New Scientist

WEEKLY March 11-17, 2017

ZIKA, SEASON 2
It's back, and more dangerous than ever

TYING THE KNOT
String theory and loop quantum gravity get hitched

PREHISTORIC ANTIBIOTIC
Neanderthals knew the medicinal power of mold

GOOD HYDRATIONS

From water to wheatgrass smoothies, what to drink – and what to avoid

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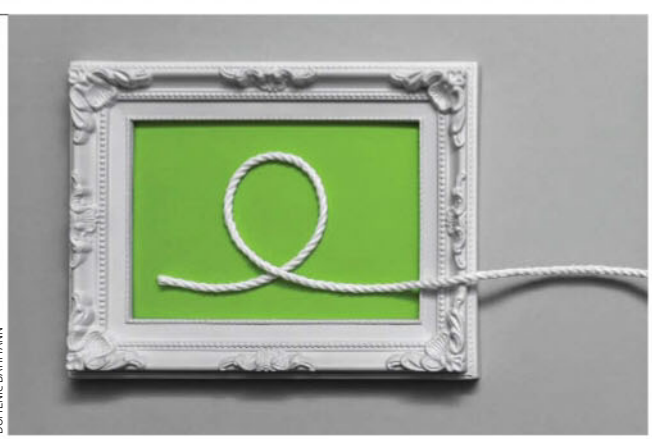

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JIM LO SCALZO/EPA

America last

Trump's assault on environmental science is self-defeating

A CHILL wind of change is blowing through climate research. To nobody's great surprise, given President Trump's rhetoric to date, the White House is said to be ready to gut the National Oceanic and Atmospheric Administration.

According to documents seen by *The Washington Post*, NOAA – the federal government's leading climate science agency – faces an overall budget cut of 17 per cent. Its basic science arm, the Office of Oceanic and Atmospheric Research, will lose more than a quarter of its funds. The money will be diverted to the military, on which the US already spends far more than any other country.

Some in the Trump camp claim they are not opposed to climate science, just to the "politicised" version of it now practised by NOAA and other agencies. This is nonsense. Climate science has been politicised only by those who deny its findings in the service of an antiquated model of US enterprise – one in which success depends on corporate freedom to trash the commons.

Most of the world recognises that cleaning up industry is not only morally responsible, but commercially sound too. Even ExxonMobil, from whose corner office Trump plucked Rex Tillerson to be his secretary of state, has made the right noises about a carbon tax, despite its appalling track record on climate change. Such a tax would impose rigour on carbon-intensive industries – and Exxon thinks it would win out in the subsequent competition. But rather than putting pressure on it to act on its words, Trump has applauded its recidivist plans to expand its Gulf Coast operations.

In the time warp that is Trump's White House, the environment is the enemy of commerce. On his first day in office, Trump signed a death warrant for Barack Obama's Climate Action Plan, which would have seen the US lead on efforts to slow and adapt to climate change. The Environmental Protection Agency is facing even steeper cuts than NOAA – up to 40 per cent of its research budget (see page 6). And a raft of measures seek to remove the EPA's ability to keep US air and water clean.

"Trump has cast himself as a modern King Canute, whose wishful thinking can hold back nature"

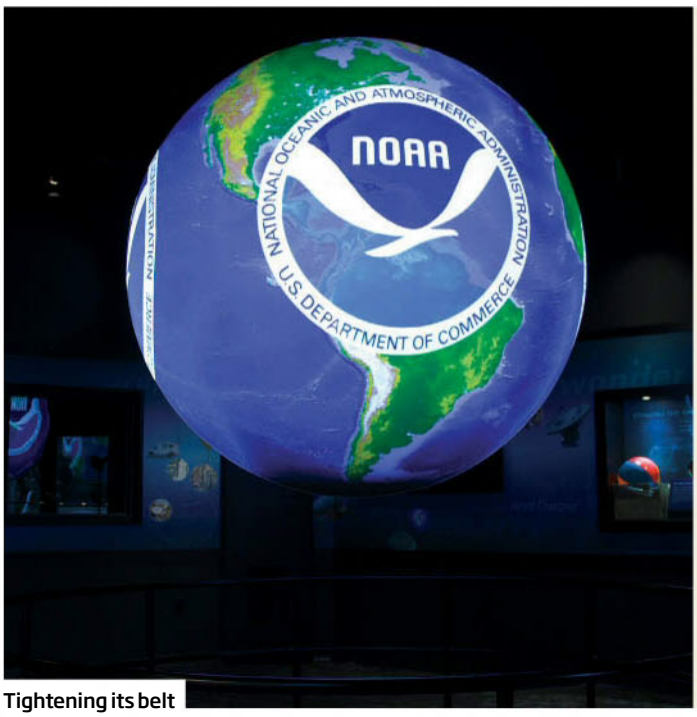
In this, Trump is going against the will of most Americans, few of whom voted for more pollution. And he is going against their best interests, too. Much of the US is vulnerable to climate change, whether it be droughts in the west or storms in the east.

Trump can ignore this for now. Given his gilded lifestyle, bluster and fondness for "alternative facts", he may be able to keep ignoring it indefinitely. Ordinary Americans won't. A new forecast predicts that atmospheric levels of carbon dioxide will rise by 2.5 parts per million in 2017 (see page 7). This week, we report both the mystery of solar brightening across the US corn belt (see page 12) and worrying ways in which climate change is affecting oceans (see page 22). This is the kind of vital research Trump and his cronies think does not matter.

One Twitter account parodying Trump has medieval king Donaeld the Unready railing against a rival: "Canute. What a loser. Can't even hold back the sea. It's just water. We're going to be so tough on the sea. Canute was too soft. Sad."

The real Donald has cast himself as a latter-day King Canute, deluding himself that he is able to hold back the forces of nature with an executive order. Except, of course, that Canute was actually a wise ruler who wanted to show his followers that he didn't have dominion over nature. The chances that Trump is doing the same? Zero. Sad indeed. ■

NOAA



Tightening its belt

US budget cuts

THE first draft of President Trump's proposed budget is heavy on cuts to government science. The numbers aren't final, but they are a sign of how he views science-based policy.

According to reports, the National Oceanic and Atmospheric Administration (NOAA) is facing reductions to its research arm totalling $126 million, or 26 per cent of its current budget.

Its Sea Grant programme, which funds coastal research in 33 states and supplied science-based guidance to states on the Gulf of Mexico following the Deepwater Horizon oil spill, is set to be axed.

The National Weather Service may see only a 5 per cent budget reduction. But it relies on NOAA's satellite division, which provides 90 per cent of weather forecasting data and is facing a 22 per cent cut. NOAA satellites also help monitor drought, track climate change and rescue lost ships and planes.

The Environmental Protection Agency is set to see its budget fall by 25 per cent, including a 40 per cent reduction in its research and development office.

Last week, Trump also ordered a review of the agency's power to enforce clean water laws.

"Given other statements that this administration has made about climate change, it would seem quite possible that the targets are intended to impair the activities that are climate related," says Jane Lubchenco, who ran NOAA under President Obama.

AI takes on suicide

FACEBOOK is trialling new tools to help prevent suicide, including the use of artificial intelligence.

Facebook says it will use pattern recognition algorithms to spot posts that could indicate someone is suicidal. It will make the option to report these posts more prominent, helping friends flag this content.

"When the system flags posts as 'likely to include thoughts of suicide', Facebook may intervene"

When the system flags posts as "very likely to include thoughts of suicide", its community operations team may take action even if no one reports the posts. The team will review these posts to see whether the person appears in need of help, and provide assistance if they deem it appropriate. The system is now being tested on a small number of users in the US.

The social media giant is also making it easier for people to report Facebook Live videos and is working with US organisations, including the Crisis Text Line and the National Suicide Prevention Lifeline, to let users contact crisis support teams via Facebook Messenger.

The UK mental health charity Mind says the principle behind the new tools is a good one. "People in crisis may ask for help in places where the help they need is not readily available," a spokesperson said. "Signposting people to appropriate sources of support can be a really important step in helping people to access the help they need."

Secret rocket

CHINA has another rocket. In a secretive launch at 7.53 am Beijing time on 3 March, the new booster rocket KT-2 made its debut flight.

The KT-2 is the latest in a series of lightweight Chinese rockets launched in recent months. It took off from the Jiuquan space centre, a military-run base in China's Gobi desert, carrying a small, experimental satellite called Tiankun-1 (TK-1).

TK-1 will be used for remote sensing, telecommunications and experiments in "minisatellite-based technologies", according to the Xinhua news agency.

The satellite is the first to be developed by the state-owned China Aerospace Science and Industry Corporation, which aims eventually to launch commercial satellites. The KT-2 is capable of launching a 300-kilogram satellite into low Earth orbit.

This was the third Chinese space launch this year, and the second from Jiuquan.

China is also developing a heavy-lift rocket called the Long March 5 and plans to launch a permanent space station by 2022.

A.P.S. (UK) / ALAMY STOCK PHOTO

On the decline

UK emissions drop

THE UK's carbon dioxide emissions have fallen to their lowest level since the 19th century as coal use continues to plummet.

Emissions of the major greenhouse gas fell almost 6 per cent year-on-year in 2016, after the use of coal for electricity more than halved to a record low, according to the Carbon Brief website, which reports on climate science and energy policy.

The assessment suggests that

around 381 million tonnes of carbon were emitted in 2016, putting the UK's carbon pollution at its lowest level – apart from during coal-mining disputes in the 1920s – since 1894.

Carbon emissions in 2016 were around 36 per cent below those of the reference year of 1990, against which legal targets to cut climate pollution are measured.

The analysis uses figures from the Department for Business, Energy and Industrial Strategy and comes ahead of the department's own estimates for UK carbon dioxide emissions, due at the end of the month.

Prize for dopamine

UNPICKING the secrets of the brain's reward system has earned three neuroscientists a reward of their own.

Wolfram Schultz, Peter Dayan and Ray Dolan this week won the €1 million Brain prize given by Denmark's Lundbeck Foundation. The prize recognises vital contributions to understanding how brains work.

Together, their research has revealed how brain reward systems that involve the signalling chemical dopamine influence our behaviour, playing roles in gambling, drug addiction and decision-making.

"This is the biological process that makes us want to buy a bigger car or house, or be promoted at work," says Schultz, who is at the University of Cambridge.

Having shown how dopamine shapes our behaviour and helps us make better decisions, researchers in the field are now exploring how the brain responds to penalties. Dayan, at University College London, says the smart money is on another brain signalling chemical, serotonin. "That may be involved in punishment," he says.

Global CO_2 forecast

AND now for the carbon dioxide forecast: levels of this gas in the atmosphere will rise by 2.5 parts per million to average 408 ppm in 2017, the highest level for at least 800,000 years.

And the monthly average could exceed 410 ppm for the first time ever during this year's peak in May. The precise projection is 409.86 plus or minus 0.61 ppm.

It is just four years since the peak level of CO_2 first exceeded the symbolic milestone of 400 ppm. If the gas's concentration keeps rising at this rate, it will reach twice its pre-industrial level well before the end of the century. A doubling of CO_2 is likely to warm the planet by about 3°C in the following decades and by up to 6°C over the next few centuries.

The prediction of a 2.5 ppm rise this year is the first official CO_2 forecast by the UK's Met Office. "Now we're getting happier with the method, we are going to start to do it as a routine forecast every year," says Richard Betts, who leads research into climate impacts at the Met Office's Hadley Centre.

The forecast is specifically for Mauna Loa in Hawaii, where CO_2 levels have been monitored since the 1950s, providing plenty of fodder for forecasters. Levels at other sites can differ slightly.

Women's health counter-strike

THE Trump administration's efforts to restrict the availability of abortions around the world have been dented – but not defeated – by international pledges of funding for organisations promoting women's health.

On 2 March, representatives from 50 countries met in Brussels at the invitation of She Decides, an initiative to push back against the so-called global gag rule, which denies US federal funding for non-governmental organisations that provide or discuss abortions. Around $600 million of funding a year will be lost.

So far, just over $190 million has been pledged, which will be directed to international aid groups whose funding is threatened. Of the 12 countries who offered donations, Finland and Sweden pledged the most with around $21 million each. The Bill & Melinda Gates Foundation pledged $20 million over four years and an anonymous US donor pledged $50 million.

Since its inception in 1984, the gag rule – officially called the Mexico City policy – has been alternately imposed and repealed as control of the White House changes hands. The Trump administration reinstated it in January, and further expanded it to include all global health programmes funded through US government agencies.

Conference chairs say they hope to reconvene at future women's and human rights meetings, including the UN General Assembly in September.

TIM BOYLE/GETTY IMAGES

At risk again

60 SECONDS

Dodge a moon

NASA's MAVEN spacecraft had to change its orbit to avoid the Martian moon Phobos. On 28 February, the orbiter performed a rocket burn to change its speed by about 0.4 metres per second, shifting its trajectory enough to dodge a predicted collision with Phobos a week later.

Lightning on show

The US National Oceanic and Atmospheric Administration's orbiting lightning mapper just sent back its first images. Launched in November, the instrument continuously monitors the western hemisphere for lightning. This will give forecasters a window into how storms form and strengthen, and will assist firefighters in dry, wildfire-prone parts of the US.

Rain catapults microbes

When water hits the ground, bacteria take to the skies. High-speed footage reveals that raindrops can carry soil microbes into the air in tiny water droplets. It's not yet clear if this can disperse bacteria long distances or cause outbreaks of disease (*Nature Communications*, doi.org/b2q9).

Avoidable kids' deaths

Every year, 1.7 million under-5s die because of air pollution, unsafe water, poor hygiene and other problems of unhealthy environments. A World Health Organization report says clean water and cooking fuels could save many of these infants' lives by preventing diarrhoea, malaria and pneumonia.

Uber for hospitals

Non-emergency National Health Service patients could soon be sent to hospital appointments in Uber taxis, after London's Barts Health NHS Trust and social care firm Cera struck a deal. Patient carers will also be able to use the service in an effort to make transport provision more efficient.

Dormant Zika is back for round two

Mosquito season is coming, and the virus has some surprises in store

Jessica Hamzelou

ZIKA virus is set to return to the fore once the mosquito season starts again in the coming months, and it looks like it could spread further and do more damage than we thought.

Cases of Zika virus – and the neurological disorders it causes in babies – have been declining across the Americas in recent months, in part because of a drop in mosquito numbers during winter. There is also evidence that people in affected countries are developing immunity to the virus – although this may be short-lived if the virus evolves, or as newly vulnerable people are born or move to affected areas.

Yet while Zika may have gone quiet, research into the virus has continued in earnest. It was assumed that only a few species of mosquito could spread Zika, including *Aedes aegypti* and *Aedes albopictus*, found in tropical regions across the globe. But now it seems many more species could carry the virus, including 26 not previously considered a threat (*eLife*, doi.org/b2ps). Some are found in more northerly reaches of the US, to which Zika hasn't yet spread. The onset of warmer weather in the US could bring many more cases, as mosquitoes begin to breed and feed on blood.

Meanwhile, other means of transmission may further propagate the virus. Gabriela Paz-Bailey and her colleagues at the US Centers for Disease Control (CDC) have been investigating how long Zika can remain in human body fluids. It seems to linger in semen the longest; of the 55 infected men who have donated semen samples so far, half had cleared the virus within a month, but 5 per cent still had traces three months later. Bailey presented her findings at the Conference on Retroviruses and Opportunistic Infections in Seattle last month.

"Only a handful of sexually transmitted cases have been identified so far, but there are probably more"

Although only a handful of sexually transmitted cases have been identified, there are probably more out there, says Laurent Hébert-Dufresne at the Santa Fe Institute in New Mexico. What's more, the discovery that Zika survives for so long in semen means that men who have sex with men are at particular risk of becoming infected and spreading the virus. They are also less likely to be tested for the virus, Hébert-Dufresne adds.

Testing is offered during pregnancy as babies born to infected women are at risk of microcephaly, which causes them to have small heads, along with nervous system disorders. Last week, the CDC reported a 20-fold increase in such birth defects in Massachusetts, North Carolina and Georgia. Even babies that appear healthy at birth can develop neurological problems down the line, and it may be a while before the full impact of the virus is known.

Those aren't the only possible side effects of Zika infection in the womb. Problems with vision, limb development, hearing, digestion and breathing are beginning to emerge in babies exposed to Zika. Around 42 per cent of infected pregnant women have babies with at least one of these issues (*JAMA Pediatrics*, doi.org/b2qz).

"It does more than microcephaly," says Catherine Spong, deputy director of the US National Institute of Child Health and Human Development.

Zika may have consequences for adults, too. A handful of cases of Guillain-Barré syndrome, in which a person's immune system attacks their own nerves, have been reported. Research in mice also suggests the virus may affect the growth of neurons in adult brains, and potentially shrink the testicles.

Other question marks surround the presence of the virus in South East Asia; we don't yet know if it is as dangerous, or how it might spread. "We see Zika there, but we're not sure if it's the same, or if there could be larger outbreaks," says Alain Kohl at the University of Glasgow in the UK.

Globally, efforts are under way to control the virus by destroying mosquito habitats, killing the insects or using genetically modified insects to drive them into oblivion. Several groups are also working on vaccines for the virus, one of which appears to protect mice and monkeys.

For now, though, there are no treatments available. "Until we get to a situation where we can treat it effectively, we need to be worried about it," says Kohl. ■

UESLEI MARCELINO/REUTERS

Zika is especially bad for babies

First supergiant stars had giant black hole kids

THE earliest supermassive black holes may have been big to start with. If so, it would help explain the recent detection of such beasts within a billion years of the big bang.

Supermassive black holes take a long time to build, so we expect to see only a few in the early universe. The more of them we find, the less likely it is that they all grew the way most modern black holes do, by devouring dust and gas.

"You can have a few black holes that accrete at the maximum possible rate for a very long time, but not all of them," says Marco Ajello at Clemson University in South Carolina.

In principle, though, stars can gain mass faster than black holes. Joseph Smidt at the Los Alamos National Laboratory in New Mexico and his colleagues say this could explain the presence of supermassive black holes so early on.

If a star of around 100,000 solar masses collapses, it could form a substantial black hole right away. Fed by streams of cold gas, that black hole could grow at a more stately pace to reach a billion solar masses within the first billion years of the universe.

Smidt and his colleagues made the most detailed simulation yet of this "direct collapse" scenario. It produced the black holes we observe, as well as the ionised gas around them and the star formation rate in their host galaxies (arxiv.org/abs/1703.00449).

"Other results showed that you can get the right mass - but black holes are more than mass," says Smidt. "We've shown that we can match several other independently observed features."

However, it's still possible that early mergers of smaller black holes also played a part in forming supermassive ones. And so far, astronomers have not directly spotted supergiant stars in the young universe. But if they exist, the James Webb Space Telescope should be able to see them after its launch next year. Leah Crane ■

DDP IMAGES

I feel ill, pass the poplar

Neanderthal Paleo diet was meat, veg and drugs

THE real Paleo diet might have depended on where you lived. Neanderthals living in prehistoric Belgium enjoyed their meat – but those in what is now northern Spain seem to have eaten an almost exclusively vegetarian diet. This is according to new DNA analysis that also suggests sick Neanderthals could self-medicate with naturally occurring painkillers and antibiotics.

Our extinct cousins didn't clean their teeth very well, which is good news for archaeologists. Over time, plaque built up into a substance called dental calculus, which still clings to their teeth.

Now Laura Weyrich at the University of Adelaide, Australia, and her colleagues have shown that dental calculus carries ancient DNA that can reveal what Neanderthals ate and which bacteria lived in their mouths.

The team focused on three Neanderthals – two 48,000-year-old specimens from El Sidrón in Spain and a 39,000-year-old specimen from Spy in Belgium. What they found suggested that the Spy Neanderthal often dined on woolly rhinoceros and sheep, while the El Sidrón Neanderthals ate moss, bark and mushrooms – but, apparently, no meat (*Nature*, DOI: 10.1038/nature21674).

"That was really a surprise to us," says Weyrich. "I think the assumption has always been that

"The sick teenager seems to have medicated with naturally occurring painkillers and penicillin"

Neanderthals had diets based [on] heavy meat consumption."

There is a certain irony to the finding, says Paola Villa at the University of Colorado Museum, Boulder, given that cut marks on Neanderthal bones found at El Sidrón are often interpreted as evidence of cannibalism. "They may have had a diet of mostly plants but paradoxically they provided meat to the Neanderthals that killed them," she says.

Other researchers say it makes sense that Neanderthals would have eaten a plant-rich diet if there was less opportunity to hunt in their local environment. "To imagine otherwise would be a bit simplistic," says Amanda Henry at Leiden University in the Netherlands .

But Henry cautions against taking the findings too literally. "The overwhelming component of the DNA is from the oral bacteria," she says – only about 0.3 per cent of it comes from the animals, plants and fungi that the Neanderthals ate. "To suggest they are recovering the entirety of the diet here is a bit premature."

It's likely that the Spy diet did contain plants as well as meat, says Luca Fiorenza at Monash University in Clayton, Australia, because humans, and probably Neanderthals, can't survive on a diet exclusively based on animal protein.

One of the two El Sidrón individuals – a teenage boy – is known to have had a large dental abscess. The new DNA analysis shows he had a diarrhoea-causing gut parasite, too. Previous studies have suggested the teenager was eating plants with anti-inflammatory properties. The new study finds DNA from poplar plants, which are known to contain the natural painkiller salicylic acid. But that may not have been his only medication: there was DNA from *Penicillium* fungus – the source of penicillin – in his dental calculus.

It is difficult to say for sure whether Neanderthals consumed the fungus deliberately for its medicinal properties. *Penicillium* grows naturally on plant material as it goes mouldy, so they could have eaten it by coincidence. But Weyrich points out that the *Penicillium* was only found in the dental calculus of the sick teenager, and not in the calculus of the second El Sidrón individual, who is thought to have led a healthy life. "They might have had some knowledge that mouldy grains could help them when they were sick – we just don't really know," she says. **Colin Barras** ■

Brain signals show robots their errors

Matt Reynolds

TRY again robot, you're doing it wrong. A brain-computer interface lets people correct robots' mistakes using the power of their thoughts.

The system uses electroencephalography (EEG) to measure a person's brain signals as they watch a robot work. When it detects a signal suggesting the person has witnessed a mistake, it alters the robot's course. The system could be used to let humans control industrial robots simply by observing them.

"We're taking baby steps towards having machines learn about us, and having them adjust to what we think," says Daniela Rus at the Massachusetts Institute of Technology.

Rus and her team used an EEG headset to measure how the electrical signals in five volunteers' brains responded as they watched a robot reach towards one of two LED lights. In each test, one LED was randomly selected as the "correct" one. If the volunteer saw the robot reaching for the wrong one, the headset detected this in their EEG readings and sent a signal to the robot, making it reach for the other. The industrial robot, known as Baxter, was made by Rethink Robotics in Boston, Massachusetts.

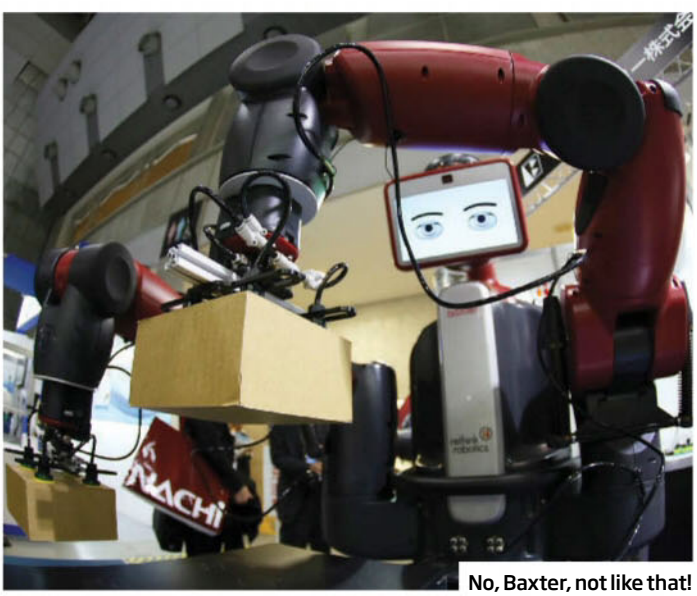
When we witness a mistake, we generate brain signals called "error potentials", says Ricardo Chavarriaga at the Swiss Federal Institute of Technology in Lausanne. Error potentials have a distinctive shape, which makes them a good choice for controlling a robot, he says.

In 70 per cent of cases where the volunteers noticed that the robot was making a mistake, the system correctly recognised an error potential and altered the robot's actions. The result was similar on a task in which volunteers watched Baxter sort paint bottles and reels of wire into different boxes.

An advantage of using error potentials is that people don't need any training to use the system, says Andres Salazar-Gomez at Boston University, who also worked on the project. Other EEG-controlled devices require humans to think about specific words or movements to generate commands.

Rus says error potentials could be used in autonomous cars to alert the car when its passenger has spotted something its sensors haven't noticed. If a passenger hears an ambulance siren, for example, their brain signals could put the car on high alert.

Adding learning algorithms to error potential systems could also help robots make better decisions over time. Robots are usually programmed to perform specific actions or trained to accomplish tasks using huge data sets, but error potential systems could help us teach robots in a way that comes more naturally to humans, says Rus. "In the future it will be wonderful to have humans and robots working together on the terms of the human." ■



YAMAGUCHI HARUYOSHI/GETTY

No, Baxter, not like that!

OCD makes it harder to learn things are safe

THE thoughts and urges that are characteristic of obsessive compulsive disorder (OCD) may be caused by an inability to distinguish between safe and risky situations.

People with OCD feel they have to carry out certain actions, such as washing their hands again and again, or repeatedly checking the oven has been turned off. Those worst affected may spend hours every day on these compulsive "rituals".

To find out more about why this happens, Naomi Fineberg of the Hertfordshire Partnership University NHS Foundation Trust in the UK and her team trained 78 people to fear a picture of an angry face. They did this by sometimes giving the volunteers an electric shock when they saw the picture. About half the group had OCD.

The team then tried to "detrain" the volunteers, by showing them the same picture many times, but without any shocks. Judging by how much the volunteers sweated when they saw the picture, the team found that people without OCD soon learned to stop associating the face with the shock, but people with the condition remained scared.

Brain scans revealed that the people with OCD had less activity in their ventromedial prefrontal cortex, a brain area involved in signalling safety and predicting rewards (*PNAS*, DOI: 10.1073/pnas.1609194114).

Fineberg says the study shows that people with OCD aren't always more fearful – the groups sweated the same amount during training. However, people with OCD sweated more than the others during detraining.

This fits with why situations that trigger OCD rituals often have some potential for danger. "They're not usually off-the-wall bizarre," says Fineberg. "The obsessions are the sorts of things that most people would understand as being rational but exaggerated – for example, the need to wash your hands after going to the toilet."

"Most people would understand OCD obsessions as being rational but exaggerated"

Exposure response prevention therapy is usually used to treat OCD. It involves trying to experience triggers without doing the associated rituals – such as touching a toilet seat without washing your hands afterwards – to learn that nothing bad happens.

The new findings may explain why people with OCD find this approach so difficult, says Fineberg. "The bit of their brain that should be telling them it's safe isn't working. Now we can say to them this is why it's taking so long and we should stick with it." Clare Wilson ■

Interval training rejuvenates ageing cells

HIIT it! We're often told that exercise is the best medicine, and it now seems that regular high intensity interval training (HIIT), in particular, is great for reversing the declining ability of our cells to generate energy.

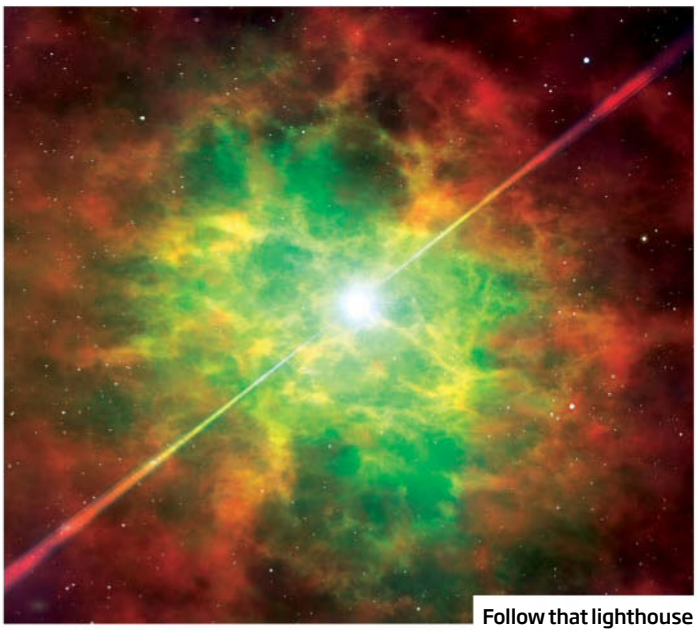
HIIT involves short bursts of very intense activity, interspersed with recovery periods of lower-intensity exercise. Sreekumaran Nair at the Mayo Clinic in Rochester, Minnesota, and his colleagues assigned groups of people aged between 18 and 30 and between 65 and 80 to three months of interval training, weight training or a combination of the two. Muscle biopsies were taken before and afterwards to measure the impact of these regimes on their cells.

Interval training boosted the ability of the mitochondria within cells to generate energy by 69 per cent in older volunteers and by 49 per cent in the younger group.

Mitochondrial activity declines with age, which may aggravate fatigue and reduce the size and ability of muscles to burn excess blood sugar – a risk factor for diabetes. But this decline was halted and even reversed in the older interval-training group. "After three months of interval training, everything converged towards what we saw in young people," says Nair.

Interval trainers also saw surges in lung, heart and circulation health. The amount of oxygen they could inhale and consume at full tilt rose by 28 per cent in the younger group and by 17 per cent in the older group. There was no corresponding change among weight trainers, although combination training boosted oxygen consumption by 21 per cent among older exercisers (*Cell Metabolism*, DOI: 10.1016/j.cmet.2017.02.009).

Nair says the greatest benefit from weight training was the addition of new muscle mass, but it triggered none of the mitochondrial and respiratory benefits. The combination regime generally produced intermediate results. Andy Coghlan ■



MARK GARLICK/SCIENCE PHOTO LIBRARY

Follow that lighthouse

Fuzzy pulsars could help unmask quantum gravity

WANT to get to the bottom of one of the biggest mysteries in science? The best way might be to catch sight of a fast-spinning stellar corpse.

General relativity, which describes massive objects like black holes, and quantum mechanics, which governs subatomic particles, are tremendously successful in their own realms. But no one has yet come up with a way to unite them.

A theory of quantum gravity is one of the most sought after in physics (see "When loops become strings", page 28). Several candidates exist, but current Earth-based experiments can't test them directly. Now, Michael Kavic at Long Island University in New York and his colleagues have devised a cosmic test. Their apparatus: a binary system made up of a black hole and a pulsar.

Only tens of kilometres across, a pulsar forms when a star at least eight times the mass of the sun runs out of nuclear fuel and explodes as a supernova. What remains is a rotating object that also emits beams of radio waves from its magnetic poles.

Those poles seldom coincide with its rotational axis, meaning a suitably placed observer will see the radio signal "flashing" past with near-perfect regularity, like a lighthouse beam. This eerie repetition meant that when pulsars were discovered in the 1960s, they were thought to be alien beacons. That regularity also makes them good quantum gravity probes, says Kavic.

"If they do observe something, that would be big. It would be a whole new field of study"

Some theories, like one proposed by Steven Giddings at the University of California, Santa Barbara, in 2014, predict that the black hole's internal state can be linked to quantum fields outside, in the black hole's "atmosphere". This coupling would show up as fluctuations in the space-time around the black hole.

If a pulsar is orbiting it, its radio signal will look normal whenever the pulsar passes in front of the black hole. But when the black hole eclipses the pulsar, the radio beam will reach us via a region of space-time that is steeply curved by the immense gravity.

General relativity predicts that as a result, the signal will arrive early or late at our radio telescopes, with the discrepancy altering smoothly as the pulsar orbits. Quantum gravity, however, says the fluctuating space-time will alter the signal in irregular ways – such that a graph of the arrival times will look "fuzzy".

Studying a fuzzy pulsar could confirm Giddings's version of quantum gravity. Kavic and his colleagues propose searching for pulsar-black hole pairs using planned instruments such as the Square Kilometre Array and the Event Horizon Telescope (arxiv.org/abs/1607.00018v3).

Crucially, this type of measurement has been done before: astronomers have examined pulsars in binary systems with neutron stars, which are stellar corpses that don't emit a lighthouse-like radio beam. "We know how to do this," Kavic says.

Those observations failed to detect any departures from general relativity. But black holes are more massive than neutron stars, so warp space-time more dramatically and could show a measurable effect.

Some theorists are sceptical. Samir Mathur at Ohio State University in Columbus says the test might just not work. The quantum effects would need to extend far enough outside the event horizon – the surface inside of which matter can't escape the black hole – to affect those pulsar beams that skirt the black hole. Even Giddings says there's some luck involved in finding a binary that fits the bill.

That said, Mathur feels the idea is a good one. "If they do observe something, that would be big," he says. "It would be a whole new field of study." **Jesse Emspak** ■

RADIUS IMAGES / ALAMY

Blame it on the sunshine

Brighter sky secret to bumper crops

Chelsea Whyte

THE US corn belt is having its moment in the sun. Corn yields have been rising there ever since the mid-1930s thanks to improved agricultural technologies. But it now turns out that improvements to fertilisers, pesticides and equipment aren't the only things maintaining the increase over the past 30 years.

Instead, 27 per cent of the increase is due to a phenomenon called solar brightening over the northern states that make up the corn belt. This happens when the air is clear and more light can reach the ground. Places like China and India have seen solar dimming over the past few decades, but since the mid-1980s, the US corn belt has brightened significantly. The exact causes of solar brightening aren't yet certain.

"There's a question to what extent it's pollution-driven or to what extent it's natural variation in cloudiness and cloud properties," says Martin Wild, a climate scientist at ETH Zurich in Switzerland who wasn't involved in the study.

Crop physiologists Saratha Kumudini and Matthijs Tollenaar created a computer model looking at corn yields over the 30 years up to 2013. They included data such as fertiliser use and how much solar radiation reached the ground during the 60 days following plant pollination.

To their surprise, they found that changes in the sun's radiation accounted for a quarter of the overall increase in corn yield.

"A quarter of yield gains in US corn have come from solar brightening, and not from better technology"

"Solar radiation is the driving force for photosynthesis," says Kumudini. "You need to convert light energy into biomass or glucose and therefore this is an important driver for yields."

Without solar brightening, we would need to expand the area needed for corn production from 90 million acres to 135 million acres to produce the yields seen today, Tollenaar says.

Solar brightening hasn't been incorporated into agricultural or climate models before, Kumudini says. "They're assuming, like we all did, that investment in agricultural technologies would continue and we would continue to have these yield improvements year after year," she says.

That may not be the case. Tollenaar says we haven't reached the limit of crop yields yet, but without solar brightening, the increases would be far lower – a worrying prospect. There is no telling how long the effect will last, he says.

"Corn is in almost everything," Tollenaar says. "It's the cheapest renewable energy source we have and that's the reason why it's so dominant. Corn is so efficient at converting solar energy to usable energy." Corn is the basis of much of the world's feedstock and contributes to sweeteners, oils, industrial alcohol and fuel ethanol. As the world's population increases, we will need to produce more corn to feed livestock as well as humans, says Tollenaar.

If the rate of solar brightening declines thanks to cleaner air, the team says climate change studies that use historical rates of yield gain will overestimate future yields in regions where solar brightening has played a role. ■

Device turns your mood into friend's actions

IF YOU'RE happy and you know it, clap someone else's hands. A muscle stimulation system aims to evoke empathy by triggering involuntary hand gestures in one person that mirror mood changes in another.

"If you're moving in the same way as another person you might understand that person better," says Max Pfeiffer at the University of Hannover in Germany.

Pfeiffer and his team wired up four people to an EEG machine that measured changes in the electrical activity in their brains as they watched film clips intended to provoke three emotional responses: amusement, anger and sadness. Each of these "emotion senders" was paired with an "emotion recipient" who wore electrodes on their arms that stimulated their muscles and caused their arms and hands to move when the mood of their partner changed.

The gestures they made were based on American Sign Language for those emotions. To express amusement, the volunteers raised an arm, to express anger they raised an arm and made a claw gesture, and to express sadness they slowly slid an arm down their chest.

The system could be used to emotionally connect couples in long-distance relationships, says Pfeiffer. It could even be linked to social media to share emotions with multiple friends simultaneously.

But Brian Parkinson at the University of Oxford is sceptical that gestures can evoke a single emotion and says it wouldn't always be desirable to experience someone else's feelings. "Sometimes a more detached form of sympathy is better for communication," he says.

The researchers will present their work at a human-computer interaction conference in Denver in May. Next, Pfeiffer plans to use electrical muscle stimulation to make the arm movements of one person mimic those of their partner. Matt Reynolds ■

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AI turns phone into Parkinson's test

Timothy Revell

DEEP learning could reveal new insights into Parkinson's disease. A smartphone app that uses AI to test symptoms in just minutes aims to help monitor the disease's progression more closely, as well as uncover how lifestyle factors may affect symptoms.

"There's very little understanding as to how Parkinson's arises, and patients say that every day the condition is different," says George Roussos at Birkbeck, University of London. People report symptom changes related to everything from exercise to socialising to diet, but it's not clear how these factors interact. "To understand these differences, we need to monitor the condition regularly, in a quick and easy way, over a long period of time," says Roussos.

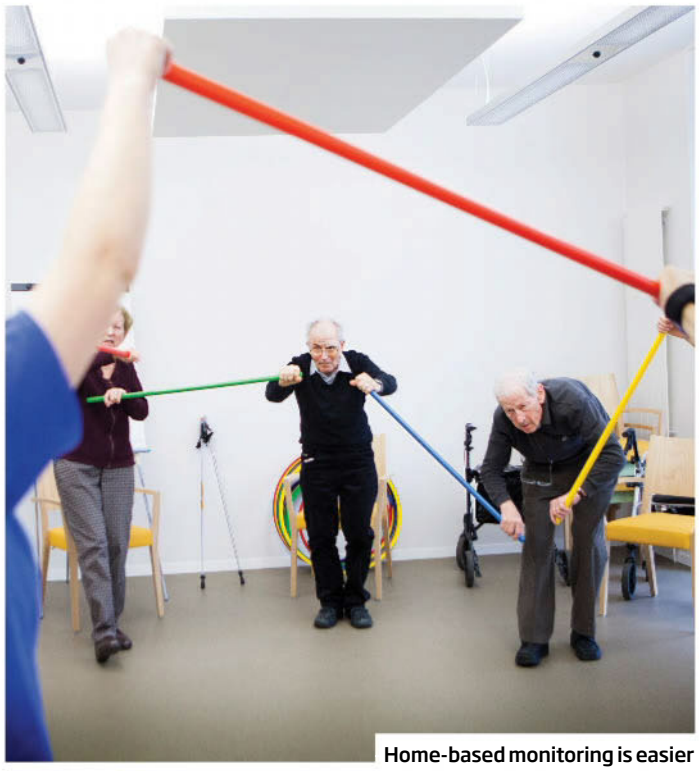
People with Parkinson's may only see a specialist once or twice a year. With their Android app, called CloudUPDRS, Roussos and his colleagues want to make it easier for people to track symptoms at home, and to flag potential problems earlier.

Similarly to how a clinician would conduct a Parkinson's severity test, the app uses both self-assessment questions and physical tests that exploit a smartphone's sensors. For example, one test measures tremors by asking the user to hold the phone flat in their hand.

A deep learning feature can distinguish between good and bad data – like the smartphone being knocked. If someone performs the wrong action or the smartphone sensor picks up meaningless vibrations, the app simply ignores it.

After being trained to recognise these differences using data labelled by experts, the system discards bad data with an accuracy of 92.5 per cent. "Then as soon as we've registered enough good data, the user is told to stop," says team member Cosmin Stamate.

The app also offers a personalised "quick test" option. It measures only three symptoms that are most indicative of the individual's overall performance, and can reduce assessment times from 25 minutes to less than 4 minutes. The team will present their work later this month at a computing conference in Hawaii.



AMELIE-BENOIST/BSIP/SPL

Home-based monitoring is easier

"I have to admit, I'm really impressed with the accuracy," says Dragana Miljkovic at the Jožef Stefan Institute in Ljubljana, Slovenia, who uses machine learning to find patterns in Parkinson's data. This could really help identify important features of Parkinson's disease, she says.

A clinical trial of the app, which is certified as a medical device by the UK's Medicines and Healthcare Products Regulatory Agency, is already under way. Since October, 60 people with Parkinson's have been using the app to assess their symptoms every 2 hours. Experienced clinicians perform assessments on the same people every two weeks for comparison.

"The overall aim is to empower people with Parkinson's," says Stamate. "This app can help them find the things that improve or worsen their symptoms." ■

Foam sucks up and releases oil like a sponge

OIL begone! A new material can absorb 90 times its own weight in spilled oil and then be squeezed out like a sponge and reused. It could make it easier and greener to clean up oil spills.

Most commercial products for soaking up oil, called sorbents, are only good for a single use before they are incinerated together with the oil. But the oil sponge created by Seth Darling at Argonne National Laboratory in Illinois and his colleagues is different. It consists of a simple foam made of polyurethane or polyimide plastics and coated with "oil-loving" silane molecules for capturing oil.

In lab tests, the team found that when engineered with just the right amount of silane, the foam could repeatedly soak up and release oil without significantly changing its capacity (*Journal of Materials Chemistry A*, doi.org/b2j8).

To see if it would work outside the lab, the team dragged the sponges behind a pipe spewing crude oil in a large pool specially designed for practising emergency responses to oil spills. They put the sponges through a wringer to remove the oil and then repeated the process, carrying out many tests over multiple days.

"Our treated foams did way better than either the untreated foam that we brought or the commercial sorbent," says Darling.

"This could be a simpler and less wasteful way of cleaning up oil spills if it can be scaled up"

The group hopes to scale up production and thinks this material could be used for spills near shores, where clean-up is particularly difficult.

"In an ideal world, you would have warehoused collections of this foam sitting near wherever there are offshore operations... ready to go when the spill happens," says Darling.

"I see it as a major advance in cleaning small spills and spills close to coastlines where dispersants cannot be used easily," says Vijay John at Tulane University in New Orleans, Louisiana. Carolyn Wilke ■

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Embryos grown in dish without eggs

Andy Coghlan

ARTIFICIAL mouse "embryos" grown from stem cells in a dish could help unlock secrets of early development and infertility that have until now evaded us.

"They are very similar to natural mouse embryos," says Magdalena Zernicka-Goetz at the University of Cambridge. "We saw that the cells could self-organise without our help."

This is the first time something resembling an embryo has been made from stem cells without using an egg.

Zernicka-Goetz's team used embryonic stem cells, the type of cells found in embryos that can mature into any type of tissue in the body. The trick was to grow these alongside trophoblast stem cells, which normally produce the placenta. By growing these types of cell separately and then combining them in a gel matrix, the two mixed and started to develop together.

After around four-and-a-half days, the embryos resembled normal mouse embryos that were about to start differentiating into various tissues and organs (*Science*, doi.org/b2j7).

The embryos have been engineered so their cell types fluoresce in different colours, providing insights into how these cells move during crucial changes.

Mammal embryos start as a symmetrical ball, then elongate, form a central cavity and start developing a type of cell layer called mesoderm, which ultimately goes on to form bone and muscle. "We didn't know before how embryos form this cavity, but we've now found the mechanism for it and the sequential steps by which it forms," says Zernicka-Goetz.

"The work is a great addition to the stem cell field and could be extended to human stem cells," says Leonard Zon at Boston Children's Hospital in Massachusetts. "Using the system, the factors that participate in embryo development could be better studied and this could help us understand early embryogenesis."

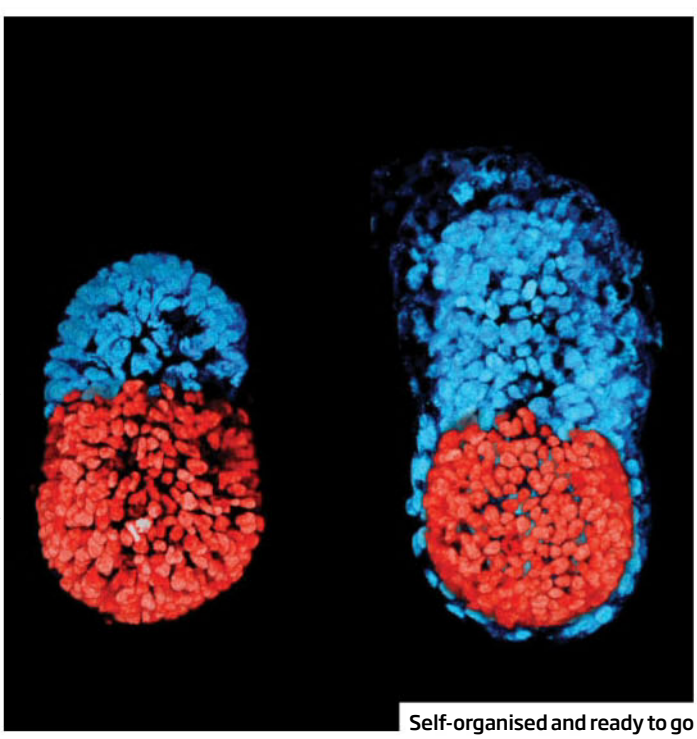
Robin Lovell-Badge at the Francis Crick Institute in London points out that the embryos lack two other types of cell layer required to develop the bodies' organs: ectoderm and endoderm. Zernicka-Goetz hopes these will develop in future experiments involving a third type of stem cell.

"They are very similar to natural mouse embryos. We saw the cells self-organise without help"

If a similar feat can be achieved using human stem cells, this could tell us much about our earliest stages of development. Current research is limited by the number of excess embryos donated from IVF procedures. But the new technique could produce a limitless supply of embryos. Disrupting their development may help us understand miscarriage.

The work probably won't lead to fully lab-grown babies. Lovell-Badge says the artificial embryos are unlikely to develop in vitro much further than this stage, as they would soon need the supply of nutrients and oxygen that normally comes from the mother.

"We're not planning to make a mouse in the lab using stem cells," says Zernicka-Goetz. But her team now plans to add the third type of stem cell, which normally makes a type of fetal membrane, to their experiments. She is hopeful that adding these cells will allow the embryos to survive long enough to study the beginnings of organs such as the heart. ■



SARAH HARRISON AND GAELLE RECHER, ZERNICKA-GOETZ LAB, UNIVERSITY OF CAMBRIDGE

Self-organised and ready to go

WW2 bomb craters full of rare aquatic life

SOME bombs can help create life. A rich mix of rare saline water species has been found thriving in ponds formed in second world war bomb craters in Hungary. This backs the case for conserving such artificial ponds, especially as natural ones are being lost across Europe to make way for farmland and city growth.

"These 'wartime scars' might be unnatural, but still can be regarded as valuable bioreserves – just like sunken warships or submarines scattered in the ocean that turned into coral reefs giving refugee to many species," says Csaba Vad of WasserCluster Lunz, a research centre in Austria.

A series of miscalculated bombing raids aimed at an airport created more than a hundred ponds near the village of Apaj in central Hungary. The bombs fell on a type of habitat called sodic meadows, which give rise to a saline environment when covered in water. In all, 274 species, including turtles and water beetles, were found in the 54 bomb crater ponds sampled.

Among the globally rare and near-vulnerable organisms identified were algae (*Halamphora dominici*) that, apart from central Europe, are only found in Chilean salt lakes, and an endemic fairy shrimp (*Eubranchipus grubii*) only recorded twice in the past 25 years in Hungary (*Biological Conservation*, doi.org/b2j6).

The biodiversity was comparable with that of naturally occurring saline ponds called soda pans that are unique to this region of Europe.

"[Crater ponds] are very understudied habitats, even though there are many bomb craters in the old war zones of Europe," says Vad.

Orsolya Mile of Kiskunsági National Park in Hungary agrees that the Apaj saline ponds could be important microhabitats, yet says their value will never match that of larger, natural ponds. But as 80 per cent of natural soda pans here are already gone, the crater ponds could still be worth protecting, says Vad. Kata Karáth ■

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MICHAEL NICHOLS/NATIONAL GEOGRAPHIC CREATIVE

Wild elephants get the least sleep of any mammal

IT'S another sleepless night in the savannah. Previous studies looking at the sleep habits of captive animals found that elephants sleep for 3 to 7 hours a day. But faced with danger and pressure to find food, their wild counterparts tend to sleep less.

Paul Manger at the University of the Witwatersrand in Johannesburg, South Africa, and his colleagues monitored sleep in elephants in northern Botswana's Chobe National Park. They fitted motion sensors to their trunks, a part of the elephant's body that is rarely idle while the animal is awake. "We figured when it hadn't been used for 5 minutes, the elephant was probably asleep," says Manger.

Two matriarchs monitored for 35 consecutive days slept for an average of 2 hours each night, less than any other mammal, and not in a single slumber but in four or five short bursts. They mostly slept between 1 and 6 am, snoozing in different places each night (*PLoS One*, doi.org/b2jg).

On five occasions, they got no shut-eye at all for up to 48 hours. The animals travelled far during these periods, venturing around 30 kilometres possibly to evade lions or poachers. They didn't appear to compensate with extra sleep later on. Although the study involved just two animals, Manger thinks it offers a reasonable reflection of wild elephants' sleep habits.

What makes the dark net so resilient?

THE internet is amazingly robust, but it can still suffer big outages. The dark net – the internet's hidden underbelly, invisible to search engines – is less vulnerable, and network analysis tells us why.

Think of each site or server on the regular internet as a node, connected to numerous nodes in turn. Take out a node or two and the network continues to function just fine. But take out many at once, as happens in a distributed denial of service attack, and failure can cascade through the network. Hubs of particularly well-connected nodes increase this risk.

Manlio De Domenico and Alex Arenas of Rovira i Virgili University in Spain found that the dark net's unique topology makes it more resilient. It uses "onion routing", a way of relaying information that hides data in many layers of encryption. The information is bounced through intermediary nodes before being delivered to the desired location, and well-connected nodes are also more dispersed. These stop attacks from spreading so easily.

Through their analysis, the researchers found that an attack would need to hit four times as many nodes to cause a cascading failure on the dark net (*Physical Review E*, doi.org/b2hf).

Vines use sense of 'taste' as they climb

VINES are antisocial climbers. They send out tendrils to "taste" nearby plants, identifying and then steering clear of similar varieties.

Yuya Fukano at the University of Tokyo in Japan has shown that some vines can sense chemicals, such as oxalate. If they don't like the taste of the plant to which they are tethered, they will uncoil themselves and retreat. Fukano found that tendrils of *Cayratia japonica* only stayed wrapped around other plants if they were non-vine species like shrubs. When presented with other *C. japonica* plants, the tendrils held on for less than 2 hours.

Vines probably avoid climbing up other vines because they are flimsier than other plants, says Fukano. Moreover, it is easier to compete with a non-climbing plant for light and space, he says (*Proceedings of the Royal Society B*, doi.org/b2jh).

Wasp stubbornness is hereditary

ANNOYING and stubborn. That's how most of us think of the wasps that often buzz around our food.

But there may be more to wasp personality than this, says Colin Wright at the University of California, Santa Barbara. His team predicted the behaviour of paper wasps six weeks before they hatched – by observing the queen. This suggests wasps get their personalities from their mothers, either by nature or nurture (*Animal Behaviour*, doi.org/bzx6).

The team found that the queen's obstinacy in the face of intrusion was reflected in her colony's response to simulated predators. The differences between how colonies respond to various threats in the wild may affect their survival, says Wright.

App acts like Shazam for art

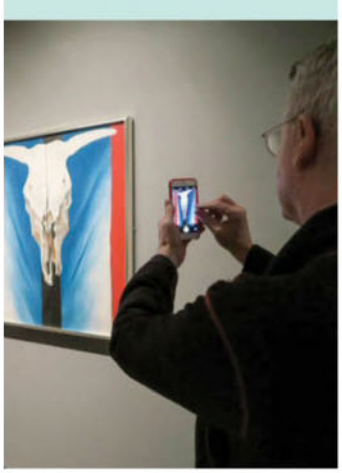
TAKING a souvenir home from an art gallery no longer has to mean a trip to the gift shop. A new app will let you scan a painting with your smartphone camera to learn more about it and save a digital copy.

The app, called Smartify, uses image recognition to identify artworks, which users can then add to their digital collection. Smartify co-founder Thanos Kokkiniotis describes it as a combination of music discovery service Spotify and music recognition app Shazam – but for visual works.

The app will launch in May for selected artworks at the Louvre in Paris and New York's Metropolitan Museum of Art, and for all the art at the Rijksmuseum in Amsterdam and the Wallace Collection in London.

Creating an app that can recognise paintings is relatively easy because most galleries already have digitised versions of their collections, says Kokkiniotis. So it is just a matter of matching up what's seen through the smartphone camera with these databases of digitised artworks. The challenging part is convincing galleries to let the app access this information.

Galleries that sign up will be able to access anonymised demographic data about those who use Smartify and the artworks they interact with, which could assist in their marketing.



PATTI MCCONVILLE/ALAMY STOCK PHOTO

Multiple sclerosis and psoriasis linked to higher dementia risk

PEOPLE with autoimmune disorders may be 20 per cent more likely to develop dementia, according to an analysis of 1.8 million hospital cases in England.

For example, people who have multiple sclerosis – caused by a malfunction of the immune system – had almost double the normal risk of getting dementia.

Other autoimmune disorders were also associated with rises in dementia risk. The skin condition psoriasis was linked to a 29 per cent increase, and it was 46 per cent higher in people who have lupus erythematosus, a disorder that involves rashes and fatigue (*Journal of Epidemiology & Community Health*, doi.org/b2jk).

However, people with rheumatoid arthritis, another autoimmine disorder, had a 10 per cent lower risk of dementia. This could be because many people with arthritis take drugs like aspirin and ibuprofen, which may tame inflammation that could otherwise contribute to causing dementia. "They reduce inflammation and that could explain why there's less spillover," says Michael Goldacre at the University of Oxford, who led the study.

There was also a strong link between autoimmune disease and heart and circulatory problems, which may explain some of the increased dementia risk. Vascular dementia involves poor blood flow in the brain, and the team found that people with autoimmune diseases are 29 per cent more likely to develop this form of dementia, compared with only a 6 per cent increase in Alzheimer's risk.

Hidden craters buried on the moon

THE moon has buried scars. Maps of its gravity have confirmed the existence of hidden, ancient craters, long since filled in by lava flows.

Jay Melosh at Purdue University in Indiana and his colleagues were searching data from NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission for traces of underground lava tubes when they came across two large buried craters.

These had been hinted at last year, when Alex Evans at the University of Arizona and colleagues used GRAIL maps to find evidence of more than 100 craters buried beneath seas of basalt formed by ancient volcanic eruptions.

One of the new craters, called Earhart, is about 200 kilometres across and is almost completely masked by a later impact and subsequent lava flooding. Another discovery is a buried crater 160 kilometres in diameter, which has been called the Ashoka Anomaly (*Icarus*, doi.org/b2j9).

The approach could let us map every single impact that punctured the moon's surface since its crust formed around 4.2 billion years ago, Melosh says.

HENK BADENHORST/GETTY

Musical sense doesn't falter with age

IT MAY feel as if many of our mental abilities decline with age, but here's one that sticks – our ability to sense when music sounds wrong.

When you listen to music, your brain tries to predict the next note. To see if this changes over our lifetime, Joydeep Bhattacharya at Goldsmiths, University of London, and his team measured the brainwaves of 14 adults under the age of 33, and 15 people aged 62 and over, as they listened to music.

All participants heard 100 short pieces of music composed specially for the study. Each piece ended either in a standard melodic progression used in Western music or in an unorthodox pattern.

Many of our brain's executive functions become impaired as we get older, but this didn't turn out to be the case for sensing the unexpected ending. Both groups detected this equally well (*Brain and Cognition*, doi.org/b2jw).

The older people employed a wider region of the brain, though. "Recruiting a broader region perhaps compensates for the expected impairment that often takes place with age," says Bhattacharya.

Where did we come from?
How did it all begin?

And where does belly-button fluff come from?
Find the answers in our latest book. On sale now.

Introduction by **Professor Stephen Hawking**

New Scientist

Sea change

Discovering more ways we are damaging the ocean is also illuminating better solutions, says **Richard Schiffman**

YOU needed a microscope to see it, but there it was. After an absence of 800,000 years, *Neodenticula seminae*, a native of the Pacific Ocean, had showed up unexpectedly in the North Atlantic. Marine biologists speculated that this tiny species of plankton had drifted through the Northwest Passage, which until recent summers had been blocked by a permanent wall of ice.

Melting ice is far from the only way climate change is altering the oceans. A study published last month found that dissolved oxygen levels in the water are falling. Another suggests that the plankton crucial to maintaining the balance of gases in Earth's atmosphere are in trouble.

There is good news hiding in the bad. Some researchers think this new information points to geoengineering approaches that could solve the problem of climate-changed oceans. But we can't be sure they would work; can we risk mucking around with the world's largest ecosystem? Then again, aren't we already?

It is well known that a warmer, more acidic ocean is linked to coral and shellfish die-offs as well as the mass migration of fish. But for many years, scientists were divided on the question of how the changing climate would affect phytoplankton.

"Plankton produce nearly half the oxygen in the atmosphere, making them the lungs of the planet"

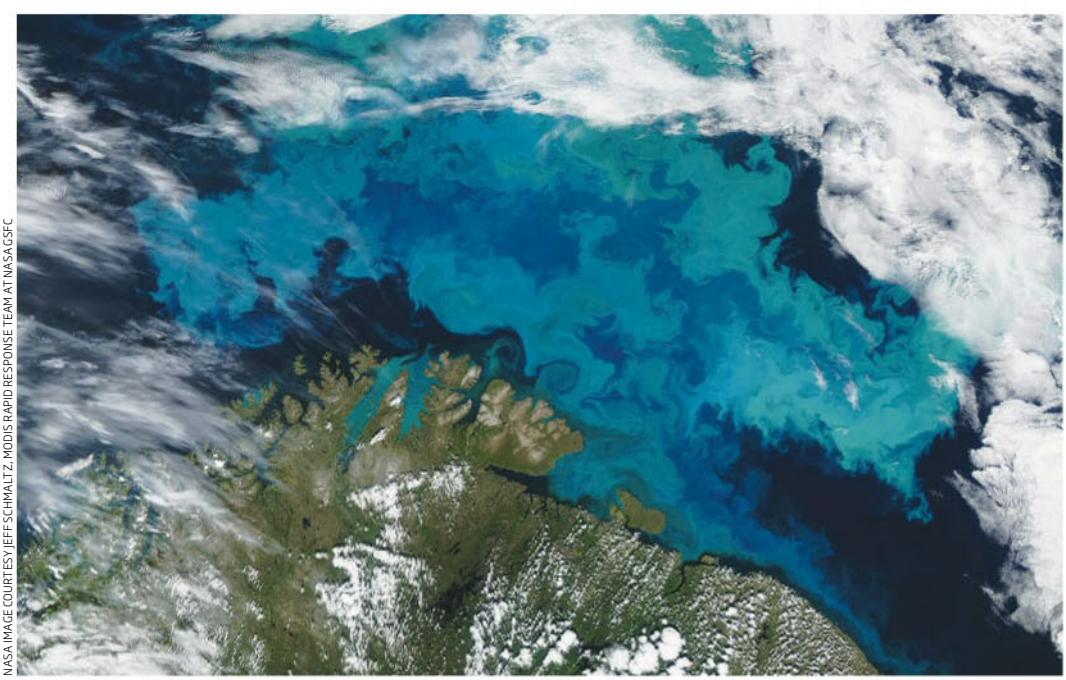
These plant-like marine organisms, which mainly live near the ocean's surface, are highly sensitive to environmental changes. Still, many scientists believed that rising levels of carbon dioxide in the atmosphere would stimulate their growth.

In 2015, a team at Johns Hopkins University confirmed that the population of a phytoplankton known as *Coccolithophores* increased tenfold in the North Atlantic between 1965 and 2010.

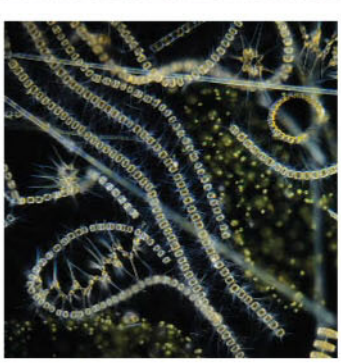
However, work by William Chivers, an ecology researcher at the University of Newcastle in Australia, confirms that not all species are thriving. Phytoplankton cannot swim, so when conditions in the water shift, they have three options: adapt, hitch a ride on ocean currents to more hospitable seas, or die out.

All three processes are currently going into overdrive. *Coccolithophores* seems to have adapted, but others are not so lucky. Many critical phytoplankton species in the North Atlantic have declined for decades, unable to survive in the warmer and more acidic seas, says Chivers.

Neodenticula seminae is far from the only climate migrant. Chivers and his team found that billions of phytoplankton now roam in a desperate search for suitable ocean habitats. Several key species have been moving poleward by up to 99 kilometres per decade in pursuit of cooler



NASA IMAGE COURTESY JEFF SCHMALTZ, MODIS RAPID RESPONSE TEAM AT NASA GSFC



L TO R: STEVE GSCHMEISSNER, WIM VAN EGMOND/SPL

Phytoplanktonare the lungs of the planet and the base of many food chains

waters (see map, right). Others are simply dying out, including one that fisheries crucially depend on.

It's not just fisheries that will suffer: phytoplankton are the base of the ocean food web, on which everything from fish to whales to polar bears depend. They also produce nearly half of the oxygen in the atmosphere through photosynthesis – more than all of the forests on Earth combined – and oxygenate the ocean. They are the lungs of the planet.

The worrying news about their losses comes hot on the heels of a study by Sunke Schmidtko and colleagues at the Geomar Helmholtz Centre for Ocean Research in Kiel, Germany. They found that oxygen levels in the ocean have dropped by 2 per cent in the past half century. This pattern shows no sign of reversing.

Untenable trend

It is clear we need to save the phytoplankton. But how?

First we need to understand the trends, something scientists are still working on, says Stephanie Dutkiewicz, an oceanographer at the Massachusetts Institute of Technology who has been modelling phytoplankton groups. "Most of the models suggest that overall there will be a decrease in phytoplankton populations," she says, "but we simply won't know for sure how this will work out for another 20 to 30 years." There are just too many variables, including ocean currents and species' evolutionary capacity to adapt.

However, one trend that scientists can confidently predict is that smaller phytoplankton species, like *Coccolithophores*, will increase, while larger ones like *Neodenticula seminae* will decline. That's because as the ocean surface heats up, there will be less mixing of the warmer, less dense surface waters where phytoplankton live with the cooler, denser waters below, which contain most of the nutrients they need to survive. Big phytoplankton need higher concentrations of dissolved phosphates and nitrates, and are therefore expected to fare poorly.

That's bad news, because the larger species do most of the heavy lifting: they trap a lot of carbon, which ends up sinking to the bottom of the sea when the organisms die, and they add the lion's share of life-giving oxygen to both air and ocean. The smaller species expected to thrive in the future are not as effective at sequestering carbon. In total, phytoplankton remove about half of the CO_2 that human industries emit, making them crucial in the battle to slow climate change.

With so much at stake, scientists like Dutkiewicz say we need to quickly ramp up research into these critical organisms. But is it also time to take a fresh look at geoengineering our oceans – an idea that has been dismissed as too incautious?

Marine biologist Victor Smetacek is best known for seeding the ocean near Antarctica with 7 tonnes of finely powdered iron sulphate, an industrial waste product, in an effort to stimulate phytoplankton growth. This resulted in a large bloom of diatoms, which survived only a few weeks before dying and falling like snow to the bottom of the sea.

Smetacek has long argued that iron fertilisation of this sort could be a relatively inexpensive way to suck carbon from the atmosphere and store it in ocean sediments. But many scientists and environmentalists have baulked, saying that such experiments could have unintended consequences. Willie Wilson, who directs the Sir Alister Hardy Foundation For Ocean Science in Plymouth, UK, does not rule out iron fertilisation, but warns that a huge continuous flux of organic matter could ultimately poison the oceans and create anoxic zones hostile to life.

Instead of aiming for a dramatic bloom and die-off, what about sustaining the plankton in a more natural way? "The real problem with the oceans," says Smetacek, "is our destruction of the megafauna, the large fish and whales, which in earlier times kept the system in balance."

The loss of these predator species has been bad news for phytoplankton, which feed on the rich nutrients in their excrement. When they were more abundant, whales also churned the sea, bringing nutrients from the deep to the surface.

Smetacek suggests mimicking this by pumping waters from the ocean depths to the surface with a series of long pipes anchored to artificial islands. The nutrients in these deep sea waters would help rejuvenate phytoplankton populations and thus the ocean ecosystem as a whole.

Some see trouble here too, though. Stephanie Henson, an oceanographer at the University of Southampton, UK, says that cold waters coming to the surface could draw CO_2 into the ocean faster, enhancing acidification.

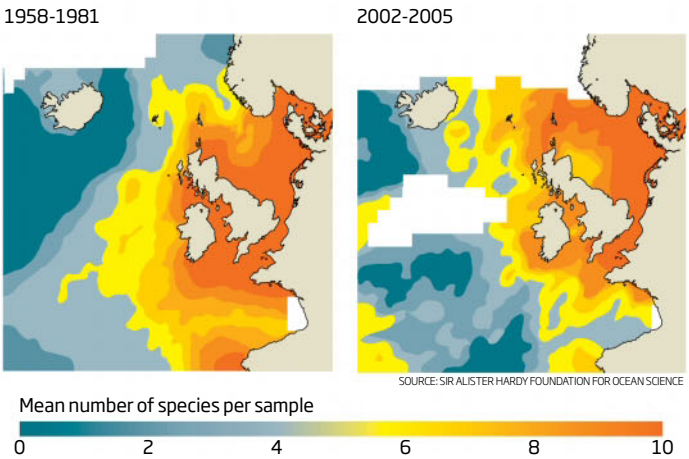
But not everyone is opposed. Mike Behrenfeld, a research scientist with NASA, says small-scale, short-term geoengineering experiments in the field have successfully demonstrated such approaches. Still, like Henson and many other scientists, he remains squeamish about altering ocean ecosystem in unknown ways.

"We could boost plankton populations by pumping waters from the depths of the sea to the surface"

But something needs to change. The oxygen depletion study also found that if nothing is done, oxygen in the ocean could fall by 7 per cent by the year 2100, a shift that would have a dramatic impact on life in the oceans. If that happens, oxygen-producing phytoplankton will become even more critical to maintaining marine life. "People accuse me of meddling with nature," Smetacek says. "But not doing anything is the worst option." ■

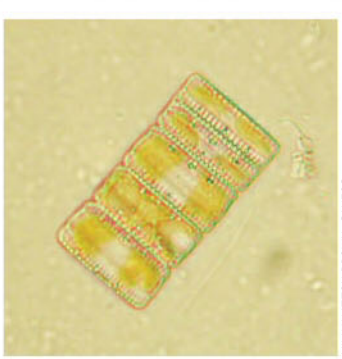
Climate migrants

Warming oceans are driving many phytoplankton species to higher latitudes as the water in their previous range is no longer hospitable



SOURCE: SIR ALISTER HARDY FOUNDATION FOR OCEAN SCIENCE

***Neodenticula seminae*: seen in the North Atlantic after 800,000 years**



MILLY HATTON-BROWN - SAHFOS

Welcome back, old friend

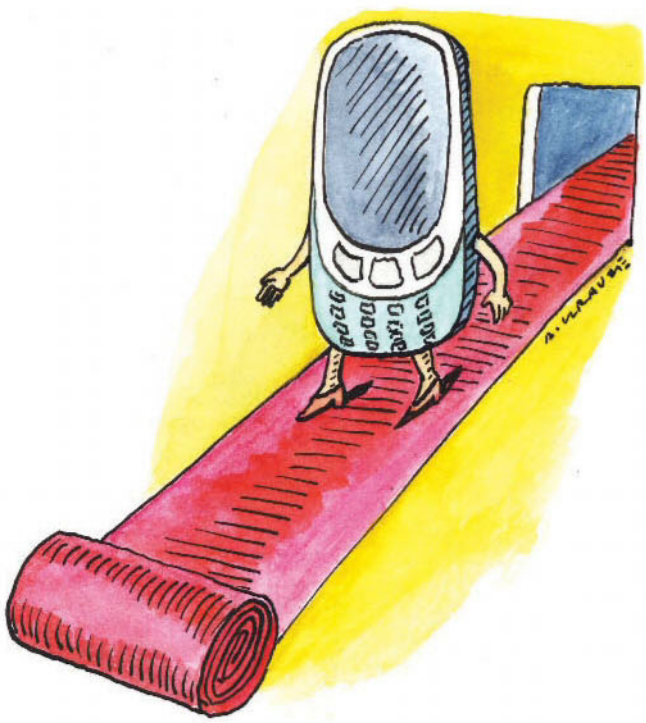
Dated technology, such as Nokia's 3310 cellphone, often gets an unlikely second wind. What's the appeal, wonders **Lara Williams**

CROWDS at last week's Mobile World Congress in Barcelona, Spain, were among the first people to hear confirmation of rumours that the compact, push-button Nokia 3310 cellphone is back.

Known for its robustness, long battery life and often garish shell, it launched in 2000. Some 126 million were sold, putting it in the top 20 bestselling phones of all time. "It has *Snake*," said Arto Nummela, CEO of HMD – the Finnish firm selling the phone – referring to the addictive game included. The audience whooped.

Given that technology is all about progress, we are strangely preoccupied with past devices.

Tech nostalgia is an increasingly pronounced conceit, with the past swiftly turned into a commodity: obscure Nintendo 64 video games sell for big money, and dedicated YouTube channels allow fans to reminisce about



1990s hardware. Why do we imbue erstwhile technology with a romanticism that we deem lacking in today's devices?

The Nokia 3310 is particularly emblematic of this phenomenon. It was released at the dawn of a new millennium that had long symbolised "the future", in a year that also unleashed other iconic technologies and devices, such as the PlayStation 2 games console, the Windows 2000 operating system and precision GPS for cars.

All these telegraphed progress and sophistication, making life easier. What's more, they were no longer for the few, but infiltrated ordinary households and lives.

I bear witness to that. The Nokia 3310 was my first phone. I had it on a pay-as-you go SIM, using it to ring my parents when I needed a lift and to text a few friends with mobiles. I was a *Snake* devotee.

It gave a sense of autonomy that

A dead loss?

De-extinction is not the wisest way to tackle declining biodiversity, says **Olive Heffernan**

THE resurrection of extinct species – as depicted in the film *Jurassic Park* – is within our grasp. Heralded as a way of turning back the clock on biodiversity loss, de-extinction sounds alluring – but does it stand up to scrutiny?

The appeal is obvious. Dinosaurs aside, who wouldn't like to see the skies of North America darken again with great flocks of passenger pigeons, or wish that the Tasmanian tiger could live another day in the sun?

De-extinction is not a new idea. But the science is making strides. Harvard geneticist George Church recently claimed he is two years away from creating a hybrid mammoth-elephant embryo. The hope is that, eventually, the embryo could develop into a fetus and reach full term. That would require development of an artificial womb – at great expense.

Even then, to be saved from extinction, a resurrected species must be reintroduced to the wild in sufficient numbers and then protected. But with each day that passes, as many as 100 species disappear and so, arguably, that money could be better spent on saving living, threatened species.

"In Australia, reviving five extinct species costs as much as saving 42 existing ones"

That trade-off has now been quantified. A new study looks at funding de-extinction over existing species conservation in New Zealand and Australia and shows that choosing the former may condemn the latter (*Nature Ecology & Evolution*, doi.org/b2g5).

It finds the cost of bringing back and protecting 11 extinct species in New Zealand equates to the cost of preserving 31 existing ones. In Australia, it found reviving five species is as expensive as saving 42 extant ones.

The simple fact is that there is only so much money in the conservation pot. But cost is not the only concern.

I hadn't experienced before: it afforded my first interactions with a device of my own. It also offered what felt like a boundless capacity for self-expression. My cover of choice was bright green, with sunflowers. I spent a long time choosing a ringtone.

But the stark difference with my current iPhone 6 is not kitschy aesthetic or durability, but my relationship with it. I never had to place my 3310 in a separate room to sit still enough to read a book, and cannot imagine blistering rows with partners for spending too much time on *Snake*.

It is telling that such a device is sentimentalised at a time when digital detoxes are big business, and Apple has developed modes of reducing blue light from screens in an attempt to stop phones disturbing sleep patterns.

We get misty-eyed for old tech because we think it shaped us or seems to solve today's problems.

But before you stump up for the Nokia, remember this: nostalgia bolsters the positive, eradicates the negative and falsely idealises the past. Like the sepia-tinged Instagram filter that dulls out the edges of photos, everything looks better through that lens. ■

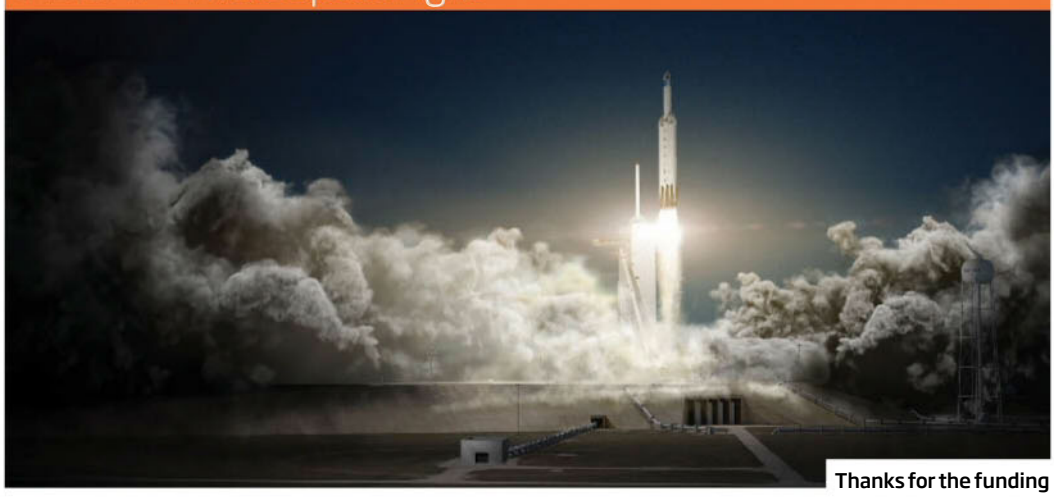
Lara Williams is a writer based in Manchester, UK

The mammoth is long gone. Could such a species survive in a world altered by humans? And the mammoth-elephant would be an analogue, not a replica, perhaps casting further doubt on its conservation relevance.

That's not to say that de-extinction will never be worth doing. Far from being the folly of rogue scientists, it reflects a deep ethical desire to make right the wrongs of our past. But with limited funds and time for conservation, great care must be taken in how it is used. ■

Olive Heffernan is an environment writer

INSIGHT Private space flight



SPACEX

Thanks for the funding

What billionaires are really doing in space

Leah Crane

In 2018, two unnamed individuals will pay an undisclosed amount of money to billionaire space entrepreneur Elon Musk. In exchange, he will make them the first civilians to be launched around the moon. "Like the Apollo astronauts before them, these individuals will travel into space carrying the hopes and dreams of all humankind, driven by the universal human spirit of exploration," announced SpaceX.

Except they'll be nothing like the Apollo astronauts. So what is the real point of sending humans round the moon in the 21st century?

They're unlikely to be pushing any technological or scientific boundaries. "This is basically a joyride," says John Logsdon at the George Washington University in Washington DC.

And they won't be driving. SpaceX's autonomous Crew Dragon capsule will be able to steer itself around the moon with or without passengers.

One thing they can do, however, is pay. This is a hint to the future of human space flight. Musk has been clear about his goal for SpaceX from the start: he wants permanent human settlements on Mars and beyond. But even his billions won't be able to pay for all the R&D.

Sending tourists around the moon will defray the costs of testing the Falcon Heavy rocket and Crew Dragon capsule beyond low-Earth orbit, especially since neither have flown any humans yet. Musk has said that he hopes to run one or two such private trips a year, providing 10 to 12 per cent of SpaceX's annual revenue.

The private takeover of space is galling to some, because nations have conventionally led the charge in this arena. But since the cold war space race and the Apollo flights to the moon, many worry that government-funded human space flight has stagnated. The shifting priorities of limited-term governments tend to undermine long-term goals. In the US, for example, NASA's funding comes with a paralysing wrapping of red tape.

"The new normal is like the old normal – science dependent on the patronage of rich people"

Frustration with government has led to the rise of a more freewheeling model, led by billionaire entrepreneurs like Musk and Jeff Bezos of Amazon.

But anyone who thinks privatisation is a novel direction is mistaken. "The idea that the government, especially the US government, is the place to fund new science and new technology is recent," says Jonathan McDowell at the Harvard-Smithsonian Center for Astrophysics. "The new normal is a return to an old normal."

And what was the old normal? A dependence on the patronage of rich people. History is full of fortune-hunting and fortune-having explorers. The first expeditions to the North Pole were self-funded, and Charles Darwin formulated his theory of evolution while a private citizen on an exploring British navy ship. Those with means often clear a path, and this old model, say some experts, has a better chance than government of paving the way for space tourism and eventually settlements on other worlds.

That is, until governments begin to tighten regulations. So far, the US Congress has given wide latitude to commercial space companies to let them advance. However, under the Outer Space Treaty the US is responsible for any damage SpaceX might do to any other nation. So the more successful space tourism is, the more red tape it could attract. As another notorious rich person once said: "mo money, mo problems." ■

Toothsome grin

THE tooth fairy would have had trouble with this one. These nested rows of stubby teeth belonged not to a dinosaur, but to a two-bar sea bream (*Acanthopagrus bifasciatus*), a reef-dwelling fish common in the Persian Gulf.

You can tell a lot about a fish from its skeleton. The specimen here, collected almost 190 years ago, reveals row upon row of molar-like teeth that together form a bumpy surface perfect for crunching and grinding up hard-shelled crustacean prey.

Measuring nearly 50 centimetres from tooth to tail, this sea bream was caught in the Red Sea. Collections of old fish skeletons like this one are still an important resource for studying these vertebrates today.

Fish skeletons show far more variety and can have many more features than those of mammals: the human skull, for instance, comprises around 25 bones, whereas the head of this sea bream has more than 150.

These new photographs capture the fish's secret weapon for breaking into its breakfast – but just imagine how hard it would be to floss.

Chelsea Whyte

Photographer

Heidi & Hans-Juergen Koch

Eyevine

DOMENIC BAHMANN

When loops

What if our two best hopes for a theory of everything

AS THE bell rings for the final round, both fighters are in their corners. The heavyweight champion is panting, against the ropes. The underdog is sprawled on the opposite side, bruised, tired but determined.

Everyone is expecting an exhilarating finale. The challenger has put on a good show, landing a few square punches. Admittedly, it was accused of cheating by ignoring the rules of physics. But that was nothing compared with the favourite's big trick: dancing in seven invisible dimensions.

This is no ordinary fight: it's for the honour of successfully explaining the fundamental make-up of the universe. The heavyweight incumbent is string theory, a complex construct that has long had pretensions to be "theory of everything". The upstart contender, loop quantum gravity, has more modest aspirations – but could still change the face of physics as we know it.

Physicists have long believed they must pin their hopes on just one contender. But as the two rivals walk back into the ring, there's a turn-up for the books: they reach out for a handshake. If the latest indications are right, it seems the two theories are not so different after all. They might in fact be the same theory in disguise – with implications that reach far and wide. "The next revolution in physics is going to come from people who can cross the boundary," says Laurent Freidel, a theorist at the Perimeter Institute in Waterloo, Canada.

At its root, this fight is all about that most perplexing of forces, gravity. In his general theory of relativity, Einstein told us that gravity is the product of an omnipresent fabric, space-time, that warps smoothly around massive objects. It works soundly for things like planets, stars and galaxies, but does far less well for all things small.

Here, it is forced to confront that other totem of modern physics, quantum theory, which tells us that everything comes in discrete chunks. This would suggest that, on the finest scales, space-time isn't smooth but must be in some way twisted and frayed.

become strings

turn out to be the same? **Jon Cartwright** pulls at the threads

So quantum theory and relativity are fundamentally incompatible. The problem is most acute around singularities, tiny regions of space-time with humongous gravitational fields, such as appear at black holes or the big bang. Here, physics just breaks down.

That's where our the heavyweight champion enters the ring. String theory started in the 1970s as a way to describe a single force of nature, the strong force, which binds particles called quarks together inside atomic nuclei. But its aspirations eventually expanded to describe nature's other three forces too, including gravity. It aims to do so by painting matter and energy as made of vibrating strings. This goes against the grain of accepted physics, which sees all matter as made from fundamental point particles – electrons, quarks, photons and so on – devoid of any shape or substructure.

Just as a musical string sounds different on a violin or a cello, so in string theory, a string's vibration pattern determines what kind of particle it manifests as: it can "sound" like a quark, electron or photon. And among the oscillation modes of these strings is something that looks not like an established particle, but like a graviton – a quantum particle that transmits gravity and gives structure to space-time.

String theory may be successful, but like many ageing competitors, it has its share of hang-ups. Strings need to vibrate in 11 dimensions, so backers believe that to tally with the three we observe, the extra dimensions must be folded up around the strings so tightly that we can't see them – and indeed, no conceivable experiment can probe them. Even if we could, the folding can be done in so many ways that the universe isn't big enough to write the number down, so we wouldn't know what to look for.

All this has led to string theory receiving a deluge of brickbats, with some suggesting its lack of predictive power disqualifies it from scientific contention.

But string theory does in fact makes one prediction: supersymmetry. A mirror ›

symmetry in the string vibrations means that our familiar particles should all have heavier, supersymmetric twins. But we have so far failed to spot them at the world's most powerful particle generator, the Large Hadron Collider near Geneva, Switzerland. The absence of supersymmetric particles may not have killed string theory, but it has injected a dose of humility, says Carlo Rovelli at the Centre of Theoretical Physics in Marseille, France. "This has not been said yet, because people are afraid of saying it."

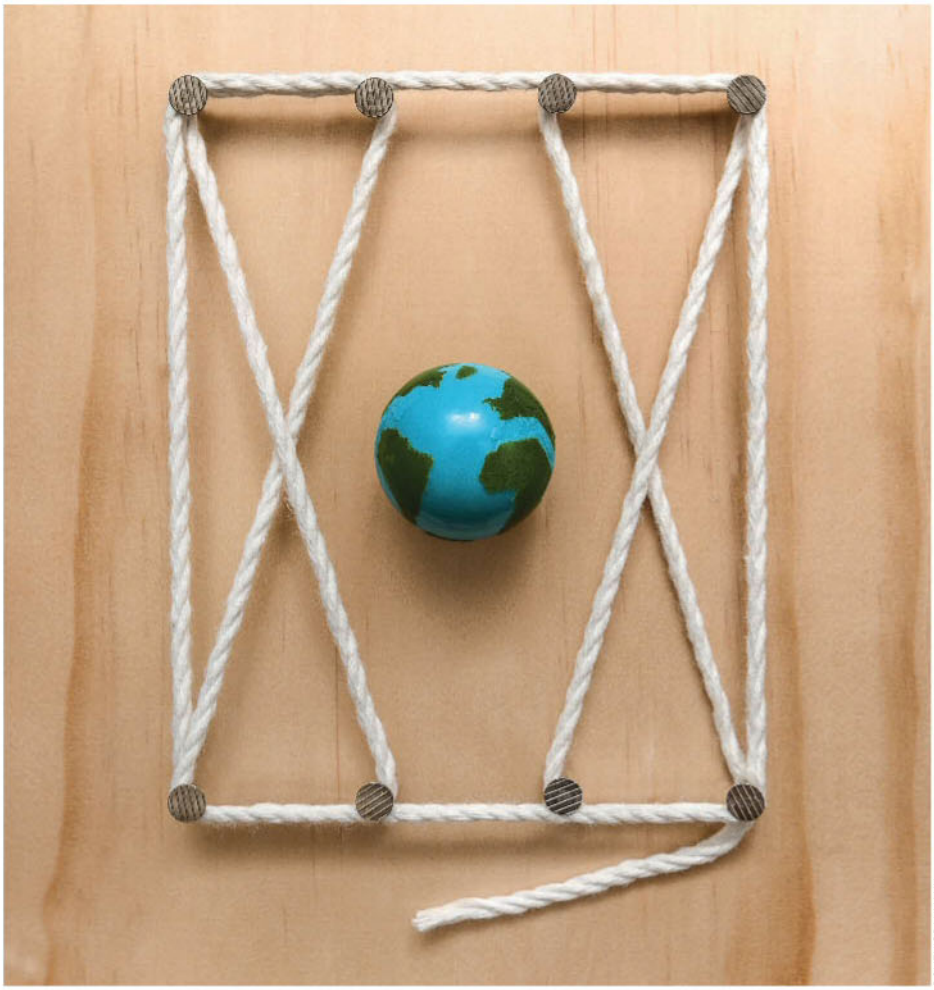
Rovelli is a pioneer and supporter of the underdog theory, loop quantum gravity. It got into the competition in the 1980s, a decade later than string theory, but likewise promised to tackle the mismatch between general relativity and quantum theory.

It does this in a far more modest fashion, however. Rather than creating a whole stringy apparatus from which space-time ultimately derives, it says simply that space-time itself must fit in with the quantum picture: it must come in finite chunks. Do the maths and these chunks turn out to be tiny loops, which evolve by themselves into a bubble-like geometry known as a spinfoam. The spinfoam is space-time written in the language of quantum theory.

While some theorists cheer string theory for its brash ambition, others are drawn to loopy space-time for its modesty. It tries to do nothing more than is necessary to reconcile quantum theory and general relativity – a slow and steady approach that some see as more likely to win out in the end. And although loops have remained just as theoretical as strings, theorists like Rovelli have generated some testable predictions (see "Closing the loop", right). That said, there is a hitch. Spinfoams are too rigid to readily adhere to Einstein's picture of a universe where space and time squeeze and stretch depending on who's looking.

Loopy space-time and vibrating strings offer very different visions of the universe's make-up. The only thing most adherents of either camp can agree on is a long history of not talking to each other. "Few people now have worked in detail on both approaches," says Lee Smolin, another pioneer of loop quantum gravity and also at the Perimeter Institute. "Most people using one approach are ignorant of and have misapprehensions about the other," he says.

Freidel believes the split actually goes right back to the ancient Greeks, and the birth of science. On one side, he says, are reductionists who, like string theorists, think we must understand smaller and smaller components of nature. On the other are those who think progress comes from understanding the bigger picture, and the nature of space, as loop theorists do. "Physics has been successful for 2000 years without settling this divide."



DOMENIC BAHMANN

Emerging hints

But with neither strings or loops landing a killer blow, things are changing. Theorists, young ones in particular, are starting to move between the camps for the first time, looking for connections between the two. "I'm surprised at how it's changed in recent years," says Rovelli.

The first hints of something in common emerged in 2011, when Norbert Bodendorfer and colleagues at the University of Warsaw in Poland rewrote string theory and its supersymmetric particles on the space-time described by loop quantum gravity, showing that the two very different frameworks could at least live with each other.

Another hint came to light three years later with an essay by loop theorists Rodolfo Gambini of the University of the Republic in Montevideo, Uruguay, and Jorge Pullin of Louisiana State University in Baton Rouge. They argued that to make relativity and loop quantum gravity fully compatible, you were forced to limit the range of possible particles using a trick borrowed from string theory.

Little came of those isolated investigations. But just recently, a flurry of studies has suggested a more solid link – one whose foundations were unknowingly uncovered in the early 1990s. At this time, the Dutch Nobel prize winner Gerard 't Hooft and Leonard Susskind of Stanford University in California proposed that the three-dimensional world in which we live, and gravity's effects on it, could be a mere projection of stuff happening on its flat, two-dimensional boundary.

In this radical picture, the bulk of the universe is no more "real" than the three-dimensional hologram on the back of a credit card. Reality is the flat boundary, and everything else is an illusion.

Since then, the holographic principle has matured into a major research area in string theory. From a perspective on the boundary, frightfully difficult physics begins to make better sense. But now, it seems, the boundary

CLOSING THE LOOP

Loop quantum gravity has been around for years, proposed as a way to reconcile our two best theories of the universe, general relativity and quantum theory (see main story). Recently, at long last, physicists have made the first tentative proposals for testing it experimentally.

One proposal has been aired by loop theorist Carlo Rovelli at the Centre of Theoretical Physics in Marseille, France. If space itself is made of discrete loops, he says, then there is a limit to how much it can be squashed. That leads him to think that black holes, which continuously suck in matter, might reach a point where they can't get any more dense, whereupon they would "bounce" and produce a burst of observable radiation.

Although we do see bursts like this, it's hard to prove they came from a bouncing black hole. Another possibility is to look back to the big bang. It might be that tiny irregularities in the ordering of loops of space-time left an impression on the universe as it expanded. Traces of this might be visible as subtle shifts in the fluctuations of the cosmic background radiation, the afterglow of the big bang. We might just see similar patterns in the gravitational waves left over from the big bang. In both cases, however, we would need more much precise instruments to have any hope of finding them.

could also provide a place for string theory to entwine with loop quantum gravity. "Both sides are making a step towards each other," says Rovelli. "There is common ground there, on the boundary."

In November last year, loop theorists Valentin Bonzom of the University of Paris-North in France and Bianca Dittrich of the Perimeter Institute found that a calculation

> "The bulk of the universe is no more real than the hologram on a credit card"

of holographic gravity that others had performed in the context of string theory could be achieved using loop quantum gravity, with exactly the same result. A month later, Bodendorfer made another breakthrough. Normally, when holographic string theory is used for calculations of gravity it gets stuck at those pesky singularities, like black holes. But Bodendorfer showed that his loopy maths could patch over those situations. "Mine was a proposal for how loop quantum gravity could fit inside string theory," he says.

These results could be flukes, but even more fundamental studies are now weighing in. Also in November last year, working with two other collaborators, Freidel went back to basics: he attempted to describe a small region of space surrounded by a boundary, using only general relativity. It turned out that the mathematical quantities defining his boundary resembled quantities in both string theory and loop quantum gravity, despite neither theory being a starting point.

Meanwhile, loop theorist Muxin Han at Florida Atlantic University in Boca Raton teamed up with string theorist Ling-Yan Hung at Fudan University in Shanghai, China, to try to calculate the probability of one spinfoam evolving into another in loop quantum gravity. Like the soap bubbles that billow while running a bath, spinfoams evolve of their own accord, but calculating just how they evolve can be tricky. To make their spinfoam calculation easier, Han and Hung mapped it on to a boundary. Once more, out popped mathematical features strangely reminiscent of string theory. "All this is teaching both string theorists and loop quantum gravity theorists something they had not considered before," says Hung. Rather than being competitors, on the boundary at least, string theory and loop quantum gravity could be one and the same.

That brings up questions about what and where this boundary is exactly. Holographic theory began by imagining it at the universe's edge, but today's string and loop theorists are less strict, thinking of a boundary as being anywhere in space. The part-loop, part-string physics that Hung and others are working on might appear on the finest scales if you took a random slice through space-time.

Casting the same shadow

That might seem arbitrary. But when you think about it, says Rovelli, we impose boundaries all the time, as portals through which to observe the world. To measure temperature, we place a thermometer on the edge of an object; to record light, we catch photons striking the flat surface of photographic film. The important point is that this flat picture can be the result of more than one happening, in the same way that a butterfly-shaped shadow can be made by an actual butterfly, or by linking your thumbs and waving your fingers. String theory and loop quantum gravity may look different in the whole, then, but they may, in a sense, cast the same shadow.

If true, that could make experimental results ambiguous. Observing a supersymmetric particle, say, could be evidence of a string-loop theory or of string theory proper; on a flat detector, there would be no way to distinguish the two.

That's assuming strings and loops can even be fully joined in the first place. "There is no string-loop theory yet," says Rovelli. "My own opinion is that we still have two different theories. One could still be right and one could be wrong, or they could both be wrong."

That may well be true. But among younger physicists there is genuine excitement for where a reconciliation between loops and strings could lead. Even if it does not end at an answer in itself, it could point the way to an even deeper reality, one that has its own unique predictions. In that case, finding a place where string and loop theorists can at least translate between their mother tongues is no bad thing. Diplomacy, after all, first requires the antagonists to stop fighting. ■

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Fancy a drink?

At some point today the answer will be yes. The average adult drinks about 1.7 litres of fluids a day: water, tea, coffee, soda, milk, fruit juice and more. But our ideas of what we should be drinking are clouded by urban myths, wishful thinking and dubious health claims. Time to mix in some fact

WATER

YOU CAN'T NOT DRINK WATER – IT IS LIFE'S MOST ESSENTIAL NUTRIENT. BUT THAT DOESN'T NECESSARILY MEAN MORE IS BETTER

It's not called Adam's ale for nothing. Water was presumably what our early ancestors drank, to the exclusion of everything else. If you stopped drinking it now you would be dead within a week. It is the only nutrient whose absence is lethal in so short a time.

But how much you should drink is surprisingly contentious. It is common to hear eight glasses a day – about 2 litres – even if you don't feel thirsty. In 2002, physiologist Heinz Valtin of Dartmouth Medical School in New Hampshire tried to track down the source of this advice. The closest he came was a 1974 book that casually advised six to eight drinks a day – not just water but also soft drinks, coffee, tea, milk and even beer.

As for its scientific validity, Valtin found none. As the Food and Nutrition Board of the US National Academies of Science, Engineering and Medicine advises: "The vast majority of healthy people adequately meet their daily hydration needs by letting thirst be their guide". The only exception is some elderly people whose feedback mechanisms go awry, meaning they can become dehydrated without thirst.

Generally, there is little to gain by doing more than just quenching your thirst. Water doesn't remove toxins from the skin, visibly improve your complexion or cure constipation. There is some support for the idea that drinking cold water makes you burn calories, and water with a meal does reduce overall calorie intake, perhaps because it helps fill you up or displaces calories from sugary drinks. But the overall influence of water on weight is far from clear.

There is a sliver of evidence that being well hydrated can protect against health problems including colorectal and bladder cancer, heart disease, hypertension, urinary tract infections and kidney stones. Good hydration makes it easier for the kidneys to extract waste, reducing wear and tear on them. Dehydration headaches do exist and water can cure them (although there are hundreds of other reasons why your head might ache), and drinking lots when you have a cold may loosen mucus, easing the symptoms.

Water may not be a cure-all, but the downsides of overdoing it are mild. Besides rare deaths through over-hydration among marathon runners and ecstasy users, the worst of it is that many people who regularly push the fluids too hard appear to be mildly hyponatremic – they have too little sodium in their blood. This is not a major problem, but has been associated with mild cognitive impairment and an increased risk of falling in older people.

Overall, though, "there are few negative effects of water intake and the evidence of positive effects is quite clear", according to a recent review.

Perhaps the most implausible claim of all has the strongest support: water can improve focus, at least among children. Several studies have found that having children aged 7 to 9 drink water improves their attention and, in some cases, recall. Perhaps children of this age are more prone to dehydration, which can cause a decline in alertness, concentration and working memory.

PLAINPICTURE

TAP OR BOTTLED?

For some, tap water is too clean, laced with chlorine-containing compounds used to sterilise it. For others it's not clean enough, teeming with nasty pathogens and traces of chemicals. Then there's the fluoride often added to it for dental health: decried as a Communist plot in 1950s America, it remains controversial in some quarters today.

Whether for those reasons or simple taste, many people prefer to buy bottled water. Either way, that could be a waste of money, in most parts of the West at least. Around 25 per cent of bottled water sold in the US is simply tap water from municipal sources. A large proportion of bottled water is chlorinated just like tap water – for good reason. Water chlorination is impressively effective at preventing serious diseases such as dysentery, cholera and typhus. Evidence that chlorination can produce carcinogenic byproducts or compounds that reduce male fertility is "inadequate", according to the World Health Organization, and the risk is extremely small compared with that from poorly sterilised water.

Tap water does contain traces of pharmaceuticals, toiletries and cosmetics, but the US Environmental Protection Agency says "There are no known human health effects from such low-level exposures in drinking water". As for fluoridation, there is no evidence that this causes any health problems except where accidents lead to over-fluoridation, which can cause vomiting and diarrhoea.

There is stronger evidence that the minerals in some bottled waters, especially sodium, can be harmful. And while the health benefits of mineral-rich waters have long been touted, the enormous variation between brands makes this impossible to test.

As for taste, that is also impossible to test objectively. But if it is an issue, just chill your tap water: it makes bad flavours much less noticeable.

PLAINPICTURE

Water, water everywhere

Some 20 to 30 per cent of an average person's fluid intake comes from food. But how much do individual foods contain?

100%	Water
90-99	Fat-free milk, cantaloupe, strawberries, watermelon, lettuce, cabbage, celery, spinach, pickles, squashes
80-89	Fruit juice, yogurt, apples, grapes, oranges, carrots, pears, pineapple, broccoli
70-79	Bananas, avocados, cottage cheese, ricotta cheese, potato (baked), corn (cooked), shrimp
60-69	Pasta, legumes, salmon, ice cream, chicken breast
50-59	Ground beef, hot dogs, feta cheese, tenderloin steak
40-49	Pizza
30-39	Cheddar cheese, bagels, bread
20-29	Pepperoni sausage, cake, biscuits
10-19	Butter, margarine, raisins
1-9	Walnuts, peanuts (dry roasted), crackers, cereals, pretzels, peanut butter
0%	Oils, sugar

SOURCE: US DEPARTMENT OF AGRICULTURE

GETTY

SODA, SQUASH AND JUICE

WE LOVE TO SPICE UP PLAIN OLD WATER BY ADDING SOMETHING SWEET – WITH POTENTIALLY DISASTROUS CONSEQUENCES

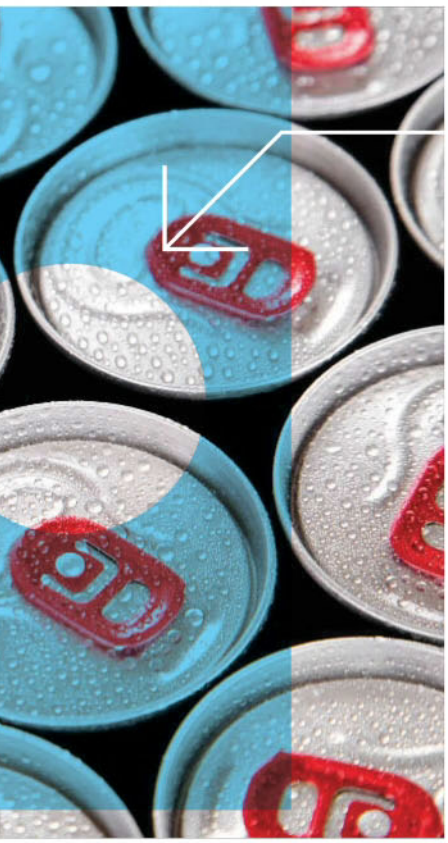
Sugary drinks rot your teeth, and the more you drink, the more they will rot. Fizzy pop is generally assumed to be the worst. That is not because of dissolved CO_2 – it is a myth that sparkling mineral water is any worse for your teeth than the plain variety – but because of the combination of sugar and common flavourings such as phosphoric acid.

Their high sugar content means squashes and sodas deliver a huge calorie hit without filling you up: one standard can of a drink like cola provides more than the recommended daily amount of "free" or added sugar. That piles in excess energy that we store as fat. Those who regularly imbibe sugary drinks are more likely to be overweight, regardless of income or ethnicity, and consuming a can of sweetened fizz or the equivalent a day increases the risk of type 2 diabetes by a quarter. Overall, this form of liquid sustenance has little to recommend it.

DIET SODAS

So, if the main problem with sugary drinks is sugar, eliminate that and you eliminate the problem, right?

Not so fast. Some studies indicate that diet sodas help with weight loss, but others find a seemingly paradoxical association with weight gain. Mice consuming artificial sweeteners can even develop glucose intolerance,



a precursor to type 2 diabetes.

It is tricky to pin down cause and effect in human studies, says Vasanti Malik, a nutrition scientist at Harvard University: people who are already overweight may be consuming diet drinks in an effort to lose weight, skewing the stats. And the animal studies have been criticised as unrealistic, with mice or rats in some experiments consuming quantities of sweeteners equivalent to us gobbling a few hundred tablets a day.

But there are plenty of reasons why low-calorie sweeteners might not always have their intended effect. One is psychology: you had a diet cola this afternoon, so you can have an ice cream this evening. Alternatively it could be that the intenseness of the artificial stuff, which can be 200 times as sweet as sugar, drives us to prefer sweet things, says Malik. Or perhaps sweeteners disrupt our gut bacteria, or our normal hormonal response to sugar intake. "As a result, the body doesn't respond as well when real sugar is consumed," says Susan Swithers at Purdue University in West Lafayette, Indiana, leading to weight gain.

The latest review concluded last year that choosing diet drinks over normal sugary drinks can contribute to weight loss. But the uncertainty should give us pause for thought, says Swithers. "The reality is that no one should be drinking a sweetened beverage every day, whether it's regular soda or 'diet' soda," she says. "It's like candy in a can either way."

FRUIT JUICES

Pure fruit juice feels like a healthy alternative. It's 100 per cent fruit, after all, and contains good stuff that fizzy drinks don't, such as vitamins, minerals and antioxidants. The UK National Health Service says one small 150 millilitre glass of pure fruit juice counts towards your five-a-day.

But only one. Fruit juice is missing a lot that fruit has: the juice of one orange contains 0.4 grams of fibre, compared with 1.7 grams in an actual orange. And it is as sickly sweet as sweetened drinks. The World Health Organization recommends that the natural sugar in fruit juice should be lumped together with that added to food and sweetened drinks as free sugar, and advises strict limits on how much we should consume. Orange juice and Coca-Cola contain roughly the same amount, and some juices even more (see "Sugar to go", below). That suggests pure fruit juices should carry the same health warnings as added-sugar drinks.

In truth, we don't know whether fruit juices are better or worse for you than soda, says epidemiologist Nita Forouhi of the University of Cambridge: other lifestyle factors such as income, diet, smoking and exercise that may differ between habitual juice drinkers and habitual soda drinkers make it hard to draw watertight conclusions.

A review by Forouhi's group and others in 2015 did conclude that added-sugar drinks, artificially sweetened drinks and fruit juices were all potentially associated with type 2 diabetes, but differing study designs mean the evidence for artificially sweetened drinks and fruit juices might be "subject to bias". In other words, the jury's still out.

One standard (330ml) can of Coca-Cola gives you

140%

of a daily 25g limit

Two pints (1136ml) of lager gives you

120%

of a daily 25g limit

SPORTS DRINKS

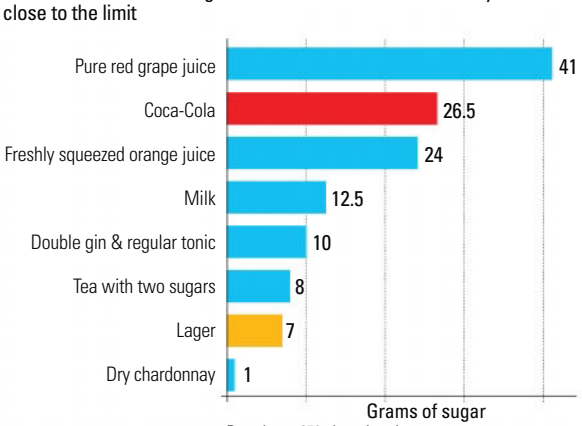
Sports drinks' main claim is that they improve athletic performance and recovery by replacing fluid, energy and electrolytes – sodium, potassium and chloride – lost during exercise. A review published in 2000 concluded that sports drinks probably do improve performance compared with drinking water. In 2006 the European Food Safety Authority agreed.

But most sports drinks also come with a stonking sugar content, and more recent studies have questioned earlier conclusions. An analysis published in the BMJ in 2012 found a "striking lack of evidence" for any claim related to sports drinks. They may help elite athletes, but are unlikely to do anything for ordinary people.

In the meantime, there's another competitor: low-fat chocolate milk. Its 4:1 mixture of carbohydrates and protein appears to be ideal for muscle recovery after a workout, and it is cheaper than most alternatives, too. "The research has been positive – most studies have found it to be just as effective or superior to an over-the-counter recovery beverage," says nutrition and exercise scientist Kelly Pritchett of Central Washington University in Ellensburg.

Sugar to go

The World Health Organization "strongly recommends" limiting consumption of free sugars to 50 grams a day, while advising a further reduction to 25 grams. Just a few drinks can take you close to the limit



Based on a 250ml serving size (gin and tonic 50ml gin, 200ml tonic)

MILK

IT'S A PLENTIFUL SOURCE OF CALCIUM – BUT MANY HEALTH CLAIMS FOR MILK AND ITS SUBSTITUTES DON'T STAND UP TO SCRUTINY

Milk is a richly nutritious mixture of water, proteins, minerals, vitamins, sugars, saturated fat and cholesterol. All mammals make it, but humans are the only ones to drink it beyond their early years. Should we?

Breast milk – or synthetic versions of it – provides the "perfect balance of nutrients" for babies in their first year, says Andy Bernstein, a paediatrician at Northwestern University in Evanston, Illinois. After that, full-fat cow's milk is recommended as a good source of fat for brain development, dropping to 1 or 2 per cent fat milk from age 2.

But although programmes in the US and UK that gave milk to children in schools were associated with huge health benefits, it is not clear why. "We don't know if there is something specific or special about milk, or if it is just the fact that these children are getting more calories, protein, nutrients in general," says Andrea Wiley of the University of Indiana at Bloomington. A recent study of children in Kenya found that supplemental milk helped those with stunted growth catch up in height, but provided no benefits over a non-milk nutritional supplement for children developing normally.

For adults, the benefits seem even more dubious. There is no conclusive evidence, for example, that getting extra calcium from milk is vital for maintaining healthy bones or avoiding fractures. Other foods besides milk – "beans and greens", largely – are also rich in calcium, and most researchers now argue that a generally healthy diet and plenty of weight-bearing physical activity is what keeps bones healthy.

> "All mammals make milk, but only humans drink it as adults"

And we should perhaps be careful not to overdo the white stuff. A Swedish study published in 2014 found that drinking three glasses of milk a day over an average of 20 years increased overall mortality compared with drinking just one – while showing that consuming fermented milk products such as yogurt and cheese reduced both fracture risk and overall mortality.

The authors of that study recommend caution in interpreting the results, though, as there were a number of potentially confounding factors they couldn't control for. The fermentation finding is not fully understood either, says Amy Lanou of the University of North Carolina at Asheville, although it might have something to do with a reduction in the milk sugar lactose during fermentation. "If some of these effects are mediated by milk sugar, that may be a reason," says Lanou.

SOYA MILK

If cow's milk isn't necessarily all that healthy, what about its most common substitute? Soya milk has a bit less fat than cow's milk, but often comes pre-sweetened, counting towards your intake of free sugar. Its reputation for reducing harmful LDL cholesterol is overblown, too – even if you drank about eight glasses per day that would only equate to a 3 per cent drop in LDL.

Other supposed health benefits – preventing breast and prostate cancer, reducing risk of osteoporosis and hot flushes associated with the menopause – are ascribed to soya milk's high levels of compounds known as phytoestrogens. These can mimic the effect of the hormone oestrogen or, in some instances, block it. But none of these effects has been convincingly demonstrated in trials, while a few studies have suggested consumption of soya milk may actually increase breast cancer risk.

PLAINPICTURE

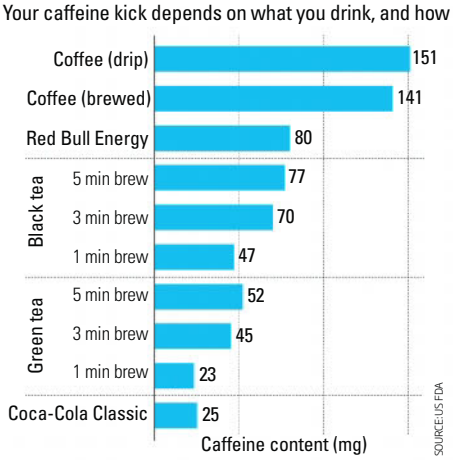
ORGANIC OR NON-ORGANIC?

Organic milk contains higher levels of omega-3 fatty acids than non-organic milk: it comes from cows that eat more grass, which is high in these acids. But even with this boost, total levels of omega-3s are still low in organic milk. And neither kind is allowed to have any traces of antibiotics.

Another common reason to go organic is fear about hormone levels in non-organic milk. All milk naturally contains hormones, but in areas where cows are treated with growth hormones – as happens in some US states but not in the European Union, Canada, Australia and New Zealand – non-organic milk may have higher levels of insulin-like growth factor, a hormone linked to increased risk of some health problems. But the US Food and Drug Administration concluded that it poses no health risk at the levels present in mass-produced milk.

Charting hits

Your caffeine kick depends on what you drink, and how



Based on a 250ml serving size

COFFEE

MANY OF US SEEK LIQUID STIMULATION, AND CAFFEINE IS OUR DRUG OF CHOICE. IT'S PROBABLY NOT AS BAD A HABIT AS WE THINK

Coffee is no good for you – that's the received wisdom, at least. It is full of caffeine that's addictive and can make you bounce off the walls, give you headaches and disrupt sleep. Excessive consumption has been linked to heart disease and cancer. And although coffee increases alertness and focus, the effects are short-lived. Users quickly become tolerant: people who regularly drink coffee are no more alert on average than those who don't. For regulars, the morning brew merely reverses the fatiguing effects of caffeine withdrawal, bringing them back to a baseline level of alertness.

Sounds like one to avoid, then. But Kirsty Pourshahidi of the Northern Ireland Centre for Food and Health in Coleraine, UK, thinks that's overbrewed. "Having looked into it, I don't feel so bad having three or four cups of coffee a day," she says.

Pourshahidi has just carried out a review of the evidence, in work partly funded by the Italian coffee company Illycaffè. For a start, she finds few grounds to suppose that imbibing a moderate amount of caffeine is harmful. For an addictive substance, caffeine is surprisingly easy to kick, too: simply getting people to gradually cut their intake over four weeks is an effective strategy.

Beyond caffeine, coffee contains high levels of compounds called chlorogenic acids, known to slow the body's absorption of glucose. How this works isn't clear, but it backs up the observation that coffee drinkers have a lower risk of type 2 diabetes.

On the other hand, two oily compounds in coffee, cafestol and kahweol, do seem to increase "bad" cholesterol that clogs blood vessels – but most coffee we drink, including instant, doesn't contain much of either, says Pourshahidi. Espresso machines almost entirely get rid of them and French presses don't do a bad job either. The thing to avoid is the boiled, unfiltered coffee popular in Turkey, Norway and Sweden.

Studies on coffee consumption and cancer typically find no correlation or a mildly beneficial effect, except among people who gulp down 40 or more cups a day and those who drink Turkish-style coffee. Even where coffee drinkers appear to be at greater risk than non-drinkers, the studies generally fail to show a proportional relationship between the amount consumed and risk, suggesting some other factor is involved – perhaps that people who drink coffee also drink more alcohol or smoke more, says Pourshahidi. Last June, the World Health Organization changed its stance on coffee from "possibly carcinogenic" to "no conclusive evidence". The sole caveat was that any hot drink – above 70 °C – increases the risk of oesophageal cancer.

> "Coffee drinkers are no more alert on average than others"

So enjoy the odd coffee, but do yourself a favour: let it cool.

TEA

Tea drinkers are often bathed in smug satisfaction: unlike coffee drinkers, their beverage of choice full of life-giving, leafy goodness. Much of the buzz centres on flavonols, with a particular focus on green tea and its most abundant flavonol, epigallocatechin-3-gallate (EGCG). It boasts antioxidant and anticancer effects, at least when added to cells in a dish.

Time to pour some cold water. Although some studies have found that drinking green tea (and to a lesser extent, black tea) lowers the risk of breast, gut and lung cancers, a 2009 ›

review of 51 studies involving a total of 1.6 million people concluded that the evidence was highly contradictory.

It is a similar equivocal story for other supposed benefits. Extracts of both green and black tea reduce blood sugar levels in diabetic rats and mice, and boost glucose metabolism in healthy human volunteers. Tea and its extracts may also reduce cholesterol and blood pressure in people at risk of cardiovascular disease, and animal studies suggest that catechins, compounds found in black tea, can inhibit enzymes that digest fat and starch and perhaps boost metabolism. Some or all of that might explain a small correlation between tea consumption and weight loss in overweight or obese people. So far so good, but the bad news is that the amount of weight lost was so small as to be irrelevant to health, and probably outweighed by other lifestyle choices.

Still, a nice cuppa is unlikely to do you much harm. One woman did lose all her teeth at 47 due to a fluoride overdose from tea, but she had been brewing up 100 to 150 teabags daily for 17 years. For most of us, tea's fluoride content and anti-bacterial properties actually protect our gnashers. A study of tea's potential as a mouthwash found that green tea killed just as many bacteria as a standard chlorhexidine-based version, and would probably work out cheaper. Black tea similarly fights cavities and stimulates the mouth's own antibacterial enzymes.

PLAINPICTURE

SUPER-FLUIDS

MANY IMPLAUSIBLE DRINKS ARE TOUTED AS HAVING HEALTH-GIVING PROPERTIES. FEW OF THEM ACTUALLY DO

COCONUT WATER

Being potassium-rich, coconut water supposedly enhances your ability to absorb water during prolonged exercise. If that were true, though, it would also increase your risk of overhydration. In fact, studies show it is no better or worse at hydrating than a much cheaper beverage: water.

As yet there is no scientific verdict on more recently trending hyper-hydrating waters – including watermelon water, as endorsed by singer Beyoncé, and birch sap water, as endorsed by Nordic folklore.

BEETROOT JUICE

Rich in nitrates that can relax blood vessels and improve blood circulation, there is some scientific support to the idea beetroot juice is good for you. But drink it in moderation: its sugar content is on a par with orange and other common fruit juices (see "Soda, squash and juice", page 34). Too much nitrate has also been tentatively linked with an increased risk of stomach cancer.

WHEATGRASS SMOOTHIES

Wheatgrass contains a smorgasbord of vitamins and minerals, as well as chlorophyll, claimed by some to boost the production of red blood cells. But studies show it is unlikely to benefit you much more than munching green veg such as broccoli and spinach.

KEFIR

A fermented milk drink akin to yoghurt, kefir is prized for its supposed beneficial effects on microbes in our gut. Studies in mice suggest there might be a link – although it is too early to say whether there is an effect in humans, or how big it is.

URINE

Lost in the desert, you are far from any source of fresh water and your bottle is empty. What do you do? You know the drill: unzip your pants.

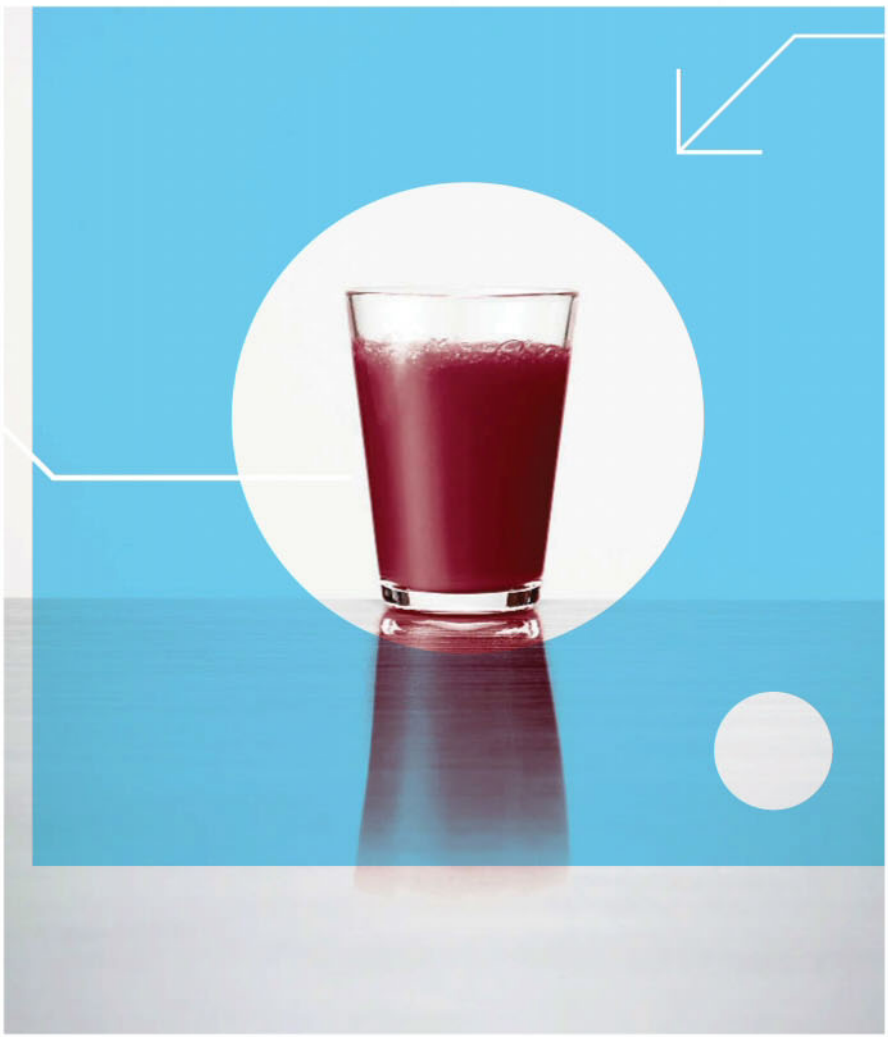
And not just there, if some have their way. From acne to anaemia via obesity and various cancers, many are the ills that urine has been said to alleviate – seeing as it contains vitamins, minerals, proteins, enzymes, hormones, antibodies and amino acids your body has discarded.

> "The myth that urine is perfectly sterile is just that – a myth"

For Joel Topf, a nephrologist at Oakland University in Michigan, though, that's a clue to how useful the active ingredients really are. "The chemicals are not necessarily toxic, but they aren't something that the body wanted to hold on to the first time," he says. Not only that, but they are at concentrations far too low to be useful.

So, urine is disgusting and unhelpful, but harmless, right? Well, maybe not. One component of urine rarely mentioned by those who promote drinking it is phosphorus, a possible cardiac toxin. The myth that urine is perfectly sterile is just that, too – a myth. Drinking it could bring you down with all sorts of nasties.

Let's seek advice from the real survival experts. When it comes to preserving precious bodily fluids, the US army's 1999 survival field manual puts urine firmly alongside blood, seawater and fish juices in its "DO NOT DRINK" category. It's not a cultural thing that we don't like drinking urine, says Topf – it's evolutionary. "Urine is waste, not medicine. Stop drinking your urine."



PLAINPICTURE

VINEGAR

Cleopatra supposedly dissolved pearls in vinegar to make Mark Antony a love potion. Some 2000 years later, people are still banging on about vinegar's power to cure erectile dysfunction – and lower your blood pressure, cholesterol and weight to boot.

On the cardiovascular front, they might be on to something. A small-scale study conducted in 2010 at Arizona State University showed that both diabetic and non-diabetic volunteers had more stable blood sugar and insulin after a meal of complex carbohydrates if they first had a drink of diluted vinegar. Other studies have shown similar, if small, effects.

Acetic acid – the source of vinegar's characteristic mouth-puckering bite – is generally thought to be responsible, although no one can pinpoint how. Vinegar also contains a teeming collection of amino acids and polyphenolic compounds that might play a part. The jury is still out on whether all this actually makes you lose weight – although one South Korean study on the effects of drinking pomegranate vinegar did show that, regardless of whether participants lost weight, they did lose a particularly dangerous type of body fat.

Any benefits must be set against the deleterious effects of acetic acid on tooth enamel. And would-be Mark Antonys should note: for pearls to improve your sex life, they are best served whole.

ALCOHOLIC DRINKS

"Wine is the most healthful and hygienic of beverages." So said that master of liquid health and hygiene, Louis Pasteur. With more than 100 studies confirming a link between moderate alcohol consumption – one or two drinks a day – and a decreased risk of heart attack or stroke, it is tempting to raise a glass to him and to that.

Stay that hand, though. A confounding factor in most such studies is that people who drink in moderation also tend to share characteristics that lower heart-disease risk: they exercise more regularly, have a healthier weight, sleep better and are more affluent than those who drink to excess or never drink (perhaps because they quit due to health problems).

Overall, there is no consensus on who, if anyone, might benefit from moderate alcohol consumption, and by how much. Older people do seem to benefit more, but that could be because their overall risk of

"There's no consensus on who, if anyone, benefits from alcohol"

heart disease is higher. There is similarly no undisputed evidence that red wine arrests cognitive decline, as has been suggested.

Set these small and disputed benefits alongside the 3.3 million deaths that the World Health Organization attributes directly to alcohol consumption each year, and the fact it is classified alongside asbestos as a class 1 carcinogen, and things start to look that much less positive.

But let's not go overboard. There's a lot to be said for alcohol's role as a social lubricant, and few studies connect moderate consumption with any significant increased mortality risk. One drink also makes you better at creative problem-solving. As with so much, the difficulty is knowing when to stop.

For more of the latest research on the effects of alcohol, go to https://www.newscientist.com/article-topic/alcohol/

Words by Sally Adee, Daniel Cossins, Joshua Howgego, Graham Lawton, Tiffany O'Callaghan, Richard Webb and Caroline Williams

Be the architect of your emotions

Feelings like happiness and anger are thought to be hardwired and universal. Not so, says **Lisa Feldman Barrett**, your emotions are yours alone

What are emotions?
The classical view says your brain is off, then something happens and a defined set of neurons fires to cause an emotion. So, say a snake slithers towards you – it supposedly triggers a built-in circuit for fear: your heart races, you sweat and you make a specific, universal facial expression that everybody in the world can recognise.

Every time you feel fear, the same neurons produce the same reaction, and that's true not just for you but for every other healthy human in the world.

So in the traditional picture, emotions are hardwired in all of us?
Right. Definitely happiness, sadness, anger, fear, surprise and disgust. It is a very commonsensical view.

This view has held for nearly a century, but you say it is flawed. Why?
The problem is the data don't bear it out. People don't generally scowl when they are angry, they don't pout when they're sad, and they don't widen their eyes when afraid.

I lost faith in the classical view at graduate school. I tried to reproduce a finding that had been published a number of times, which should reliably lead people to experience anxiety or depression. In eight experiments over three years, I was never able to replicate it.

When I looked closely at my data, I realised that my subjects weren't distinguishing between anxiety and depression. So I figured I would just measure emotion objectively – without asking how they felt. I thought it would be straightforward because everybody knew that different emotions have unique facial and physical signals.

But it didn't work. If you look at the literature on facial expressions, most studies that support universality use a kind of psychological cheat – experimenters might force subjects to pick from a small set of emotion words when shown a facial expression, or unwittingly train subjects in the appropriate emotion concepts.

My lab and others have shown that if you remove these cues, say, by asking subjects what a face means without a list of words to choose from, the whole effect falls apart. Studies of cardiovascular changes, brain imaging and measurements of the neurons themselves consistently call the classical view into doubt.

So what really goes on in our brains when we experience emotion?
Put simply, your brain constantly takes in information and tries to make sense of it to regulate your body appropriately. What caused this flash of light, your brain asks, or this change in air pressure, this ache or tightness? What are they most similar to from the past? This constant stream of guesses produces your feelings.

How does emotion arise from this process?
When the sensations from your body are very intense, your brain categorises them as an emotion. It does this using concepts. To understand how this works, think about money. It is a human-created concept: those pieces of paper have no objective value, but we impose a function on them that they would not have otherwise. Emotions are similarly ›

PROFILE
Lisa Feldman Barrett is a University Distinguished Professor of Psychology at Northeastern University in Boston. Her book *How Emotions are Made: The secret life of the brain* (Houghton Mifflin Harcourt) is out this month

Photographed for New Scientist by Ken Richardson

made with concepts. If I smile at you, it has a meaning for both of us as happiness because we have learned and agree on that meaning.

Your brain makes an emotion by using learned concepts to make predictions and give your sensations meaning. It constructs a concept of fear in the moment and predicts that your change in heart rate, the feeling of tension and the urge to run are caused by fear. If you have anticipated correctly, then fear becomes the explanation for why your body is in this state. Sensations from your body and physical actions are not intrinsically emotional. They become part of an emotion when your brain makes them meaningful.

So fear and happiness only exist because we, as a society, decide they do?
Yes. Happiness exists because we impose functions on smiling, on bodily changes and on certain other behaviours. We have collective agreements about those functions.

Are you saying that you have to have a concept of an emotion in order to feel it?
Tahitians don't have a concept for sadness, but they will still have that low, draggy, affective feeling that Westerners often construct sadness out of – though we could also construct fatigue, boredom and even hunger from it. If a Tahitian mother loses a child, she feels physical sickness. She feels the loss but there is no guarantee that she feels it the same way as someone from a different culture.

The Dutch have a concept called *gezellig* that is best translated as cosiness, comfort and a feeling of togetherness. It is not about feeling close to another person – it is more a way of experiencing a situation. The first time I felt *gezellig*, my brain combined conceptual knowledge of "close friend", "love" and "delight" with a touch of "comfort" and "well-being".

But the idea that emotions are hardwired and universal underlies many things…
Very much so. The example that really gets me is the training of autistic children to recognise the stereotyped expressions stipulated by the classical view. This training is supposed to improve children's social functioning. But nothing changes for these kids because these facial expressions don't generalise outside the lab.

Do other projects face similar problems?
Huge amounts of money are being spent on technology rooted in the idea that facial expressions are universal. For example, the US Transportation Security Administration spent $900 million on a method of reading faces and bodies that is rooted in the classical view. It didn't work.

Microsoft and Apple are trying to develop emotion-detection tools using the same stereotypes. They are going to fail, and when they do, instead of realising that they were trying to measure the wrong thing, they will probably abandon the entire enterprise. It's really unfortunate, because their methods could be used to read emotion by learning the emotional vocabulary of individuals.

What about the common trope that women are more emotional than men?
This belief is pervasive in Western cultures. But when you measure people on a moment-to-moment basis or look at physiological changes, you don't see any evidence for it. Some experiments find that women move their faces more than men – not just for emotion, but as a baseline. Given that the classical view of emotion puts so much importance on facial expressions, you could hypothesise that it helps to maintain the stereotype.

"I have a word for the feeling you get after eating an entire bag of potato chips"

And this stereotype is extremely damaging – there is evidence that when you refer to a woman as emotional, it usually means too emotional. So there's a catch-22: if a woman is emotional, she's seen as childish or out of control. If she's not emotional enough – she defies the stereotype – she's seen as a cold, untrustworthy bitch. For men the rules are not so strict. This is a real problem in courtrooms. There are people who can't get a fair trial because jurors – and judges – accept the stereotype and believe that, generally, emotions can be easily read.

Does this view have other legal implications?
Much of the law is rooted in a Cartesian view of the mind, that we are basically animals at our core, wrapped in the safe rationality of cognition. The animalistic brain contains automatic emotional reactions that you try to control with cognition. But you don't always succeed – and in this view you are less responsible for your behaviour when it has been hijacked by emotion. A crime of passion implies that your actions were caused by emotion, and this affects how people are sentenced.

If emotions are constructed, can we build them in different ways?
Yes. You are an architect of your own experience. Your experience in the here and now is constructed out of your past, because your brain can take bits and pieces of that past and recombine them in new ways. I'm not saying you can snap your fingers and change how you feel. But the horizon of your control is much bigger, much broader than you think.

For example: a student preparing for a test will be in a high arousal state. They might experience this arousal as anxiety, but they could learn to recategorise it as determination, which research shows will allow them to perform better on tests. This recategorisation can reduce stress, so they feel physically better too.

Can I really train my brain to feel differently?
You can cultivate experiences and curate concepts that give your brain the ingredients to make emotions more flexibly later. A great resource is emotion concepts from other cultures. For example, Japan has *arigata-meiwaku*, the negative feeling when someone does you a favour that you didn't want, are perhaps inconvenienced by, yet must still be grateful for. Learn this concept and your brain can make emotions with it.

You can also create new emotion concepts in concert with others. In my house, we have "chiplessness", which is what I feel when I finish something I really enjoyed but probably should not have done, like eating an entire bag of potato chips. It combines guilt and disappointment with a hint of desire.

When you feel angry or sad, or dejected, or chipless, you have a repertoire of things you can do. The more emotion concepts you know – not just one anger but many angers, each one fitting a particular situation – then the better you will be at regulating your emotions. Concepts are tools for living.

It is also important to maintain your physical health, because your brain uses body sensations to help make emotions. If you tax your body too much, the emotions you create are more negative.

What advice do you have for parents?
Research shows that teaching kids emotion words expands their vocabulary of concepts and improves academic performance. This may be in part because a larger vocabulary tunes emotions more finely to the situation – being "frustrated" or "irritated" instead of just "angry" – and that improves self-control.

Why has the idea that emotions are universal lasted so long?
Universality props up a particular theory of human nature – that there is only one kind of human mind with parts that we all share, like anger, sadness, fear and so on. But there's a porous boundary between what's outside and inside your head. Brains wire themselves to the physical and social world, making many kinds of minds. We are responsible for the social reality that helps to create the minds of the next generation. ■

Interview by Shannon Fischer

A new tragedy?

How will green thinking fare under very different politics, wonders **Fred Pearce**

A Good That Transcends: How US culture undermines environmental reform by Eric T. Freyfogle, University of Chicago Press
The Politics of Scale: A history of rangeland science by Nathan F. Sayre, University of Chicago Press

AMONG the pledges that won Donald Trump the US presidency was one to shred the legislation underpinning federal environmental control – opening up wilderness and the wide open spaces of the American West to coal mining, oil drilling, pipeline laying and much else. It's not just climate change that Trump's supporters are sceptical about: there is pushback against environment law of all sorts.

What's going on? In his book *A Good That Transcends*, lawyer Eric Freyfogle doesn't mention Trump. But he is clear that what lies behind long-standing and growing "popular resistance" to green thinking is a devotion to the primacy of the individual and private property at the expense of any ideas that require collective endeavour, such as environmental management of the great spaces and wildernesses where bison once roamed.

In theory, that doesn't mean Americans are opposed to the environment. After all, even Trump recently claimed that he is "a very big person when it comes to the environment. I've received awards on the environment." But everything is ultimately seen through the lens of the rights of the individual. Private property eclipses everything.

Thus, the heroes of environmentalism tend to be philanthropists who buy up land to protect it, such as media mogul Ted Turner's bison prairies, or the purchase of big chunks of Patagonia by fashion entrepreneurs Doug and Kris Tompkins.

The science gets skewed towards this agenda too, with consequences that have been bad not just for the US heartlands but for much of the world. Take the ascendancy of perhaps the most influential idea of all in modern environmental management, the "tragedy of the commons", coined by US ecologist Garrett Hardin.

"The heroes of environmentalism tend to be philanthropists who buy up land to protect it"

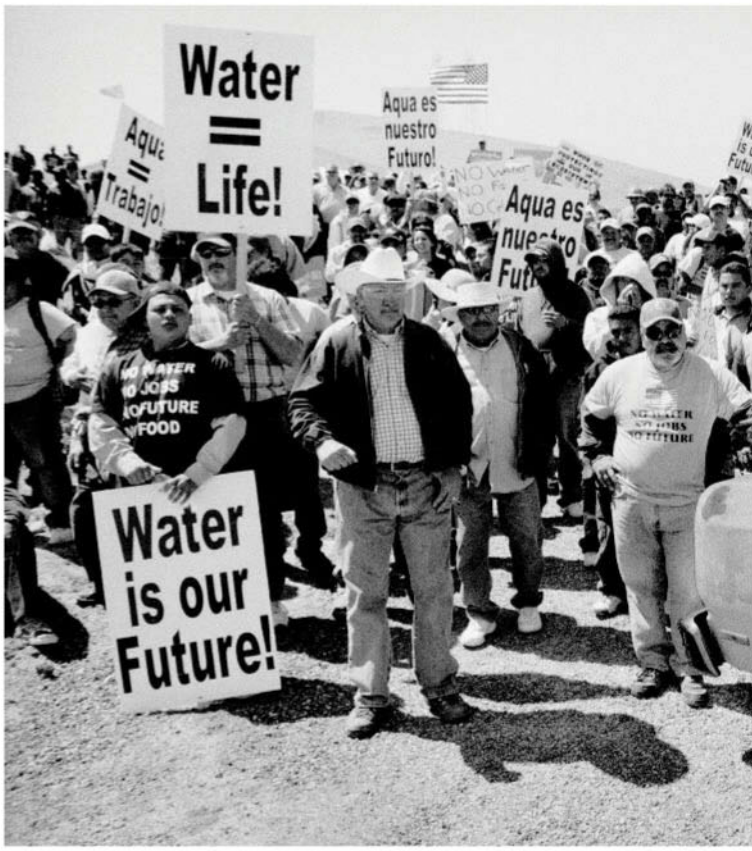
In essence, it holds that collectively owned land is doomed to be destroyed, while private land will prosper because it has value to an individual. In one of the most cited papers ever in *Science*, published in 1968, Hardin argued that a commonly owned pasture, where many cattle herders graze their animals, would always be overexploited.

This was because those with the most animals would make the most profit, while everyone – however many or few animals they have – would share in the suffering as the actions of those individuals turned the pasture to desert.

The only way to prevent this tragedy was to turn common land into private property, whereby the owner had a personal interest in protecting it for the future. By inference, privatising the planet is the key to conservation.

No, no, no, says Freyfogle. If not controlled by strong environmental law, private property destroys natural assets by converting them into cash. Look at how fences and ploughs have wrecked the ecosystems of the US Midwest. Privatisation didn't prevent the dust bowl of the 1930s. Even access to rainfall – a quintessentially collective asset – is handed out as a private right that goes with land. Result: California is parched as farmers defend to the death their legal right to keep abstracting.

This is a tragedy not of the commons but of private property. And perhaps of the US Constitution, too. "Life, liberty and the pursuit of happiness" won't save nature. To do that, says Freyfogle, we have to "curtail individual liberties". Landowners cannot have absolute rights to their land. We need to



STUART PALLEY/ZREPORTAGE.COM/EYEVINE

MATT BLACK/MAGNUM PHOTOS

No more deserts: how should we best manage assets such as water?

banish the idea that individuals or markets can fix nature.

This is a well-argued critique of land ethics in the US. But where does science fit in? Freyfogle is pretty hostile to it. The Enlightenment "weakened" ideas about collective management of nature, he says, and promoted the primacy of the individual and "the market-based view of nature". That's a bit harsh. Collectivisation hardly treated the steppes of the Soviet Union well, creating conditions for famine worse even than the American dust bowl.

In *The Politics of Scale*, geographer Nathan Sayre makes a not dissimilar case. The US rangelands – the grasslands, steppe, prairies and deserts of the American West – have been badly managed because of bad science, he says. Science encouraged people to demonise cattle grazers as ecological despoilers and to obsess about preventing fires – even though the grasslands were created by grazing and fire is an essential part of many ecosystems.

Much of this he puts down to the "fateful mistake" of academic devotion to the early 20th-century ideas of Nebraskan botanist Frederic Clements on ecological succession. Clements held that every place had only one correct "climax" ecosystem, and any variance on that had to be resisted. Fires destroyed climax ecosystems, and grasslands had to be maintained in their present state through rooting out weeds and imposing fixed stocking rates for grazing animals.

Such environmental management is bound to fail. It has, all over the American West. So how did such ideas gain widespread and long-lasting acceptance?

Sayre calls the mistakes "blind spots", but also blames the "institutional context". Or, as Freyfogle might have put it, scientists were too keen to do the bidding of their paymasters, the big landowners who alone could deliver the fences and fire beaters that their diagnosis required.

This tragedy of land privatisation isn't restricted to the American West. Efforts to prevent "desertification", notable in Africa in the 1970s and 1980s, built on failed US science, says Sayre.

"Science won't change anything until cultural ideas come into line with ecological imperatives"

In their work for the World Bank, UN development agencies and others, US scientists explained their degraded ecosystems back home "not as evidence of their own failure, but as proof of the urgency to intervene in other arid and semiarid rangelands to prevent 'desertification'".

Here Sayre agrees with Freyfogle about the unwritten political agenda of the scientists – how "outside capital was portrayed not as the cause of rangeland degradation but as the solution to it". The common pastures had to be privatised.

Are things any better now? Sayre is guardedly optimistic. The ideas of Clements and Hardin have been largely discredited among scientists, he says. But Freyfogle isn't so sure. Even if Sayre is right, science won't change anything until our wider cultural ideas come into line with ecological imperatives. He quotes Pope Francis's 2015 environmental encyclical, which said that "it is we human beings above all who need to change".

That doesn't feel like a Trump agenda. ■

Fred Pearce is a consultant for *New Scientist*

You've got 48 hours to write a sci-fi gem

WRITERS are often asked where they get the ideas for their stories. Replies are generally terse. "The mortgage company's final demand" is a favourite.

Equally, waiting around for inspiration is a mug's game. Far better to put yourself under the right kind of pressure. The US science fiction writer Harlan Ellison once pulled off a stunt to make the point.

At the close of one of NBC's *Today* shows in April 1981, interviewer Tom Brokaw held up an envelope containing a piece of paper that read, "August afternoon a person walking along a rocky beach in Maine picks up a pair of broken sunglasses."

At 9.45 am the next day, Ellison climbed into a window of a Fifth Avenue bookstore, read Brokaw's words for the first time as a crowd looked on, and began to write. Five hours later, he had finished his short story "The night of black glass".

In that spirit, we've partnered with the Sci-Fi-London festival and Urbanfantasist.com to run an exciting short story competition, the 48-hour Flash Fiction Challenge. The competition will take place over the weekend of Saturday 8 April.

We will give you the title and a piece of dialogue. Using those elements, you will write a story of no more than 2000 words in 48 hours. The best story we receive within that time will be published on *New Scientist's* website, and the author will win £500 and a VIP pass to Sci-Fi-London, which runs from 27 April to 6 May.

To enter, visit sfl.to/ns48ff now and register so you can access the title and dialogue you'll need to complete your story. The full competition rules are also available from that web page. ■

Strange futures

What was hippie modernism? **Jonathon Keats** explores

Hippie Modernism: The struggle for utopia, UC Berkeley Art Museum and Pacific Film Archive, University of California, to 21 May

VISITING the Dutch Antilles in the Caribbean in the early 1960s, Alfred Henry Heineken was distressed to find many islanders lacking decent housing. He was also appalled to see beer bottles littering the beaches. Reasoning that the empty bottles could be used to build with, the heir to the Heineken brewery commissioned a new glass vessel ideally shaped for stacking and mortaring.

Heineken's factory started to produce the WOBO (world bottle) in 1963, and initial tests showed the flat-sided containers to be as good as bricks. But concerns over brand image and legal liability put an end to the utopian experiment before the first bottles shipped.

Today, the WOBO is an oddly shaped time capsule, typifying an era of rampant idealism tempered by bitter disappointment. It is an apt intro to Hippie Modernism, UC Berkeley Art Museum and Pacific Film Archive's survey of bold efforts to reimagine society in the 1960s and early 1970s.

As curator Andrew Blauvelt concedes in the superb catalogue, "hippie modernism" seems at first to be a paradoxical term, but it turns out to be useful when considering the era's visionary products and initiatives. "Unlike the technocratic impulse that viewed scientific advances as intrinsically progressive and socially good, the hippie modern sought alternative uses which were increasingly adapted for personal creative effect and collective betterment," he writes.

While the WOBO was unusual for its corporate origins, one of the cleverest and cheapest of the movement's inventions also focused on trash. It comprised a simple radio housed in a recycled fruit juice can and powered by cow dung.

Conceived by the industrial designer Victor Papanek and his student George Seeger, receivers were made for less than 9 cents apiece and distributed to illiterate Indonesian villagers, connecting them to the outside world in the hope they would be empowered by what they heard. The radios were enthusiastically received and festooned in local fabrics. They also probably made village life more interesting – but they failed to meet Papanek's grandiose ambition: nothing less than to end global inequality.

However, the mood of the time wasn't entirely optimistic. After all, one countercultural credo was to question everything. Some strains of hippie modernism embraced that scepticism, few more playfully than Archigram, the architectural and design collective. Many of its concepts – such as cities on feet that could walk away from their problems – were unbuildable. Others, such as an electronic tomato, teetered on the brink of plausibility.

"Simple radios in fruit juice cans, powered by cow dung, were distributed to illiterate Indonesians"

Represented by a collage of a mod girl wired to an enormous tomato, it was allegedly able to "direct your business operations, do the shopping, hunt or fish", or you could "enjoy the electronic instamatic voyeurism" from your home. In other words, a vegetal forerunner to the smartphone.

Like most Archigram projects, the tomato satirised mainstream modernist tendencies, especially technology's stultifying embrace. This critical mode needed few resources compared with the WOBO or Papanek's radios. Together with other collectives, such as Superstudio and Haus-Rucker-Co, Archigram influenced the mainstream from the outside.

Haus-Rucker-Co was perhaps the most compelling of this first generation of speculative design groups. It specialised in inflatables, self-contained environments (often transparent plastic bubbles) that it presented as refuges from air pollution. While clearly not intended for mass production, the bubble worlds still seem a little too useful to be strictly polemical. As solutions to problems created by our technologies, they are alluring and troubling, provoking us to question everything.

For all its failings, hippie modernism succeeded in generating questions by design. This worthy legacy is an incentive for practising it today. ■

Haus-Rucker-Co's perception-altering "Flyhead" helmet

ENVIRONMENT TRANSFORMER/FLYHEAD, 1968; DIGITAL PRINT; ARCHIVE ZAMP KELP. PHOTO: GERALD ZUGMANN. © HAUS-RUCKER-CO.

Jonathon Keats' latest book is *You Belong to the Universe: Buckminster Fuller and the future*

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Fermi GBM Observations of LIGO Gravitational Wave event
published by V. Connaughton, USRA, E. Burns and A. Goldstein, NASA Postdoc, et al.

Image Credit: NASA/C. Henze

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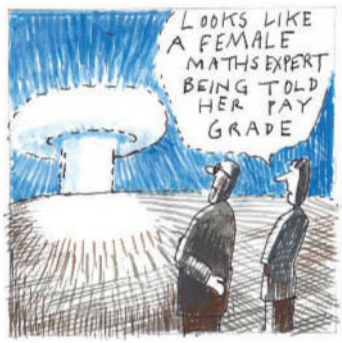
EDITOR'S PICK

More than NASA depended on women



From Kathryn Nelson, Caversham, Berkshire, UK

It wasn't just NASA that depended on the skills of women mathematicians (21 January, p 40). My mother, Dolores Guarneri Nelson, worked for General Electric in the 1950s on the liquid metal fast reactor for the USS Seawolf, the US's second nuclear submarine. She was tasked with setting up calculations to validate the engine design.

She had a degree from Purdue University, but engineering posts were not given to women so she was graded as an assistant and given a significantly lower salary. There was one African-American on the team; when they went to Washington for meetings, he had to stay in a different hotel.

She gave up work, as expected, when she started a family and so was unable to keep up with advances in software development. How far we have come, not just in technology but in equality of opportunity. I know I've been fortunate – society is by no means free of gender and race bias – but my daughters' response to their grandmother's stories is "Really? You've got to be joking!"

If I'm still not awake, then you're not real...

From Richard Weeks, Felixstowe, Suffolk, UK

Frequently asking myself, "Is this a dream?" apparently allows me to do the same when asleep, providing a route into lucid dreaming (18 February, p 32). Mustn't I take care not to answer the question, though?

If I habituate myself to confirm I am not in a dream, won't I program myself to confirm I am not in a dream at all times?

But if I don't answer the question when awake, why should I expect myself to when asleep? Perhaps it is best always to tell myself that I'm in a dream... which I suspect to be the case anyway.

From Allan Brash, Mornington, Victoria, Australia

Before I knew about lucid dreaming, I taught myself some techniques to deal with nightmares. I simply make my mind blank in the dream, which leads me to wake up. Sometimes it is quite an effort, but it always works.

The most enjoyable part of a lucid dream, apart from the awareness that it is a dream, is explaining to people there that they are just figments of my imagination. They look at me, as they would in real life, as though I were barking mad.

This doesn't make the dream any less dream-like, but it does increase the entertainment value.

A space rose by another name smells sweeter

From Javier Martin-Torres, Kiruna, Sweden

I am working on the HABIT instrument that will be part

"My dog woke up and looked around in confusion when I played that sound"

Christine H experiments further on sounds birch caterpillars make with their anuses (4 March, p 19)

of the European Space Agency's ExoMars 2020 mission (18 February, p 7). I appreciate that naming space missions after great personalities in the history of science, such as Darwin, Galileo and Cassini, is a gesture of respect. But the recent crash of the ExoMars Schiaparelli module made me ponder whether we should avoid naming space missions after people.

We could celebrate them after the mission is operational, and use a provisional name until then. Contradicting Shakespeare, we should name the rose after the sweet smell of success.

Why should we flunk recycling space junk?

From Adrian Bowyer, Foxham, Wiltshire, UK
The cost of lifting things into orbit is so high that everything there is effectively made of gold. So why are we trying to send space junk into a decaying orbit to burn up (11 February, p 4)? Surely it would be better to launch a fabricating satellite that could gather the junk, refine it and make it into useful satellites? There is plenty of energy available up there, after all.

If the fabricating satellite made copies of itself, junk would be cleared at an exponentially increasing rate, and we would end up with a vast orbiting production capacity.

More than one can play at national security

From Alan Ramage, Plymouth, Devon, UK
You report US President Trump's executive orders reducing the powers of the Environment Protection Agency and restricting scientists with regard to climate change research (11 February, p 4). Can these actions not be challenged through the US courts as threats to national security? After all, the Pentagon reported in 2014 on the risk climate change poses on these grounds. Trump doesn't have to be the only one playing the national security card.

If the President then turned his invective on to the military as well as judges, scientists and parts of the media, that might not go down well with his core constituency.

It's a very local sea level and the drains don't fit

From Harold Smith, Letchworth Garden City, Hertfordshire, UK
Laura Spinney mentions two reference datum points at which sea level is measured in the UK, at Newlyn and Belfast (11 February, p 38). There used to be a third, at Liverpool. The construction firm I worked for had a site in central London that crossed a boundary between two local authorities: one side was levelled to Newlyn and the other to Liverpool. The discrepancies made problems for the public health engineers trying to plan the drainage. This was obviously well known to the Ordnance Survey, who were able to supply a correction factor when given a grid reference.

Koalas should beware the wily goanna

From Guy Cox, St Albans, New South Wales, Australia
Alice Klein reports observations of Australian foxes learning to climb trees (18 February, p 9). This is fascinating, but I think the threat to baby koalas and other arboreal life is overplayed. Monitor lizards, or goannas, which can exceed ›

2 metres in length, are at least as agile in trees as foxes, and every bit as voracious. Both are probably more interested in eggs and chicks than baby koalas.

From Anthea Fleming, Melbourne, Victoria, Australia

A farmer here in Victoria told me 50 years ago of his difficulty in getting any cherries from his tree. "I went out one night to shoot the possum I thought was robbing the tree, and what fell on my head was a fox!" It had been eating the fruit. So their climbing trees is not new.

I have often seen fox scats full of plum stones or *Crataegus* seeds and also the remains of beetles and grasshoppers. They seem to be omnivorous.

Together, could baboons and orangutans talk?

From Quentin Macilray, Limassol, Cyprus

You report that baboons have mastered vowels (14 January, p 12) and that orangutans can do consonants (17/24/31 December 2016, p 15). Surely now we have the answer to the mystery of human speech? Put them together and what have you got?

If music be the food of multitasking, play on

From Ken Smith, Tunbridge Wells, Kent, UK

Emma Young's interesting report on speed-reading reminded me how easy it is to comprehend almost every article in *New Scientist* (11 February, p 34). It also made me wonder whether there has been equivalent work on reading and playing music.

I am a chartered engineer who enjoys playing the piano outside of work. To do this I have to simultaneously read the dots, comprehend the instructions they indicate and apply my fingers accurately to the piano keys using both hands.

The score often has different keys, tempos and rhythms, including handfuls of chords in a single bar. A page of music has separate bass and treble staves (at least) and requires more eye movement than reading a line of text. It is clearly much easier to read when one is on "auto pilot" with an often-played piece, but there is no room for slowing down or speeding up while determining the best fingering pattern.

How does the brain manage such a collection of variables against the relentless ticking metronome?

The infinitesimally likely can happen at any time

From Robert Jenkins, Adelaide, South Australia

Anil Ananthaswamy, suggesting we reject universes that lead to "cosmic brains", rightly says that "there is always an infinitesimal probability that a system will suddenly fluctuate from disorder to order" (18 February, p 9). Then he quotes Sean Carroll saying that at 14 billion years old, our universe is too young for this to have formed Boltzmann brains.

The infinitesimal probability of this event occurring existed in the first nanosecond of our universe and in every nanosecond thereafter. You do not need an infinite time for the vastly improbable fluctuation to occur – you just need something with an infinitesimally small probability to have occurred.

Entanglement does not send messages

From Eric Kvaalen, Les Essarts-le-Roi, France

You say that particles' states "can be entangled – such that altering one affects the other much faster than light can travel between the two" (11 February, p 7). But you do not affect the other. Measuring some property of one determines the outcome of a measurement on the other.

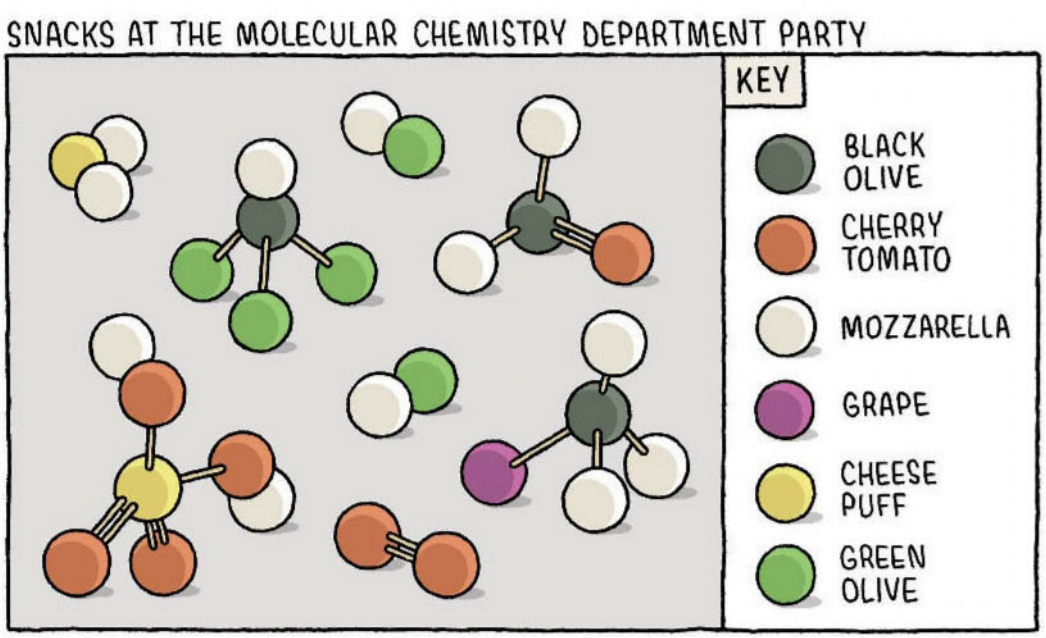
In an experiment like the one described, you cannot say the measurement at A affected the photon at B: it would be just as valid to say the opposite.

So who passed the Affordable Care Act?

From Bill Ross, Toronto, Ontario, Canada

Marilyn Lott makes a valid point about calling the "Affordable Health Care Act" by its correct name (Letters, 11 February). But it was able to pass into law because, for a short period in 2008-2009, the Democratic Party held the White House, a majority in the House of Representatives and a super-majority – enough to stop filibustering – in the Senate.

TOM GAULD



For the record

■ **Boom! It would have been more precise to say that NASA's Quiet Supersonic Technology plane is designed to emit sonic booms 40 decibels quieter than Concorde's (25 February, p 34).**

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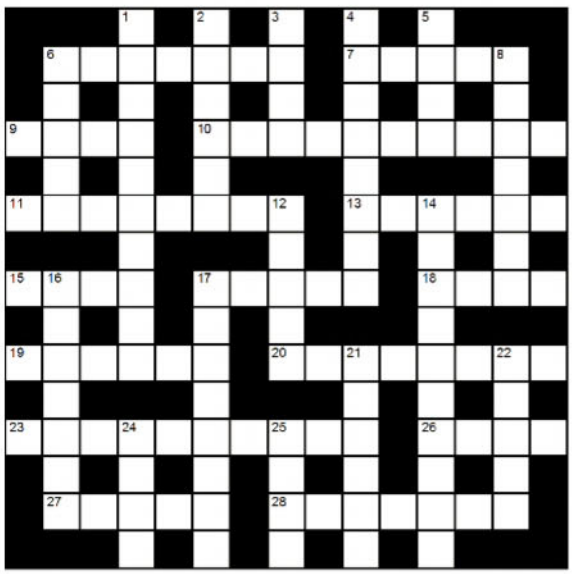
CROSSWORD

Compiled by Richard Smyth



Crossword No4

ACROSS

6 The simplest amino acid (7)
7 Blood-sucking annelid of the subclass Hirudinea (5)
9 An image, video or concept that spreads rapidly on the internet (4)
10 Device that may operate according to the principles of positive displacement, momentum transfer or entrapment (6,4)
11 Unit of length equal to 10^{-10}m (8)
13 Up and running; in 1 down (6)
15 *Darwin's Dangerous* ___, 1995 book by Daniel Dennett (4)
17 Biological compound, a precursor of certain neurotransmitters (1-4)
18 Disease of the immune system, identified in the early 1980s (4)
19 Algebraic term describing a first-order equation involving two variables (6)
20 The amount of light that reaches a photographic film (8)
23 Principle of physics proposed in 1900, relating to the spectral density of black-body radiation (7,3)
26 Six-sided, 12-edged object (4)
27 Statistics: the difference between the smallest and largest values (5)
28 Dark biological pigment, found in hair, feathers, scales and skin (7)

DOWN

1 The virtual world of the internet, as coined by William Gibson (10)
2 Element, chemical symbol Ag (6)
3 In the UK, the Natural Environment Research Council (4)
4 Disease caused by an increase in pressure within the eyeball (8)
5 Term for a tide in which the difference between high and low tide is at its lowest (4)
6 John ___ (1921–2016), US astronaut (5)
8 A human, or an ancestor of humans (7)
12 Sir Patrick ___ (1923–2012), astronomer and TV presenter (5)
14 Interval inserted into Coordinated Universal Time roughly once a year (4,6)
16 Gottlieb ___ (1834–1900), inventor of a high-speed internal-combustion engine (7)
17 Colourful parrot of Australia and New Guinea (8)
21 Cecil ___ (1903–69), English physicist noted for his discovery of the pion (6)
22 Vera ___ (1928–2016), US astronomer whose observations provided evidence for the existence of dark matter (5)
24 The only positive perfect power that is one more than another positive perfect power (4)
25 Type of safety device associated with Sir Humphry Davy (4)

Answers to Crossword No3

ACROSS: **7** ACETONE, **8** FORTRAN, **9** O-RING, **10** CAVENDISH, **11** LAMINAR, **13** ACACIA, **15** BLISTER BEETLE, **19** ACIDIC, **20** THOMSON, **23** THE LANCET, **24** LIGHT, **26** UPSILON, **27** INTEGER. **DOWN:** **1** SETI, **2** MORGAN, **3** NEOCORTEX, **4** BRINICLE, **5** BRAIN CELLS, **6** ANTHRAX, **7** APOLLO, **8** FIVE, **12** MULTIVERSE, **14** OBSTETRIC, **16** SPIRACLE, **17** PASTEUR, **18** INSTAR, **21** OOLITE, **22** SCAN, **25** GIGA.

PAUL MCDEVITT

HERE'S a tipple that will moisten your mouth and your eyes at the same time. Michael Zehse spies a company selling water from icebergs calved from Norwegian glaciers.

Svaldbardi describes its product, priced at £80 a bottle, as exceptionally pure water that was last in liquid form up to 4000 years ago. Given the remarkable capacity of bacteria to survive millennia frozen in ice, Feedback is tempted to add "untreated" to that description.

The makers of Svalbardi pride themselves on a product that is especially tasteless, a boast that Feedback won't contest. For every bottle sold, though, a donation is made to the Svalbard Global Seed Vault, meaning customers can quaff in the knowledge that they are contributing to the cost of running the vault's generators, which will be especially needed once all the ice is gone. Those who can't afford iceberg water can perhaps wait for the crack progressing through Antarctica's Larsen C ice shelf to complete its journey, dispatching an iceberg the size of Trinidad into the Atlantic. Delivery times may vary – just remember to bring your ice pick.

A COURTROOM conundrum: David Head notices a report in *The Times* of a court case in which the judge "described the defendant… as a 'self-confessed liar'."

David wonders whether this means the defendant was lying when he confessed to being a liar, and so was not a liar, and so was telling the truth when he said he was a liar, and so…

FINDING himself similarly confounded is Dick Duane, who complains that he added his phone number to the UK's national "do not call" list for warding off marketing agents as soon as it was installed. Therefore he was surprised to receive a recorded sales call.

At the end, the recording told him that if he wished to be removed from the do not call list, he should press 8. "How thoughtful of them!" says Dick.

"Marmalade is the preserve of the elderly," writes *The Daily Telegraph*. "I prefer it to be made from oranges," muses Crispin Piney

WE FIND ourselves concerned about the optimum number of corners on oatcakes, following a report of a schoolboy injured by flying flapjack (25 February).

"Square flapjacks have more corners so might be more dangerous," writes Brian Horton, "and on that basis round flapjacks have an infinite number of corners, so would be infinitely more dangerous. Except that the danger must relate to the sharpness of the corner, so maybe circles are infinitely safer than triangles."

We feel assaulted by Brian's use of the infinite in relative measures, but he does propose a solution: "Since Feedback also wants a tessellated baking tray, it is clear that flapjacks must be hexagonal, giving less acute corners that will not cause serious injury when users are hit in the face by one."

Feedback prefers the following solution: cut flapjacks into circles before serving to children, and send us the leftovers.

ON THE question of what words, printable or otherwise, can be spelled out using chemical symbols (18 February), Keith Perring notes that "of the four new elements ratified by the International Union of Pure and Applied Chemistry last November, Tennessine (Ts) seems to help – but only for forming the plurals of certain slang terms".

PREVIOUSLY Rex Waygood sought enlightenment about his light bulbs, whose output was measured in very obtuse terms of "10 kWh/1000h" (21 January). "Could they have used a more obtuse power rating?" he cries. "Surely it would have been much simpler to have used good old British imperial units," replies Barry Cash, "and defined the power rating as 13 and 2/5th horsepower per 1000 hours?"

But as the UK marches Brexitward, some are keen to reinstate old-fashioned imperial units. Feedback notes that as things stand in the metric system, 1 cubic centimetre of water contains 1 millilitre, weighs 1 gram and takes 1 calorie to warm by 1 degree Celsius. A cubic inch of water, meanwhile, contains 0.58 fluid ounces, weighs 0.58 ounces and takes 0.0036 British Thermal Units of energy to warm by 1 degree Fahrenheit. Best dust off those slide rules.

A FROSTY reception awaited Adrian Simper in his hotel room: the air-conditioning dial ran from a chilly +3 K to an impossibly cold −3 K. "I asked for an extra blanket," says Adrian. Maybe those concerned about dwindling ice at the Svalbard Global Seed Vault could open an auxiliary store here?

FINALLY, a company with a keen interest in maintaining the terroir of its ingredients (or should that be meroir?). London's 'O ver Italian restaurant boasts that all its pizzas are made with "pure" seawater. Whether it meets the Vienna mean standard (12 March 2016) we're not sure, although the restaurant says the ingredient brings "less sodium and more minerals" to make a lighter, more digestible dish.

After all our wrangling over the correct labelling of Himalayan "sea salt" (5 November 2016), we never for one moment considered calling it dehydrated seawater.

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.

Grain train

I was weighing sugar into a plastic jug that had been recently washed and dried. There was too much sugar so I spooned some out with a teaspoon. The sugar sprayed off the spoon and coated the sides of the jug. Why?

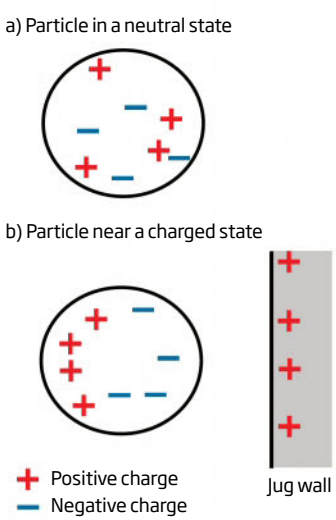
Drying the plastic jug by rubbing it with a tea towel has probably caused an exchange of charge between the towel and plastic, leaving the jug in an electrostatically charged state. Plastic is a good insulator, so it would take some time for this charge to leak to earth. A charged object creates an electric field around itself.

The sugar grains start neutrally charged, containing a uniform mixture of positive and negative charges (see diagram, below). When the particles are placed near the charged walls of the jug, opposite charges are attracted to the side of the particle nearest to the charged object and like charges are repelled to the opposite side of the particle, creating an electric dipole. Because the opposite charges, which attract, are now closer together than the like charges, which repel, the attractive force is stronger. This means there is a net attractive force created between the particle and the wall. If the particle is small enough, this force can overcome its weight and make the sugar jump off the spoon and attach to the wall.

A similar effect can be seen in the party trick of rubbing a balloon against your shirt until it becomes charged. Holding the charged balloon near someone's hair should then cause their hair to lift from their head.

This principle has many commercial applications, such as in the electrostatic precipitators used to remove fine particulates from flue gas at power stations.

Simon Iveson
Faculty of Engineering & Built Environment,
The University of Newcastle,
New South Wales, Australia



This is due to electrostatic charge separation, causing the container and the small-grained insulating material within it to have opposite charges. A similar behaviour is seen when you draw a plastic comb through dry hair and it develops a charge that can attract charge-sensitive items, like flecks of paper.

The exact mechanism is a source of some debate, with recent research suggesting that the electrons involved are moving to or from the water layer that is inevitably present on all materials exposed to ambient air. Either way, the net effect is that the fine powder is attracted to the oppositely charged container.

Martin Falatic
San Francisco, California, USA

Bolted on

Is the exact spot where a bolt of lightning will strike the earth pretty much predetermined at the moment it leaves a cloud? Or does it continuously change direction on the way down? (Continued)

Earlier answers to the question regarding the behaviour of lightning (21 January) raise a number of issues.

First, one answer states that the base of a cloud is negatively charged and another that it is positively charged: is only one of these correct or can it be either?

Second, there is much mention of negative flow, presumably of electrons, in one direction and positive flow (ions) in the opposite. But due to the huge difference in mass between electrons and positive ions, surely these two currents must take place over different timescales and thus cause a difference between cloud-to-ground and ground-to-cloud "flashes". Is this so?

Finally, the mention of St Elmo's fire and the action of lightning rods is, I believe, not mainly connected to lightning strikes but to the prevention of such phenomena. In the physics lab, I used to demonstrate this using a Van de Graaff generator with a neon bulb attached to a nail, which was pointed at the charged sphere.

In a darkened room, one can see both the ionisation glow from the tip of the nail (St Elmo's fire) and the neon glow caused by the flow of current. This partially discharges the sphere and prevents spark discharges to a nearby earthed object, demonstrating how a lightning conductor's primary function is to reduce the likelihood of strikes, as well as the usual explanation of reducing damage if a strike occurs.

Does anybody else have more information to answer my questions?

Richard Horton
Whixley, North Yorkshire, UK

This week's question

HAY FEVER FEVER

With the Australian spring comes seasonal allergic rhinitis, or hay fever. But why do humans have a physiological response to pollen and dust? I can't see any benefit to suffering from sore eyes, a scratchy throat and nasal congestion. So why does it occur?

Wendy Akers
Canberra, Australia

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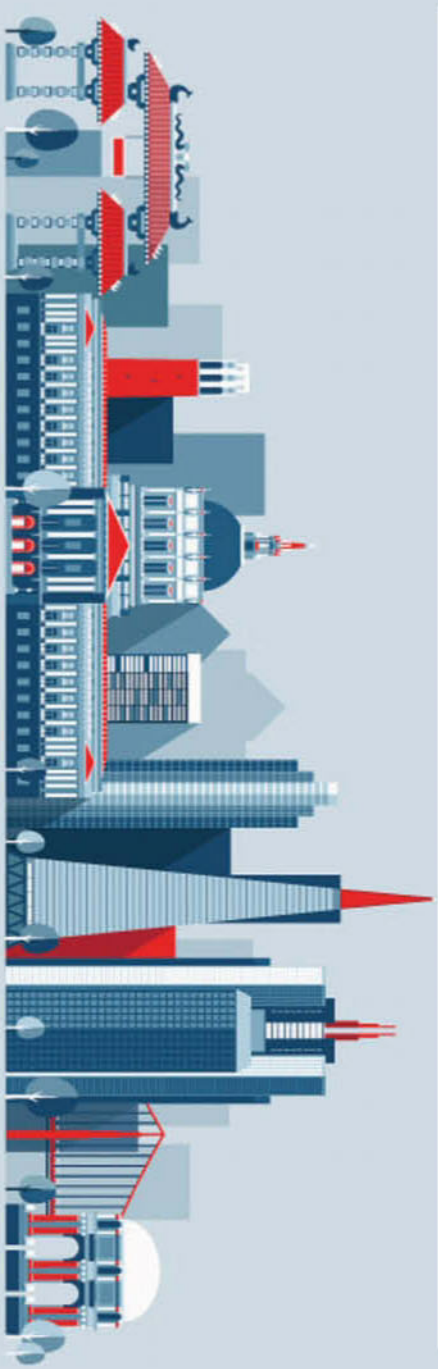

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