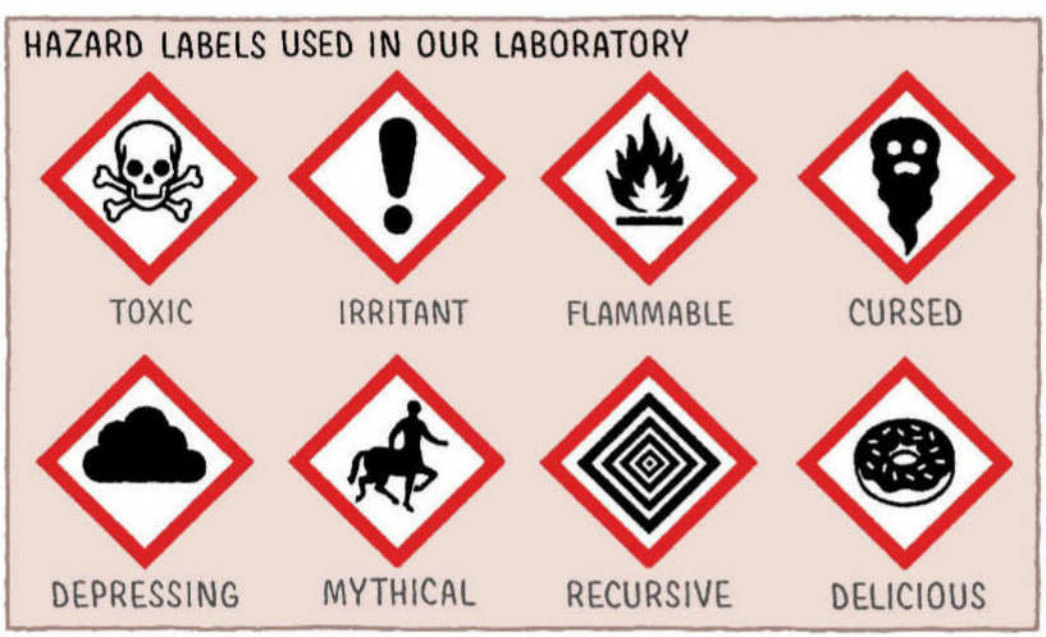
*From Peter Inkpen, Amersham, Buckinghamshire, UK*
You report that mitochondria operate at temperatures around 6 to 10°C higher than the rest of the cell (13 May, p 18). There is a broad consensus that the mitochondria within eukaryotic cells are the result of two prokaryotic cells forming a symbiotic relationship around 1.5 billion years ago.

Could the latest finding indicate that the prokaryote that evolved into mitochondria was a thermophile – that is to say that it was already tolerant of a higher operating temperature?

## This will come in handy one day, maybe

*From Tony Compton, Hexham, Northumberland, UK*
I enjoyed Elizabeth Landau's look at hoarding (29 April, p 34), and at least partly recognised myself. I have a "10 per cent rule": I will only ever reuse 10 per cent of the junk in my garage – but I don't know which 10 per cent. I can, however, get the car in.

TOM GAULD




## Gongs all round

*New Scientist* has been winning awards and accolades left, right and centre in recent weeks. Biomedical news reporter Jessica Hamzelou was named British science writer of the year by the Association of British Science Writers. New Scientist Live won best consumer show at the Exhibition News Awards – plus a gold award for event of the year and a silver award for launch of the year at the British Media Awards. Our social media videos won bronze in video product of the year. Our editorial, marketing and events teams have also been shortlisted by the British Society of Magazine Editors, the Professional Publishers Association, the Association of British Science Writers and the Association of Event Organisers. We'll let you know how we get on.

## For the record

■ **Astrobiologist Lewis Dartnell is now at the University of Westminster (13 May, p 36).**

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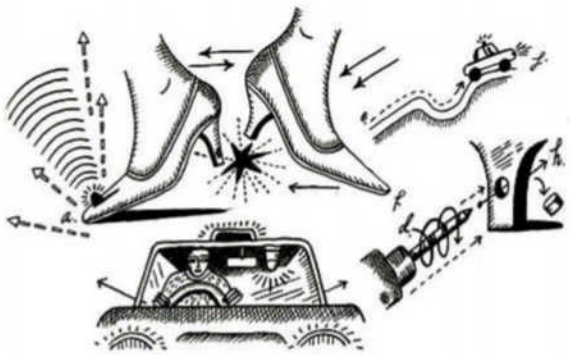

RUSSELL COBB

# Bring taxis to heel with some Wizard of Oz-style slippers

Step aside Dorothy, here is a 21st-century way to fly home in a hurry – with no magic involved

**"Squinting at my phone to call a cab at the end of the night gives me a headache," says Christine Wright. "I wish there was a magic button I could press to take me home. Can your fairy godmother help?"**

Stranded in Oz after missing her ride home, Dorothy discovers she can click the heels of her ruby slippers three times for a safe return. Modern technology has brought us so many magical ideas already, so why not a pair of shoes that can call you a cab?

First I picked out something Dorothy would wear on a 21st-century trip to the big city: an understated peep-toe with a moderate heel and a bit of a platform at the toe (essential for holding all the necessary tech – I mean, magic).

My initial idea was to use an Arduino microcontroller with a separate GPS/GSM module so it could tell you're not in Kansas anymore and share that information. But then the shoes would need a SIM card, and I didn't fancy pay-as-you-go footwear. Instead, I used a 1Sheeld device, which can connect to a smartphone with GPS and access the internet through its mobile data connection to request a ride from Uber.

After much cutting and drilling, I'd hollowed out the toe and heels ready for my hardware. We'll have to assume the superstition about new shoes on tables doesn't count when they're disassembled. I added a button in the heel, a few status LEDs to confirm the cab was on its way and a generous dose of red glitter.

The end result is beautiful, and only gives me a slight limp from the extra weight on my right leg. Technically these are now the most expensive shoes I own, if you count the value of the electronics inside.

To avoid accidentally triggering the shoes on a night out and being followed down the street by a motorcade of angry Uber drivers, I coded them to wait for three heel clicks in under 1.5 seconds. Even the most energetic dance number won't set them off prematurely. All together now: "There's no place like home…"

**Hannah Joshua** ■

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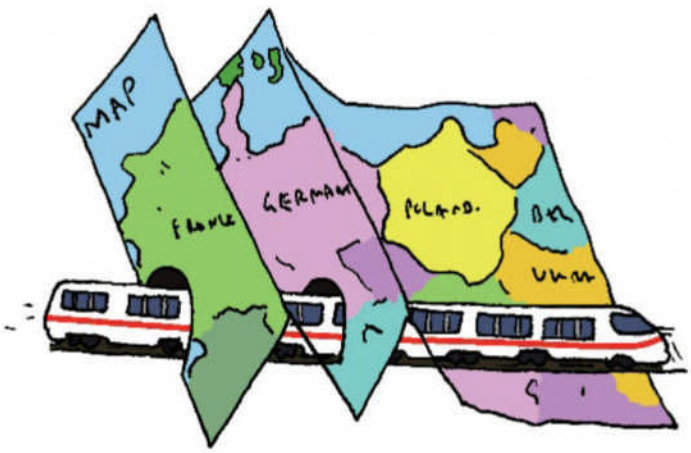


PAUL MCDEVITT

**BUS stops are the new butterflies of chaos theory, discovers Stephen Jorgenson-Murray while perusing Google Maps. Looking for travel routes across Europe, he says, "I was pleasantly surprised to find that Frankfurt to Warsaw – previously a 10-hour journey by train – was now possible in 5, at one point running in a perfectly straight line for 700 kilometres, in just 3 minutes."**

**Sadly, this isn't the result of a new bullet train lying under eastern Europe. A bit of investigation led Stephen to deduce that a bus stop in the Mikulczyce suburb of Zabrze, Poland, normally located at longitude 18.79° west, has instead been placed at 8.79° west. "By sheer coincidence, this happened to be right next to Dornheim railway station in Germany," allowing for quick connections between the two countries.**

**"This tiny error has left Google Maps unable to give accurate train routes across a huge chunk of Europe," says Stephen. Let's just hope that the bus drivers of Mikulczyce aren't reliant on Google for directions, lest their passengers suffer a longitudinous detour.**

MORE examples of retronyms, words coined by attempts to sound out an acronym, punctuate our inbox. David Roffey informs us of the Sydney suburb with an unusual name: Dee Why. "This is definitely a retronym dating back to at least 1840," says David. "Though no one knows what the original DY stood for."

Lately, the name has mutated a stage further, he says, with the locale being referred to as DW. We look forward to revisiting the topic in 50 years, and telling readers about the strange town of Dee Dubbleyew.

**MEANWHILE, Lance Hartland writes that "okay" might be the only example of a retronym being based on a mis-spelling, explaining that "OK is the abbreviation of 'all correct'".**

HOWEVER, John King provides an alternative theory. "There is a strong body of opinion that OK is derived from the Scots' 'och aye', suggesting the reverse process of using letters to imitate words."

John adds that, "among acronyms made into words, perhaps the most notorious is Nazi", stemming from *Nationalsozialistische Deutsche Arbeiterpartei*. "*Na* is the German n, and *tzi* is modified *tzett*, z, taken, perhaps, in preference to the less assertive *ess*, s."

**AND Tony Griffin complains that the challenge "has hijacked my attention off and on for several days now, and so far I've only been able to come up with a couple of rather pathetic near-misses: 'Beemer' to describe a vehicle made by BMW, and 'Beemo', a word referring to the Bank of Montreal."**

HAVING given the issue our full attention for far too many days, we can produce two further examples. Belgian cartoonist Hergé, creator of *The Adventures of Tintin*, coined the pseudonym from the reversed initials of his own name: Georges Remi.

And finally, if you're getting rather tired of all these retronyms, we have a handy one to add to your lexicon: "teal deer", a dismissive internet slang word taken from the abbreviation of "too long; didn't read".

**IN A shocking discovery that could solve all our energy worries, David O'Neill writes that his new car battery charger is listed as being suitable for powering up the following items: saloon car, sports car, SUV, pick-up, motorcycle, launch, solar system. The last entry leaves him wondering "where I would plug it in, and how long it would take".**

MEANWHILE Allan Reese spots the UK's *i* newspaper reporting earlier this month that "scientists at Nasa have dubbed the void around Saturn 'the big empty' after astronauts made their first dive into the space between the planet and its rings and encountered almost no dust or debris".

It's incredible that NASA was able to keep an interplanetary crewed mission quiet for so long, says Allan. Amid plans for a "grand finale" dive into Saturn's atmosphere, Feedback wonders how NASA plans to get the diving astronauts back.

**THOSE who like their beer served warm would do well to pay the Otter Brewery a visit. Adrian Wilkins is told via their website that two-thirds of the ground floor is – contrary to the name – built below ground. This sunken floor allows the brewery to do away with expensive climate control systems.**

**"Using the Earth's core temperature," explains a promotional beer mat, "our underground cellar saves us 6.5 tonnes of carbon emissions every single year." Exactly how deep is that cellar?**

THE octopus *Haliphron atlanticus* is not only rare "but appears to have a most unexpected capability", says Graham Hubbard. He directs us to *New Scientist*'s own coverage (8 April, p 19), in which it is claimed that a researcher had seen "... three of them using remotely operated vehicles".

**THE assertion made by Andy Ward in these pages – that there are no elements represented by J "rather ignores the German version of the**


**periodic table", says Alan Wells, "where *jod* (iodine) is represented by the letter J".**

**While this may help readers making words from the elemental alphabet, Feedback can't help but feel that any words containing a J ought to be German ones, *JA*?**

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

A chill wind blows? The UK Foreign Office has issued a travel advisory that "although there's no recent history of terrorism in the British Antarctic Territory, attacks can't be ruled out"

## The hole story

**I found this rock on the beach when I was on holiday in Wales. It has lots of holes, and I couldn't find any other rock with holes like it. What made them? Was it an animal or the sea?**

■ The indentations on the rock are all that remains of holes bored by the bivalve mollusc *Pholas dactylus*, better known as the common piddock (see photo below). Piddocks are fairly widespread and I, too, have found them in Wales.

The creature is able to bore a hole into a rock by locking on with a sucker-like foot and then twisting its shell to drill. A close look at the shell shows that it is covered with tiny rasping teeth, rather like a file.

Inside the rock, the piddock is safe from predators and continues to drill as it grows, the burrow widening and deepening, effectively trapping the piddock in its rocky home. The questioner's rock has obviously become detached and rolled in the surf, so the long burrows have been ground down to the indentations seen.

Piddocks are filter feeders and draw in seawater, containing food and oxygen, at their burrow opening through siphons that stretch up to 15 centimetres. This same burrow opening is used to get rid of drilling waste and as a route for eggs and sperm, the larvae living as plankton before settling into a crack in a rock to drill a new burrow.

Piddocks have another claim to fame. When a low tide and darkness coincide, you may witness a weird bluish-green glow because the animals are bioluminescent. So while the piddock may be a boring mollusc, it is far from uninteresting!

*Kelvin Boot*
*Exeter, Devon, UK*

■ *Pholas dactylus* is also known as the angelwing. This alternative name comes from the shape and colour of its delicate white shells.

Piddocks live below the low tide mark on the seashore, but may be seen in situ on a very low tide in suitable rocks.

I found some of these holes deep in a limestone sea cave on the Gower peninsula in south Wales, well above the present low tide level. This indicates a higher sea level that probably dates back to the last interglacial sea level rise about 120,000 years ago.

*Greg Nuttgens*
*Porthcawl, Mid-Glamorgan, UK*

■ The rock has been attacked by a mollusc, possibly *Pholas dactylus*, but also maybe a *Teredo* species, also known as shipworms. When *Teredo* infest the bottom of a wooden boat, they can seriously weaken it. In the Napoleonic period, it was common (but expensive) to cover the bottom of ships with sheets of copper, which the molluscs disliked.

This persists in English in the term "copper-bottomed" for something that is expensive but likely to last a long time. More recently, the same effect was achieved with paints containing tin, but these have been recognised as serious pollution sources.

*Aidan Karley*
*Brechin, Angus, UK*

■ Both shipworms and piddocks exude shell material to line their burrows and prevent them collapsing. The civil engineer Isambard Kingdom Brunel learned from this, and used the same strategy to successfully complete the first tunnel under the Thames in London.

Piddocks glow in the dark with a phosphorescent blue-green light. They are edible, and apparently the Roman author and naturalist Pliny the Elder noted that the mouths of people who ate them glowed.

*Jon Noad*
*Calgary, Alberta, Canada*

## This week's questions

**BROTHERS APART?**

Gold and lead are both forged in supernovae and are but a few subatomic particles apart in the periodic table. So why is there so much more of one than the other?

*Gregory Sams*
*London, UK*

**ABSOLUTE HOTNESS**

I was reading about the quest for absolute zero temperature in *New Scientist* (18 March, p 10). Is there an equivalent maximum temperature? If so, what is it? And how could one reach it?

*Robert Patterson*
*Scarborough, North Yorkshire, UK*

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