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WEEKLY March 25-31, 2017

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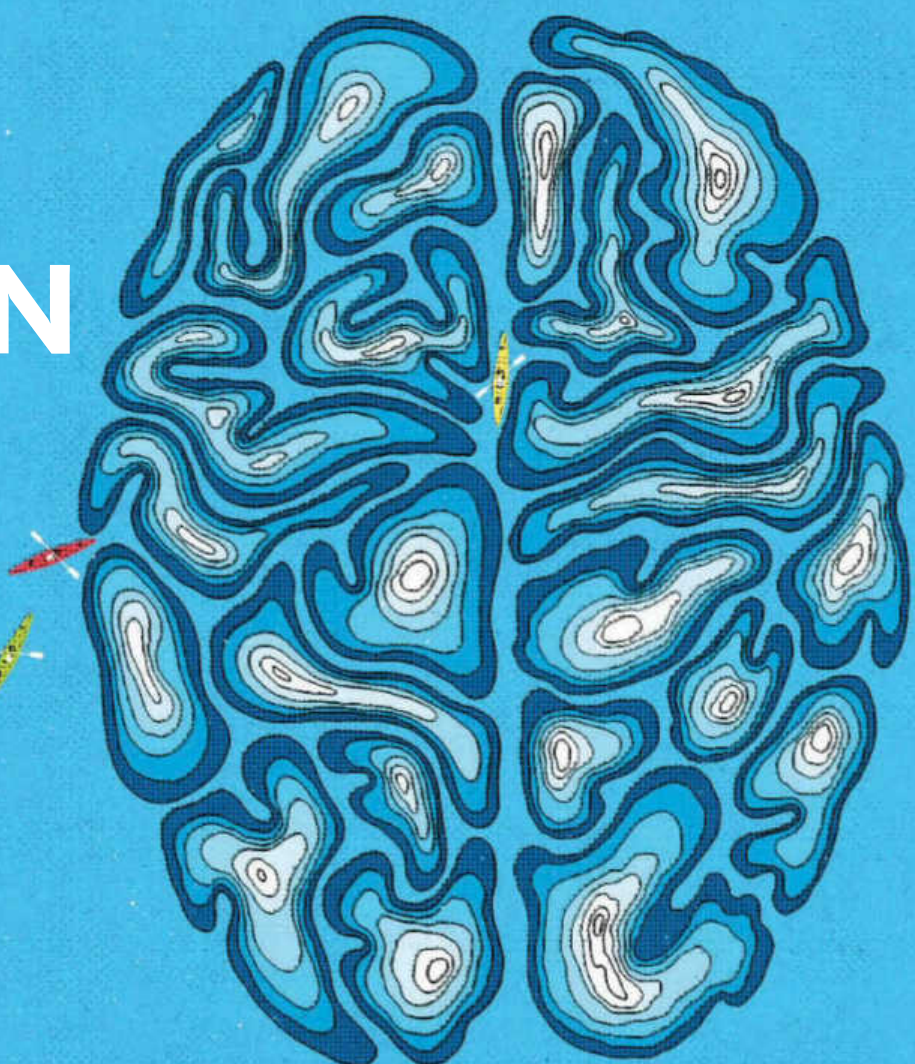
The hidden connections that keep thoughts flowing



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Introduction by **Professor Stephen Hawking**

New Scientist

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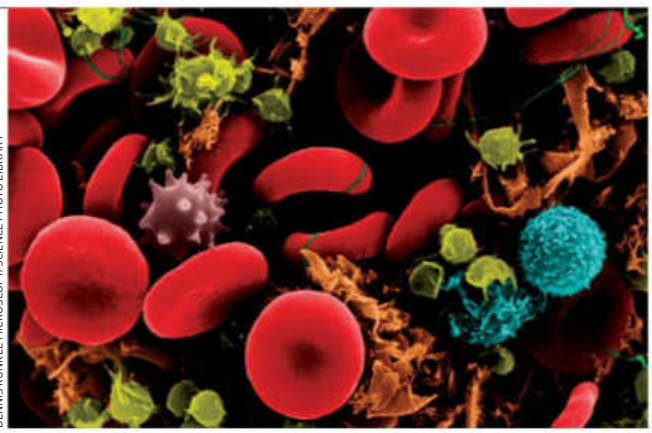

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A quick click, a quick buck

It's time new media companies admitted what they are

WHEN is a media company not a media company? When it's on the internet. YouTube and Facebook mediate what their users read and watch, and sell advertising next to it. Edited content, financed by advertising? It sounds a lot like the model that dominated media for much of the 20th century.

And yet these firms have long claimed to be mere "platforms", passively hosting content they say they are neither able nor willing to assess. It's true that they are not like traditional media companies. Much of their content is donated by their users; and algorithms, not editors, decide what is most worthy of attention. But they are getting more like them every day.

The furore over "fake news" has led Facebook to employ fact checkers, hire editorial staff to rein in the algorithms, crack down on the spread of junk and invest in tools to help out journalists. There is even chatter about it funding media organisations, which right now laboriously generate content only to see it become grist to the social media mills, where it is ground exceedingly fine.

So what kind of media companies are Facebook, YouTube and the rest? Not good ones. Their enormous power to inform, and the huge potential value of forging connections between people around the world, has in fair measure been squandered by prioritising attention-grabbing content – regardless of its quality, veracity or decency. That has cheapened the content of online discourse and coarsened its tone.

Users' complaints on this have gone largely disregarded. Why? Because the social media titans aren't driven by the needs of their users, but by those of their real customers: advertisers. Anything for a quick click – and a quick buck.

"A draft law in Germany has threatened huge fines if Google and Facebook don't clean up their acts"

The tech giants are now coming under mounting pressure to clean up their acts. British MPs last week grilled Google, Facebook and Twitter representatives over their ineffectual efforts to police their platforms for abuse and hate speech. A draft law in Germany has threatened huge fines if they don't improve how they operate.

Perhaps more pertinently, the advertisers have begun to revolt. Developing "programmatic" advertising, which chases an audience wherever it goes and pays whoever attracts them, has proven effective: Google and Facebook now take nine out of every 10 new dollars spent on online advertising, although they have been accused of "marking their own homework", making unconvincing and unverifiable claims about its efficacy.

But while an adventurous 16-25-year-old might make a good customer for your energy drink, they might also be an aspirant jihadi; so your beverage ad ends up next to a beheading video – and paying those who posted it. Faced with a growing backlash, Google this week announced new ways for its customers to avoid such maladroit placement (see page 6).

So is that an end to it? Not really. The companies are still ducking responsibility for setting rules over the use of their services. Excuses that the problem is too technically complex don't wash: their engineers have proven adept at cracking down on, say, copyright violation when it suits the firms. Nor does an absolutist stance on free speech hold up. History is replete with examples of how a fair balance can be struck. Those have involved dialogue and democratic considerations that social media companies have thus far mostly disdained. They should do so no longer. The firms have enjoyed the privileges and profits of media for long enough: it's time they picked up the responsibilities too. ■

Storm over YouTube ads

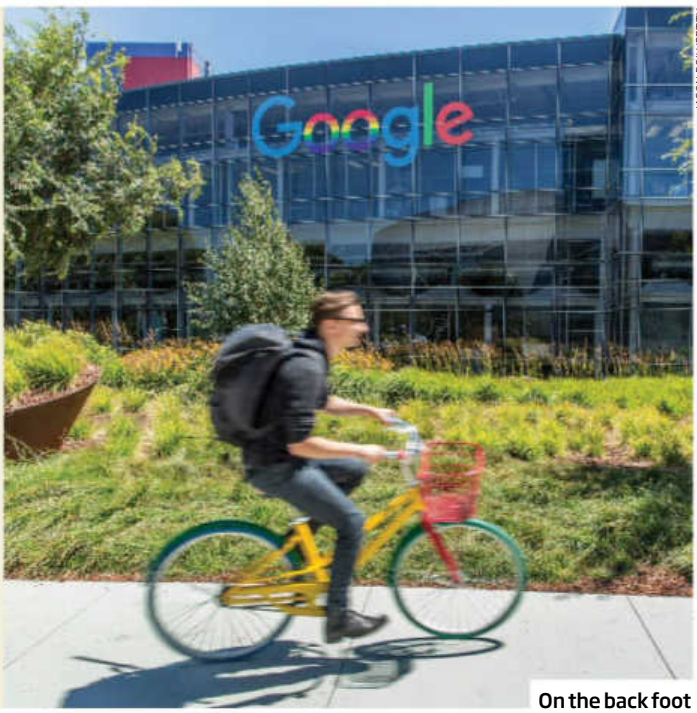
GOOGLE has promised to change its procedures after major brands' ads were shown alongside extremist material on its YouTube service.

The UK government last week suspended YouTube advertising and demanded an explanation from Google after taxpayer-funded ads were attached to videos by alleged hate preachers. Advertising company Havas has pulled Google ads for all of its clients, and firms including L'Oreal and Marks & Spencer have also withdrawn theirs.

Google apologised to companies whose ads "appeared on content that was not aligned with their values". In a blog post, chief business officer Philipp Schindler wrote that the company would tighten policies to remove ads from hateful content more effectively, introduce "safer" default ad settings, and give advertisers the ability to exclude material from specific sites and channels.

Schindler also announced that Google would hire "significant numbers of people" and develop tools based on AI and machine learning to better review questionable content. Google would soon be able to resolve issues "in less than a few hours", he wrote.

But the tech giant will also have to address complaints about a lack of transparency on content guidelines in general. Last week, for example, YouTubers reported that some LGBTQ-themed videos were needlessly being filtered by the site's "restricted" mode.



JASON DOIY/GETTY

On the back foot

Flight gadget ban

PASSENGERS travelling to the US on flights from eight countries will be banned from carrying laptops, iPads, cameras and most other electronics in their hand luggage. As *New Scientist* went to press the UK government had just announced a similar measure. The reason for either ban hadn't been made clear at that time.

The US ban was revealed on Monday in statements from Royal Jordanian Airlines and the official news agency of Saudi Arabia. It will apply to non-stop flights to the US from 10 international airports serving 10 cities in Egypt, Jordan, Kuwait, Morocco, Qatar, Saudi Arabia, Turkey and the United Arab Emirates, according to a US official.

"Thefts from baggage will skyrocket and it will be more difficult to detect battery fires"

Royal Jordanian Airlines said cellphones and medical devices were excluded from the ban. Everything else would need to be packed in checked luggage.

The nature of the security measure suggests it was driven by intelligence of a possible attack, says Brian Jenkins, an aviation security expert at US-based think tank the Rand Corporation. He says there could be concern about inadequate passenger screening in some countries or even conspiracies involving airport or airline employees.

Jeffrey Price at the Metropolitan State University of Denver in Colorado says there are disadvantages to having everyone put their electronics in checked baggage. Thefts from baggage will skyrocket, as happened when the UK tried a similar ban in 2006, he says, and it is more difficult to detect battery fires when gadgets are packed in the cargo hold.

On Tuesday afternoon, the UK government announced a ban on carrying large electronic devices in cabin luggage on flights from Egypt, Jordan, Saudi Arabia and Turkey, as well as Tunisia and Lebanon. The ban was said to have been ordered by Prime Minister Theresa May following a series of meetings on aviation security.

Mars orbiter dip

WE ARE dipping a toe into the Red Planet's atmosphere.

The European Space Agency's Trace Gas Orbiter (TGO), part of the ExoMars project, went into orbit around Mars on 19 October.

On 15 March, it performed the first of seven thruster burns that will bring its orbit low enough to feel drag from the Martian atmosphere without endangering the spacecraft. This is the start of a process called aerobraking, which will slowly bring the orbiter closer to the planet's surface.

If it goes well, by early 2018, TGO will drop from an elliptical one-day orbit to a two-hour circular one.

But the manoeuvre will require near-constant monitoring. "The atmospheric models aren't perfect, so we have to 'feel' our way down," Chris White, a spacecraft operations engineer, wrote in an ESA blog post.

Once in its final orbit, TGO will begin its main science phase, measuring methane, looking for water and talking with rovers.

Climate science savaged

PRESIDENT Trump's proposed budget is under fire for big cuts to US science while diverting billions of dollars to defence and the Mexico border wall.

The deepest cuts are aimed at the Environmental Protection Agency, which would lose nearly a third of its funding. The National Oceanic and Atmospheric Administration and Department of Energy are also hit.

"These cuts are ominous and represent a full-scale, ideologically motivated assault on environmental research," says atmospheric physicist Raymond Pierrehumbert, who sits on the science and security board of the *Bulletin of the Atomic Scientists*.

NASA's Earth Sciences division would lose $102 million – less than feared. Casualties there include its Earth-facing instruments on DSCOVR, a satellite used to monitor climate, but the savings will be tiny, as it is already launched and sending data.

The budget, for the year from October, needs approval in Congress.

Deadly yeast

A FUNGUS could be the next hospital-acquired infection we have to worry about. Some strains are resistant to all three major classes of antifungal drugs.

On 16 March, the US Centers for Disease Control and Prevention (CDC) reported that 53 people in the US have been taken ill with *Candida auris* infections, mostly in New York state. A further 27 healthy carriers have been found.

"Some strains of *Candida auris* are resistant to all three major classes of antifungal drugs"

C. auris was first identified in Japan in 2009. Since then, cases have been seen in 15 countries, but the latest reports represent a spike in infections.

The fungus can cause infection of the bloodstream, wounds or ear. In the worst cases, it can trigger organ failure. Information isn't available on all patients, but the death rate could be as high as 60 per cent.

People with weak immune systems are at highest risk of infection. These include premature babies, people with diabetes, people on dialysis and those who have had recent transplants or other surgery. Ordinary hospital patients and those in the wider community aren't currently considered at risk.

DSCOVR EPIC/NASA

No more data like this?

DAVID MCNEW/GETTY

Low flow could worsen

Vanishing snow

IN 2015, after four years of drought, the snowpack in the Sierra Nevada mountains of California hit a record low. Global warming is to blame for a quarter of that loss, a study based on climate models suggests.

As the planet continues to warm, more than half the Sierra snowpack is likely to vanish over the next century. "We found pretty grim results," says Neil Berg of research institution the Rand Corporation.

"Without ways to store the extra meltwater, California's water problems could get much worse"

This is bad news for California as the snowpack provides a third of its water. The state's water infrastructure relies on snow building up in the mountains in winter and then gradually melting throughout the summer.

In the future, overall precipitation levels in the mountains will stay the same, the study suggests. But without ways to store the extra water flowing down from the mountains during the warmer winters – and with higher losses from evaporation in summer too – the state's problem with water shortages could get much worse (*Geophysical Research Letters*, doi.org/b4km).

One solution could be to capture the extra winter run-off by injecting it into groundwater reserves, says Noah Diffenbaugh, a climate scientist at Stanford University, California. This kind of groundwater recharging is more cost-effective than building more dams or desalinating seawater, he says.

Wild weather

THE hottest year ever recorded, unusually warm ocean temperatures, record sea ice lows in the Arctic and Antarctic, droughts and ever-rising carbon dioxide levels: the World Meteorological Organization's statement on the global climate in 2016 paints an alarming picture.

The planet continues to warm rapidly, by around 0.1 to 0.2°C per decade. Last year saw yet another record: the average global surface temperature was 1.1°C above pre-industrial levels, slightly above the previous record set in 2015.

The extreme weather has continued into 2017, with periods of unusual heat in the Arctic and in Australia. "Human-driven climate change is now an empirically verifiable fact," says Phil Williamson at the University of East Anglia, UK. "Those who dispute that link are not sceptics, but deniers."

60 SECONDS

Bee navel navigators

Call it gut feeling. Honeybees use a magnetic field detector in their abdomens to navigate. When this magnetite-based detector is reset using an external field, bees are no longer able to sense a local change in magnetic field (*Proceedings of the Royal Society B*, DOI: 10.1098/rspb.2016.2873).

Space bones

A SpaceX Dragon capsule returned to Earth on 19 March carrying tissue from 40 mice sent to space so we could study how bone fractures heal without gravity. The results might help future astronauts, who lose bone density on long missions, and people with osteoporosis.

Shifting evidence

They may seem static, but fingerprints change. A study supported by the UK Home Office has found that part of a fingerprint slowly migrates, and can compromise the integrity of a print after only 15 days (*Forensic Science International*, doi.org/b4kt). It may let us determine how long ago a print was left at a crime scene.

Hawking, astronaut?

Stephen Hawking has been offered a seat on a Virgin Galactic spacecraft and says he plans use it. Hawking is 75, and has lived with motor neurone disease since he was a young man. He told TV show *Good Morning Britain* that he had never expected to get a chance to experience space – Virgin Galactic has yet to fly any commercial passengers, however.

Venom treatment

A compound from one of the world's deadliest spiders may become the first drug for preventing the loss of neurons after a stroke. The molecule, called Hi1a, resembles a chemical known to protect the brain. When given to rats 2 hours after an induced stroke, Hi1a reduced brain damage by 80 per cent (*PNAS*, doi.org/b4kc).

Old blood made young again

Can we rejuvenate our blood to fight ageing, asks **Jessica Hamzelou**

BLOOD from the young seems to have healing powers, but how can we harness them without relying on donors? The discovery of a protein that keeps blood stem cells youthful might help.

The rejuvenating properties of young blood came to light in macabre experiments that stitched young and old mice together to share a circulatory system. The health of the older mice improved, while that of the younger ones deteriorated. Other animal studies have since shown that injections of young or old blood have similar effects.

This may work in people too. Young blood is being trialled as a treatment for conditions like Alzheimer's, and aged mice that received injections of blood from human teenagers showed improved cognition, memory and physical activity levels.

But these studies rely on young people donating their blood: if this became the go-to therapy for age-related disease it would be difficult to get enough donations to fulfil demand.

"We think the drug will improve signs of ageing and boost the immune systems of older people"

The stem cells in our blood could provide an alternative approach. Our red and white blood cells are made by stem cells that themselves come from "mother" stem cells in bone marrow. But as we age, the number of these mother stem cells declines. One of the world's longest-lived women seemed to only have two left in her blood when she died at age 115.

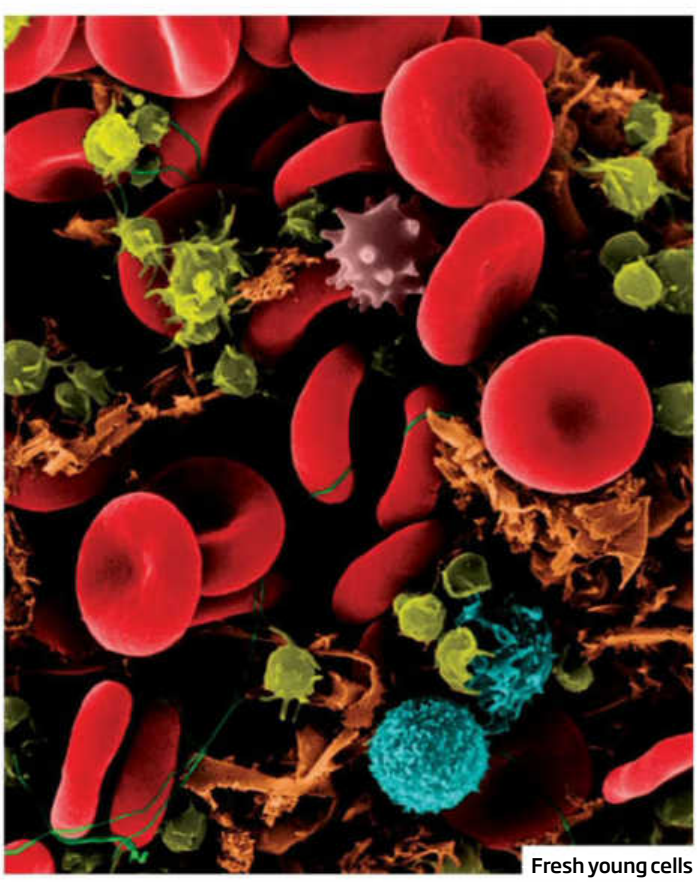
The decline in mother stem cells causes people to have fewer red blood cells, and white blood cells called B and T lymphocytes. These declines can cause anaemia and weaken the immune system. "Usually the immune system in the elderly is not prepared to fight infections very hard," says Hartmut Geiger at the University of Ulm in Germany.

When Geiger's team examined the bone marrow in mice, they found that older animals have much lower levels of a protein called osteopontin. To see if this protein has an effect on blood stem cells, the team injected stem cells into mice that lacked osteopontin and found that the cells rapidly aged.

But when older stem cells were mixed in a dish with osteopontin and a protein that activates it, they began to produce white blood cells just as young stem cells do. This suggests osteopontin makes stem cells behave more youthfully (*EMBO Journal*, doi.org/b4jp). "If we can translate this into a treatment, we can make old blood young again," Geiger says.

"It's exciting," says Hanadie Yousef at Stanford University in California. But longer term studies are needed to see whether this approach can rejuvenate the whole blood system, she says.

Until now, most efforts to use blood as a rejuvenation agent have focused on plasma, the liquid component, as some believe it carries dissolved factors that help maintain youth. But Geiger thinks the cells in blood might play a key role, because they are better able to move into the body's tissues.



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Fresh young cells

Heart health

Both soluble factors and blood cells are likely to be important, says Yousef. While injections of young plasma rejuvenate older animals, the treatment doesn't have as strong an effect as when young and old animals share a circulatory system, she says.

Geiger's team is developing a drug containing osteopontin and the activating protein to encourage blood stem cells to behave more youthfully. "It should boost the immune system of elderly people," he says.

Such a drug might have benefits beyond fighting infection and alleviating anaemia. The team also think the protein will boost levels of mother stem cells. Having only a small number of such cells has been linked to heart disease, so Geiger says there is a chance that boosting them may help prevent this.

Osteopontin might also be useful for treating age-linked blood disorders, such as myelodysplasias that involve dysfunctional cells, says Martin Pera of the Jackson Laboratory in Bar Harbor, Maine. "It is possible that rejuvenating bone marrow stem cells could help with these conditions," he says.

"This study provides more evidence that cells can be rejuvenated," says Ioakim Spyridopoulos at Newcastle University, UK. "They have made old blood look young again, although whether it acts young or not will have to be shown in clinical trials." ■

Biggest change to dinosaur tree in 130 years

HIPS really can lie. In 1888, H. G. Seeley split the dinosaur family tree into two branches based on pelvic bones, but a new analysis suggests a complete rejig of early dinosaur types.

"Maybe we shouldn't just blindly accept this 130-year-old idea," says Matthew Baron at the University of Cambridge. "Seeley's idea, while it was brilliant for his time, it's arguably archaic. It's based on very few specimens."

Seeley divided dinosaurs into "bird-hipped" animals, like the herbivorous *Stegosaurus*, and "reptile-hipped" ones, including carnivores like *T. rex* and long-necked herbivores like *Apatosaurus*.

Instead of focusing on the pelvic bone, Baron and his team analysed 457 characteristics of 74 species and found that 21 other anatomical features divide the dinosaurs differently. Based on these inherited features, his new tree puts *T. rex* and other theropods on one side with the old "bird-hipped" creatures, and leaves the sauropods like *Apatosaurus* grouped with those related to *Herrerasaurus*, a bipedal carnivore found in South America (*Nature*, DOI: 10.1038/nature21700).

Because both new branches include carnivores and herbivores, Baron's team concludes that the common ancestor of all dinosaurs may have been omnivorous.

The results also suggest that the cradle of dinosaur evolution may not have been South America, as has long been accepted. It could instead have been in the northern hemisphere since fossils of the oldest members of the new branches are found there.

"It's as if somebody suddenly said, actually chickens are mammals, not birds," says Mike Benton at the University of Bristol, UK. A few of the 21 features that link the new branches could be questioned, but if they hold up under scrutiny, the team's case is "undeniable", he says.
Chelsea Whyte ■

IMAGE SOURCE / ALAMY STOCK PHOTO

Who should do the questioning?

Robots could help police interview children

WOULD a child open up to a robot? A team at Mississippi State University is suggesting using robots to question children in investigations of child abuse. But not everyone is convinced.

Children's accounts are often vital evidence in cases of abuse. But even specially trained police interviewers can find it tough to stay neutral when talking to children. This can result in leading questions and bad evidence, because children can be very suggestible to saying what they think someone wants to hear.

The stakes are high: poorly conducted interviews can lead to someone being convicted of a crime they didn't commit, or a child being returned to an abusive environment.

Cindy Bethel and Zachary Henkel at Mississippi State University say robots could reduce bias and lead to more reliable outcomes.

Best-practice guidelines for police interviewers in child abuse cases include asking open-ended questions and maintaining neutral body language, facial expressions and vocal tone. Such procedures improve the quality of information obtained, but can be hard to follow. A 2014 report into child sexual abuse cases in the UK described police compliance with guidelines as "poor".

"The techniques are not perfect, because humans are not perfect,"

"Interviewers find it difficult to talk to children who have been abused. Robots don't"

says Bethel. She and Henkel suggest that an interviewer could remotely control a robot that asks questions. That way, the interviewer can focus on asking the right questions, without worrying about their delivery. More advanced future robots might be able to conduct the whole conversation. "Robots will always follow the procedure, no matter the situation," says Bethel.

Robots could also monitor a child in ways an interviewer can't, using sensors to record body movement to help see if they are upset or uncomfortable.

And there is evidence that children will open up to a robot. In one study, children were as willing to share a secret with a robot as they were with a human interviewer. In another, children were more willing to share details about bullying with a robot.

This may not always be a good thing. "There is a risk of children being tricked into disclosing information that they do not wish to disclose," says Henkel. Testimonies acquired through deception would be inadmissible as evidence, so it would be important for children to understand that their conversations with a robot will be shared with authorities.

One of the biggest hurdles could be if robots inadvertently encourage creative storytelling. "Interview rooms are normally very plain, because when they are not, people embellish their stories more often," says Henkel. We don't know if a robot could have the same effect. "Children might really want to continue talking with the robot, so could say things that aren't true to continue doing so."

Bethel and Henkel presented their work at the Conference on Human-Robot Interaction in Vienna, Austria, this month.

Michael Lamb at the University of Cambridge isn't convinced that robots would be better than adults at interviewing children. His research focuses on getting high-quality information from children by creating a caring but non-suggestive relationship during interviews. "I am doubtful that this will be easily achieved [with robots]," he says.

But Marilena Kyriakidou at Coventry University, UK, who trains police interviewers in Cyprus, says robots could bring huge benefits, with more research. "Interviewers say that it's difficult to talk face to face with children who have been abused. Robots won't have that problem," she says.
Timothy Revell ■

Small is wearable for artificial lungs

Clare Wilson

AN ARTIFICIAL lung small enough to be carried in a backpack has been shown to work in sheep. It's one of several devices that could transform the lives of people whose lungs are failing, and who are completely dependent on large machines.

People with lung failure are usually hooked up to a machine that pumps their blood through a gas exchanger to supply oxygen and remove carbon dioxide. This tends to mean they are stuck in bed, impeding their recovery. Even if they're well enough to get up, walking around requires several staff to manage the bulky machines and tubing. Interest in better options grew after the 2009 swine flu outbreak, when many patients ended up on this kind of support.

Artificial lungs could be a stopgap for people recovering from severe lung infections or waiting for a transplant. Yet the tech seems to be harder than making a mechanical heart, say. "The heart is just a pump," says William Federspiel of the University of Pittsburgh, whereas the lungs contain a complex network of branching air sacs permitting gases to diffuse in and out of the blood. "The lungs have a tremendous capability for gas exchange, and there's no technology that can come close for efficiency."

The challenge is further complicated by the need for a pump to push the blood through the gas exchanger, as current machines have.

Now Federspiel's team has developed a device that combines both pump and gas exchanger. It can be carried in a backpack and would connect to the patient's neck via a short tube.

Experiments in four sheep show that the device could fully oxygenate the animals' blood for 6 hours (*The Journal of Heart and Lung Transplantation*, DOI: 10.1016/j.healun.2017.02.025). Federspiel says that they have since demonstrated that it works for five days.

Another kind of artificial lung is being developed by Keith Cook and colleagues at Carnegie Mellon University in Pittsburgh. It is aimed at patients whose hearts are working well enough to pump the blood through a portable gas exchanger – the device connects via the heart's arteries and would be strapped to the patient's body.

Unpublished work shows the device kept three out of four sheep alive for two weeks.

Both the Cook team's device, and the artificial lung developed by Federspiel, need an oxygen supply – so a patient would still have to wheel around an oxygen tank, but they would be more mobile than with current tech.

However, a more efficient device that runs off the air in a room has been developed by Joseph Potkay of the US Department of Veterans Affairs, and so far it works in rats. The machine runs blood through extremely thin channels formed by polymer membranes, providing a larger area for gas exchange. The channels also help keep blood cells healthy by mimicking the pressures exerted by the tiny capillaries of biological lungs, says Potkay. ■

INNERSPACE IMAGING/SCIENCE PHOTO LIBRARY

All lungs should look like this

Glasses give us new power to see colours

IT'S sometimes practically impossible to tell similar hues apart, even placed side by side. Special glasses could improve our ability to do so, and could one day help to spot counterfeits.

Devised by a team at the University of Wisconsin-Madison, the glasses basically enhance the user's colour vision. They allow us to see metamers – colours that look the same but give off different wavelengths of light – as recognisably distinct hues.

Human colour vision relies on three types of cone cells that react to short (blue), medium (green) and long (red) wavelengths. While brushing up on his knowledge of the eye before teaching a photonics class, physicist Mikhail Kats had a brainwave. Could the eye be tricked into effectively having another type of cone cell?

To make the glasses, Kats and his colleagues designed two colour filters, one for each eye, that strip out specific parts of the blue light spectrum. The team hypothesised that giving each eye slightly different information about blue things would simulate a new set of blue cones, making any subtle colour differences more pronounced. They were right (arxiv.org/abs/1703.04392).

They tested the effect using blocks of colour, displayed on a computer and smartphone screen, that people see as metamers. "They look exactly the same, and you look through the spectacles and… holy crap, they're two different things," says Kats.

"They look exactly the same until you look through the spectacles and… they're two different things"

"It's a really fun idea," says Jay Neitz, a colour vision researcher at the University of Washington in Seattle. "There's no doubt when you do this glasses thing, you would be able to discriminate metamers."

Once extended to differentiate between more hues, Kats says the filters could be developed into tools for detecting counterfeit currency or picking out camouflaged objects. "I really want to put these on and go walk around a forest or a park," he says.

Chris Baraniuk ■

Fully recoded life form may be two years away

A FORM of life that relies on a fresh genetic language could be around the corner. Geneticists have recoded 5 per cent of a *Salmonella* bacterium's genome, introducing a record number of genetic changes as they did so.

Now the race is on to recode the whole genome and put the microbes to work. This could lead to designer proteins not seen in nature, with useful properties and potential uses in drugs and vaccines, for example.

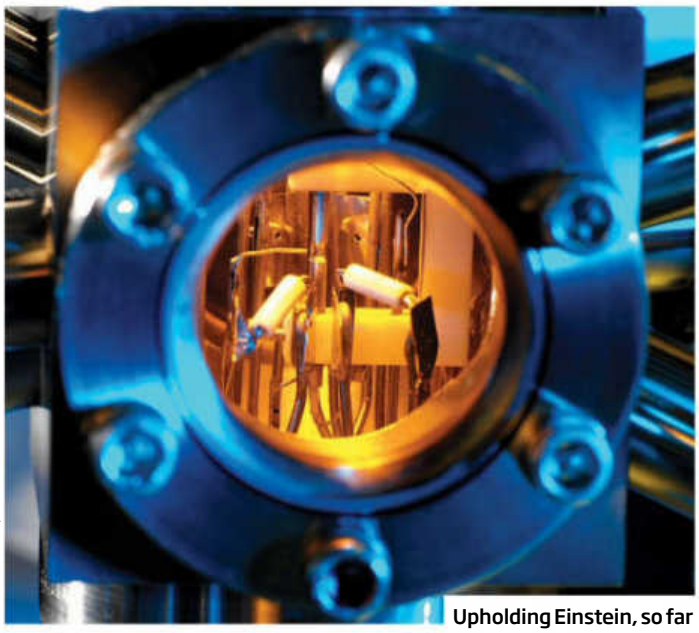
Standard proteins are built from chains of amino acids. Twenty different amino acids are encoded in DNA by triplet "letter" combinations called codons. As there are 64 distinct codons to produce the 20 amino acids, and to start or stop protein manufacture, there is a lot of redundancy. Six codons, for example, produce the amino acid leucine. If an entire genome was recoded so leucine was produced by just one codon, it would free up the other five to be reassigned.

And, because DNA from such recoded microbes would be incompatible with that in other organisms, we shouldn't have to worry about genetic contamination.

Jeffrey Way at Harvard University's Wyss Institute and his colleagues have now used recombineering, a form of "crossing over" between similar DNA strands that occurs naturally, to make more than 1550 codon changes in 176 *Salmonella* genes – the most anyone has ever done (*bioRxiv*, doi.org/b4gk).

The approach offers an efficient way to design and assemble recoded genomes, says Marc Lajoie at the University of Washington in Seattle. It lets you put big chunks of recoded DNA into cells, accelerating the process.

Way says his team may have a fully recoded genome within a few years. Because recoded bacteria would be unable to communicate with other microbes, it should be possible to use them to create safer "live" vaccines – which can be more effective than those based on dead bacteria, he says. Colin Barras ■



ANDREW BROOKES, NATIONAL PHYSICAL LABORATORY/SPL

Upholding Einstein, so far

Networked atomic clocks seek untimely behaviour

OUR most accurate clocks are probing a key tenet of Einstein's theory of relativity: the idea that time isn't absolute. Any violation of this principle could point us to a long-sought theory that would unite Einstein's ideas with quantum mechanics.

Special relativity established that the laws of physics are the same for any two observers moving at a constant speed relative to each other, a symmetry called Lorentz invariance. One consequence is that they would observe each other's clocks running at different rates. Each observer would regard themselves as stationary and see the other observer's clock as ticking slowly – an effect called time dilation.

Einstein's general relativity compounds the effect. It says that the clocks would run differently if they experience different gravitational forces.

For two decades, comparing atomic clocks aboard GPS satellites with those on Earth have helped test the effect – and always confirmed it. But since any deviation from relativity would be very subtle, we might need a more precise instrument to find it.

Most atomic clocks rely on the frequency of the microwave radiation emitted when electrons in caesium-133 atoms change energy states. Next-generation clocks that use strontium atoms have at least three times the precision, barely gaining or losing a second over 15 billion years.

"A violation of Lorentz invariance could point to a way to combine relativity and quantum mechanics"

Now, Pacôme Delva of the Paris Observatory and his colleagues have used strontium clocks to test time dilation. Two optical fibre links, one between London and Paris and another between Paris and Braunschweig, Germany, were used to compare devices in these locations.

These clocks are moving at different velocities because of their position on the Earth's surface, and relativity makes precise predictions about the extent of time dilation they experience. For example, a clock closer to the equator should tick more slowly than one closer to the North Pole. After one day, clocks in Paris and London should show a difference of 5 nanoseconds.

To compare them, the team synchronised lasers to the frequency of the radiation from each clock's strontium atoms. Then they transmitted the beams over the fibre-optic links, allowing them to superimpose the lasers to detect any telltale differences in frequency indicating one clock ticking faster than the other.

With the measurements, the team calculated a parameter called alpha, which should be zero if there is no violation of Lorentz invariance. The latest results show that alpha is less than 10^{-8} – a result two orders of magnitude better than from experiments using caesium clocks, and twice as accurate as the previous best limit, obtained by studying electronic transitions in lithium ions moving at one-third the speed of light (arxiv.org/abs/1703.04426v1).

Letting the experiments run for longer will improve accuracy even further, says team member Jochen Kronjäger of the UK's National Physical Laboratory in Teddington.

So far so good for relativity. But how would physicists react if a violation of Lorentz invariance is ever measured? "The immediate consequence would be that nobody would believe it," says Sabine Hossenfelder, a theorist at the Frankfurt Institute for Advanced Studies in Germany.

However, if a violation is ever confirmed, the implications would be huge. "Quantising gravity, [the nature of] dark matter and dark energy – these are three big questions for which Lorentz invariance violations would be an extremely important hint as to the nature of the underlying theory," she says. **Anil Ananthaswamy** ■

FIELD NOTES Male, Maldives

New islands built to fight rising seas

Nenad Jaric Dauenhauer

WHITE sand circles picked out by the sun in sparkling blue seas are the first signs my plane has arrived at the Maldives, a tropical paradise spread over almost 1200 islands.

The nation is facing a rise in sea levels – a peril that made it a poster child for the consequences of climate change. Former President Mohamed Nasheed even had plans to purchase land elsewhere so the population could relocate should sea level rise make their home uninhabitable.

But the mood has changed here. The new government, under President Abdulla Yameen, no longer seeks land to buy, but is instead determined to resist the rising seas with engineering.

The key to the new strategy is renting out islands and using the money to build new ones, through the process of land reclamation. People living on smaller, lower-lying islands could then be relocated to more flood-resistant ones when needed.

One of those artificial islands being built is called Hulhumale, near the capital Male, which contains the City of Hope. To build it, a state-owned firm is pumping sand from surrounding atolls and depositing it on shallow reefs that circle the original lagoon. It is being fortified with walls 3 metres above sea level – the highest natural island is only 2.5 metres above the sea.

Much of Hulhumale still looks like a construction site with mountains of sand, but, when finished in 2023 it will be able to accommodate about 130,000 people. Eight new islands have already been built, and three more are planned.

Reclaiming islands is the real solution to challenges thrown up by climate change, not leaving the country, says Shiham Adam, director of the Maldives Marine Research Centre.

"It is possible to reclaim any island," says Adam. "All you have to do is bring the dredgers, suck sand and pump it on the low-lying land in shallow waters. It takes four weeks to build the island and a couple more to put boulders around to stabilise it. To survive we just need money."

Leaders of two NGOs I meet here argue for a slower and more environmentally sensitive pace. One problem with reclamation is that sand pumped onto reefs can lead to surrounding corals becoming smothered and dying. Hassan Ahmed of Save the Beach organised the relocation of some of the corals that became threatened during the reclamation of Hulhumale, and he thinks this should be a standard procedure in all similar projects.

WATERFRAME / ALAMY STOCK PHOTO

It's build or sink for the Maldives

Other reef developments are also causing some islands to shrink. "Those that were damaged by explosions meant for clearing the way for boats through the reefs are losing the sand," says Ahmed. "It is carried by storms, waves and streams to the deep waters."

"This invasive process should be avoided as much as possible," he says. "Paths can be cleared in much less damaging ways by chiselling, and islands should be reclaimed only when absolutely necessary."

Shaahina Ali from Biodiversity Education and Awareness also argues for a more sustainable approach. "We understand the need for reclamation of some islands," Ali says. "But the government should take care that it is done with as little damage as possible in accord with strict, environmentally friendly projects." ■

Nenad Jaric Dauenhauer's trip was paid for by the Maldives government

Cosmic ruler could probe dark energy

MEASURING cosmological distances is tricky if your ruler isn't up to scratch. A new cosmological standard ruler could help us figure out why the universe is expanding at an accelerating rate.

This is usually put down to dark energy, a mysterious force that seems to be pushing the universe apart.

Accurate measurements of how the distance between clusters of galaxies has changed over time could tell us whether the effect of dark energy is increasing. But our current way of measuring this relies on assumptions that are difficult to check.

About 30,000 years after the big bang, gravity made normal matter collapse around random dense spots, but pressure from photons caused it to rebound outwards again. This cosmic bounce created acoustic waves, called baryon acoustic oscillations (BAO), that expanded outwards in a spherical shape and carried normal matter with them.

Because each of these spherical shells is the same size, we can use the distance between a central galaxy cluster and galaxy clusters at the edge of the wave – about 500 million light years – as a kind of cosmological ruler.

But it isn't perfect: as the universe aged, this neat structuring blurred as gravity and magnetic fields pulled galaxies in different directions. So we need to make assumptions about how galaxies have shifted over time. Some BAO distances could be spot on, but others are off by several per cent, and there is no way to tell which are which.

"Measurements of cosmic distances could tell us whether the effect of dark energy is increasing"

Now, Glenn Starkman at Case Western Reserve University in Ohio and his colleagues have come up with a ruler that sidesteps the need for these assumptions. Instead of following the galaxies' motions, the team measure distance relative to an unmoving mathematical midpoint in the BAOs called the linear point (arxiv.org/abs/1703.01275).

Starkman says the technique is up to four times more accurate than existing methods. Matt Reynolds ■

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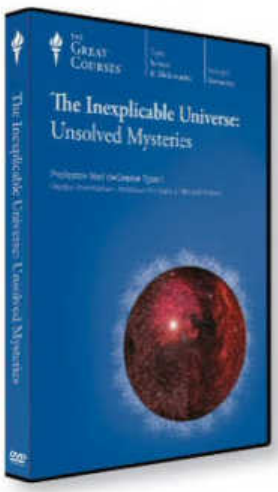

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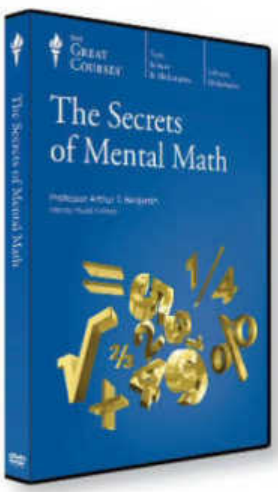

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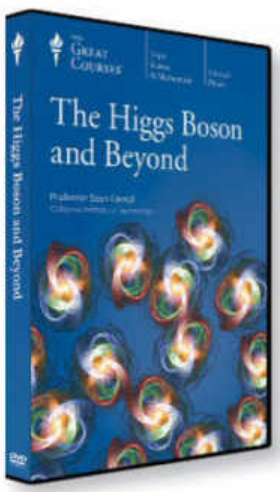

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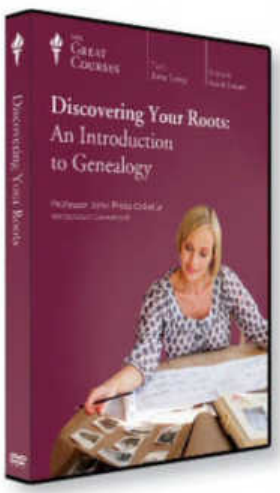

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DAN MCCOY/GETTY

Decline halted

Stem cells save woman's sight

Andy Coghlan

A WOMAN in her 80s has become the first person to be successfully treated with induced pluripotent stem (iPS) cells. Laboratory-made retinal cells have protected her eyesight against age-related macular degeneration – a common form of progressive blindness.

Unlike other types of stem cell, such as those found in an embryo, induced pluripotent ones can be made from ordinary cells from adults, like skin cells – a discovery that earned a Nobel prize in 2012. Once made, they can be coaxed to form many other types of cell.

Now, more than a decade after iPS cells were first created, they have helped someone. Masayo Takahashi at the RIKEN Laboratory for Retinal Regeneration in Kobe, Japan, and her team took skin cells from the woman and turned them into iPS cells. They then encouraged these to form retinal pigment epithelial cells, which support and nourish the retina cells that capture light.

In 2014, the researchers made a sliver of epithelial cells measuring just 1 by 3 millimetres. Next, they removed diseased tissue on her retina that was gradually destroying her sight, then inserted the small patch of cells they had created. The hope was that the transplant would stop her eyesight from degenerating further.

Now the results are in. Although the treatment hasn't made the woman's vision any sharper, it seems to have prevented further deterioration – her vision has now been stable for more than two years (*New England Journal of Medicine*, doi.org/b4gp). The woman says her vision is "brighter".

"This is a landmark study and opens the door to similar treatments for many diseases"

"Takahashi and her team have done incredible work, and deserve all the praise they get for this project," says collaborator Shinya Yamanaka at Kyoto University, who won the Nobel prize for creating iPS cells. "This is a landmark study and opens the door to similar treatments for many diseases," he says.

"This first iPSC-derived retinal graft is an important landmark in the field of retinal regeneration," says James Bainbridge at University College London, who is running a trial of similar grafts made from human embryonic stem cells instead.

One worry about the iPS cell approach is that turning stem cells into new tissues could give rise to cancer-causing genetic mutations – although the team found no evidence of this in the treated woman. However, a trial of the technique in another person was cancelled in 2015, after tests revealed that the cells intended for transplant had developed genetic abnormalities.

Yamanaka says efforts are now focusing on creating standardised stem cell treatments that would make use of donor cells. "This switch should make cell therapy more readily available, because it avoids the time to prepare and evaluate a patient's own iPS cells," he says.

Yamanaka and his colleagues plan next to use iPS cells for Parkinson's disease – caused by a lack of dopamine-producing neurons – and a blood disease called thrombocytopenia. ■

Phone controls tattooed onto your skin

MAKE the most of that beauty spot. Temporary electronic tattoos can turn body features into touch-sensitive buttons, letting you control your smartphone with your own skin.

People intuitively know the location of their own bumps and birthmarks, which makes them ideal locations for touch-sensitive buttons, says Martin Weigel at Saarland University in Saarbrücken, Germany. You could squeeze a freckle to answer a phone call, or slide a finger over your knuckles to change the volume.

Weigel's team has used conductive ink to print wires and electrodes on temporary tattoo paper. These are transferred onto skin with water and last a few days before rubbing off.

"We make use of the elastic properties of the skin, including bending and stretching," says team member Jürgen Steimle. By having the tattoos respond to changes in the skin surface, they can incorporate multiple commands. Tattoos on the knuckles, for example, could act as four distinct buttons when the hand is making a fist, but function as one long slider when the fingers are extended.

Another of the team's tattoos is electroluminescent, glowing when a current passes through it. This could allow you to have tattoos in shapes to represent your favourite smartphone apps, which would light up when you receive a notification, says Weigel.

The group connected the tattoos to a computer to test them, but in future the plan is to link them to Android smartphones. Weigel's team will present the work at a computer-human interaction conference in Denver in May.

"This is amazing research," says Chris Harrison at Carnegie Mellon University. He predicts a future in which skin-based controls are the new normal. "You'll have these digital tattoo parlours which you can go to in 2050 and 5 minutes later you can walk out with the iPhone 22 on your forearm." Matt Reynolds ■

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Exposed: Soviet nuclear cover up

Fred Pearce

IT WAS a nuclear disaster four times worse than Chernobyl in terms of the number of cases of acute radiation sickness. But Moscow's complicity in covering up its effects on people's health has remained secret until now.

In August 1956, fallout from a Soviet nuclear weapons test at Semipalatinsk in Kazakhstan engulfed the industrial city of Ust-Kamenogorsk and put more than 600 people in hospital with radiation sickness.

New Scientist can reveal that a scientific expedition from Moscow in the aftermath of the hushed-up disaster uncovered widespread radioactive contamination and radiation sickness across the Kazakh steppes. The scientists tracked the consequences as nuclear bomb tests continued – without ever telling the people affected or the outside world.

A report by scientists from the Institute of Biophysics in Moscow was found in the archive of the Institute of Radiation Medicine and Ecology (IRME) in Semey, Kazakhstan. "For many years, this has been a secret," says the institute's director Kazbek Apsalikov, who found the report and passed it on to *New Scientist*. Other such reports were moved or destroyed when the Soviet Union collapsed in 1991.

More nuclear bomb tests were conducted at Semipalatinsk than anywhere else in the world during the 1950s and early 1960s. The report, marked "top secret", shows for the first time just how much Soviet scientists knew about the human-health disaster and the extent of the cover-up.

It details how Moscow researchers on three expeditions to Ust-Kamenogorsk found widespread and persistent radioactive contamination of soil and food both there and across eastern Kazakhstan.

A month after the 1956 fallout cloud hit, dose rates in Ust-Kamenogorsk were still up to 1.6 millirems per hour, 100 times what the report deems the "permissible rate".

The following month, the expedition moved on to a number of villages. Near Znamenka, radioactive substances that affected the people and the environment had been falling repeatedly for years, the report says. The fallout there was "hazardous to health" and "more serious and dangerous than [in] the district of Ust-Kamenogorsk".

An earlier test on 12 August 1953 had sent a cloud across Karaul, which the 1956 expedition reported had consequences that were still "hazardous to health".

Boris Gusev, chief scientist at IRME, says 638 people were "hospitalised with radiation poisoning" in Ust-Kamenogorsk after the 1956 test – more than four times the 134 radiation cases after the Chernobyl accident.

Atmospheric bomb tests at Semipalatinsk stopped in 1963. Although much of the area downwind is now safe to live in, "some areas will never return to nature", says Apsalikov. "The situation in others is uncertain and potentially dangerous."

Roman Vakulchuk of the Norwegian Institute of International Affairs says this is the first contemporary record of research into the effects of the tests on local populations. But there is uncertainty about the continuing contamination and health impacts, he says. "Much of the area presents no danger," says Vakulchuk. "But some parts need to be safeguarded indefinitely." ■

ALAIN NOGUES/SYGMA/SYGMA VIA GETTY IMAGES

Semipalatinsk nuclear test site

Watery streaks on Mars might be sand flows

DUST to dust. The mysterious dark flows on Mars may not be water after all. Instead, they could be rivulets of sand, set in motion by sunlight on the Martian surface.

The dark streaks form on Mars's slopes during warm seasons, and are known as recurring slope lineae. While there's no direct evidence of water nearby, the leading theory is that they are the result of brine streaming down the sides of craters and hills.

"There's part of your brain that immediately tells you that it should be ice melting," says Sylvain Piqueux at NASA's Jet Propulsion Lab in Pasadena, California. "The problem is, it's really hard to melt ice on Mars."

Now, Frédéric Schmidt at the University of Paris-South and his colleagues have an idea that needs no liquids: sand avalanches caused by sunlight and shadow.

When sunlight hits the sand, it heats up the top layer while leaving deeper layers cool. This temperature gradient changes the pressure of tiny gas pockets around the sand particles, shifting the gas upward. This in turn jostles grains of sand and soil, causing them to slip down the Martian slopes.

The effect should be most pronounced in afternoon shadows cast by boulders or outcrops. In this situation, the contrast between the cooling surface and the still-warm layers just below creates a pressure gradient as well, shifting the gas and sand even more (*Nature Geoscience*, doi.org/b4jr).

"We can't think of Mars as a friendly planet. It's even harder to live there if these flows don't have water"

The streaks that we see originate on sloping, rocky landscapes – matching the model's predictions.

If recurring slope lineae are created without liquid, it could dismantle our hopes that they might make life easier, both for organisms native to Mars and eventual human explorers.

"We can't think of Mars as a friendly planet," says Schmidt. "It's a very hard transition to go there, and even harder if these flows don't have liquid water." Leah Crane ■

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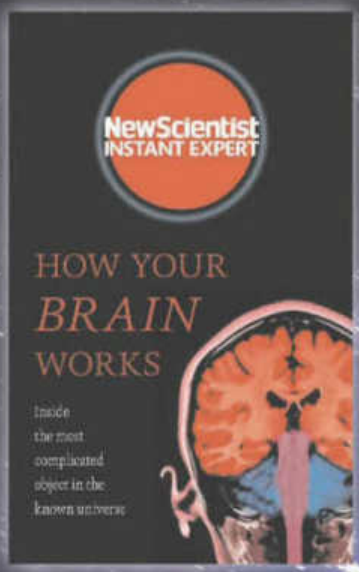

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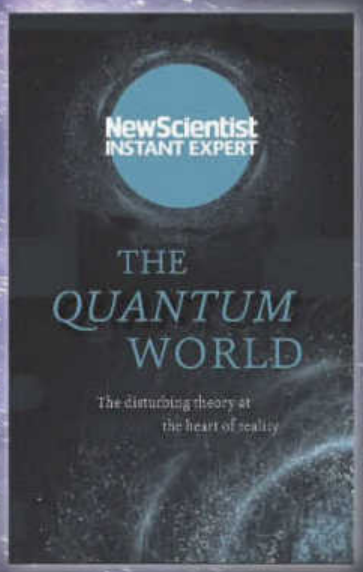

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MARK TAYLOR/NATUREPL.COM

Giggling parrots spread good vibes and high-five in mid-air

WILD keas in New Zealand spontaneously burst into play when exposed to the parrot equivalent of canned laughter – making them the first birds to respond to laughter-like sounds, as far as we know.

The parrots soar after one another in aerobatic loops, exchange foot-kicking high fives in mid-air and toss objects to each other, in what seems to be contagious behaviour. And when the recording stops, so does the party, and the birds resume whatever they'd been doing.

We already know these half-metre-tall parrots engage in playful behaviour, especially when young. What's new is that a special warbling call they make has been shown to trigger behaviour equivalent to spontaneous, contagious laughter in humans, or so it seems. Moreover, it's not just the young ones that respond; adults of both sexes join in the fun too (*Current Biology*, DOI: 10.1016/j.cub.2017.02.020).

"On hearing the calls, many birds started to spontaneously play with non-playing birds, or with an object close by, or by performing aerial acrobatics," says Raoul Schwing at the University of Veterinary Medicine in Vienna, Austria. The average number of play bouts per bird monitored was 20 times higher and the length of play 90-fold longer during the warble recordings. It means that humans and their closest relatives might not be the only species capable of such emotional contagion.

'Breeze' helps Venus's atmosphere spin

VENUS has a second wind. Air blowing from its equator towards its poles could explain how its atmosphere spins so fast.

The planet rotates once every 243 Earth days, but its atmosphere does so every four days, with wind speeds upwards of 400 kilometres per hour parallel to the equator. Energy from sunlight is needed throughout the atmosphere to maintain this frenzy. But with more sunlight hitting near the equator than at the poles, it wasn't clear how enough energy could arrive at high latitudes.

Now, Pedro Machado at the Astronomical Observatory of Lisbon, Portugal, and his colleagues have detected poleward winds blowing at just 80 kilometres per hour. These could spread the energy more evenly.

The team "saw" the wind using the Doppler effect. Just as the pitch of a siren alters as it moves towards or away from you, light waves reflected off Venus's atmosphere are compressed or elongated depending on wind motion (*Icarus*, doi.org/f9qzhb).

"It is amazingly hard to make these kinds of measurements," says Glyn Collinson at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "I just read the paper and thought, 'Holy smoke, you measured *that*?'"

Fish leave sea to escape predators

BLENNY fish in the South Pacific Ocean are gradually relocating on land to flee aquatic predators, in a case of evolution in action.

Fish first began crawling on to dry land about 400 million years ago, kicking off an evolutionary chain of events that led to us. But their reasons for abandoning the sea have been uncertain.

Now Terry Ord at the University of New South Wales in Australia and his colleagues show that one driving factor may have been to avoid being eaten. They studied some blenny species at Rarotonga in the Cook Islands, where the fish climb on to land at high tide.

The team found that predators attack models of the fish much more when they are put in the sea than on land (*The American Naturalist*, doi.org/b4f7).

If you are forced into a new habitat to escape predators, you may then stay there and adapt, says Ord.

Bacteria chip in with 3D printing

PUT those bacteria to work by popping them in a 3D printer.

Anne Meyer at Delft University of Technology in the Netherlands and her colleagues have shown that you can 3D-print *E. coli* in lines just 1 millimetre thick (*ACS Synthetic Biology*, doi.org/b4jk).

They now want to use the technique with *Shewanella oneidensis*, a bacterium that can reduce graphene oxide by removing oxygen atoms as it metabolises. Reduced graphene oxide behaves more like graphene, which has useful properties such as conductivity.

By 3D printing the bacteria in precise patterns on the graphene oxide, they hope to carve lines of conductivity, like tiny wires, on an otherwise non-conductive surface.

O My! Blood typing in 30 seconds

A, B, AB or O: a paper-based test could reveal your blood type in just half a minute, allowing hospitals to rapidly administer the right blood in an emergency. The test could be particularly useful in war zones or remote areas where there are no labs to carry out blood typing.

Knowing your blood type is essential if you ever need a transfusion, because a mismatch can send the immune system into meltdown. But conventional blood typing takes 10 to 20 minutes, so most emergency departments stock only a type of O blood. This is safer because it lacks the antigens that trigger immune reactions, but supplies are limited.

Now Hong Zhang at the Third Military Medical University in China and his colleagues have developed a rapid test that anyone can perform at a patient's bedside.

Each low-cost paper strip is impregnated with a matrix of dyes and antibodies that recognise antigens on the surface of red blood cells. When blood is applied, squares of colour develop depending on which antigens are present, revealing the sample's blood type.

In trials of 3550 human blood samples, the strip was more than 99.9 per cent accurate, and only took 30 seconds to produce results (*Science Translational Medicine*, doi.org/b4jm).

KEVIN CURTIS/SPL/GETTY

Eavesdropping robot reveals how men and women converse

DIFFERENCES in how men, women and children interact when they talk have been observed by a robot in a fur hat.

Experiments using a robotic head called Furhat aimed to spot conversational inequalities and see if a robot could help redress the balance. They revealed that when a woman speaks with another woman, she says more than if paired with a man. Two men paired together speak less than two women.

But this only holds for adults. "Gender didn't make much difference to how much children speak," says Gabriel Skantze at the KTH Royal Institute of Technology in Stockholm, Sweden.

Furhat interacted with 540 visitors at the Swedish National Museum of Science and Technology. Two people sat opposite the robot playing a game that involved sorting a set of virtual picture cards. The robot's sensors tracked how long each person spoke for during the task.

Pairs of women spoke for 45 per cent of the time on average, compared with just 26 per cent for pairs of men. When a woman was paired with a man, the speaking time was 28 per cent, with each sharing the time about equally.

But adults dominated the conversation when paired with children. The largest imbalance occurred when men played the game with girls, with the adults speaking more than twice as much as the kids (doi.org/b4f2).

Skantze hopes the robot could help rebalance conversations. When Furhat addressed the less dominant speaker, for example, they were more likely to speak.

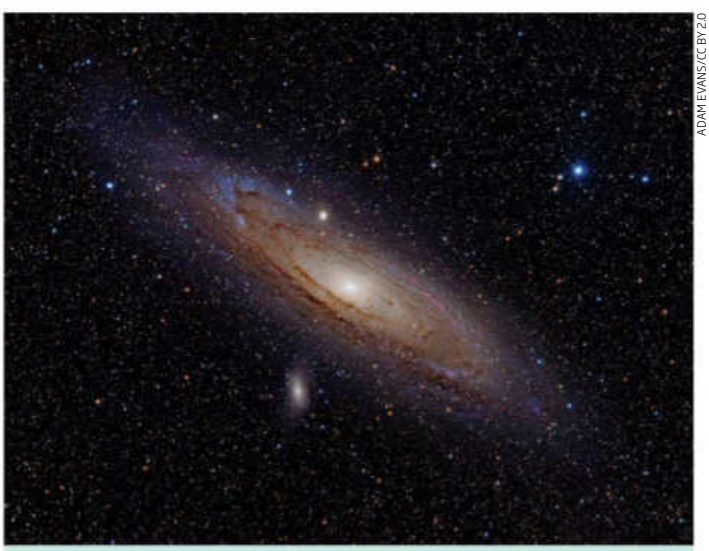
Chimp 'coroner' cleans corpse teeth

FOR the first time, a chimpanzee has been seen using tools to clean the corpse of another member of its group. This behaviour could shed light on how our own mortuary practices evolved.

In the incident, a female chimpanzee called Noel at Chimfunshi Wildlife Orphanage in northern Zambia sat down by the dead body of a young male, Thomas, whom she had previously adopted. She then selected a firm grass stem and started to remove debris from his teeth. She continued doing this even after the rest of the group had left the corpse (*Scientific Reports*, doi.org/b4gb).

"The report is important because it indicates once more that the human species is not the only one capable of compassion," says Edwin van Leeuwen at the University of St Andrews, UK.

His team says this could mean that the long-lasting social bonds chimps form influence their behaviour even after a "friend" has died. The behaviour could also indicate that chimps are curious about death and mortality. The team thinks this could eventually tell us something about how human mortuary rituals began.



ADAM EVANS/CC BY 2.0

Normal matter ruled early galaxies

DARKNESS gathers, but it takes time. Although massive star-forming galaxies are dominated by dark matter today, it was ordinary matter that was supreme in the early universe.

Since dark matter doesn't interact with light, we can only observe it via its gravitational effects. Some of the first evidence came from observing that stars at galaxies' edges move more quickly than they should. A pervasive dark matter "halo" could explain this.

But was it always that way? To find out, Natascha Förster Schreiber at the Max Planck Institute for Extraterrestrial Physics in Germany and her colleagues turned to the Very Large Telescope in Chile. With it, they made the most detailed observations yet of six massive galactic discs during the era of peak galaxy formation, 10 billion years ago.

The team found that the stars near the edges aren't travelling unusually fast. This suggests there is very little dark matter in the hearts of those galaxies (*Nature*, doi.org/b4f5). Instead, they must be almost entirely made up of visible matter, in the form of stars and gas.

New Scientist
Live Smarter

Fighting tooth and nail

Poaching is a problem with no easy fix. Can new ideas stop it at its source, asks **Chris Baraniuk**

THREE days after World Wildlife Day, poachers broke into a French zoo not far from Paris, made their way to an enclosure that housed a white rhino called Vince, shot him three times in the head and used a chainsaw to detach his horn. The poachers got away despite there being five members of staff living on the premises and plenty of security cameras.

The attack came even as many countries increasingly turn to sophisticated surveillance technologies to protect their wildlife. There have been some successes, but Vince's case illustrates how deftly wildlife traffickers adapt.

Now we are beginning to attack the problem from a totally different angle, getting to the source of the crime using data and online tools. Will it work this time?

Poaching can be a vicious crime, and rhino horn is especially lucrative – at last estimate it fetched around $65,000 per kilogram. Vince's death was comparatively merciful; more often, to obtain the horn, poachers simply take a saw to the face of living rhinos.

In Vietnam, poachers appear to have caused the extinction of the Javan rhino, and while the charismatic species garner the most outcry, wildlife crime also takes its toll on a vast number of less visible species. "The only reason these go extinct is because of this kind of trade," says Tanya Wyatt, a criminologist at Northumbria University, UK.

Governments and conservation groups have spent decades trying to solve the problem, but to little avail. One issue is the transnational nature of the crime, which makes it difficult to keep track of poachers' cargo for example.

So it is understandable that desperate conservationists have turned to technology to catch poachers in the act. This has led to significant successes. Use of surveillance drones in Kenya has been credited with an increase in poacher arrests. Thermal imaging cameras have helped law enforcement agents catch dozens of poachers hunting elephants. And Nepal has combined several of these kinds of technologies to achieve four zero-poaching years.

"The syndicates involved in wildlife crime are bigger than we previously suspected"

But the approach doesn't work everywhere – only where poachers are prosecuted. "So many times we have submitted evidence," says Christine Figgener, a marine conservationist at Texas A&M University, "and the poacher is walking free the next day because the government is not willing to try that person."

Paula Kahumbu, a lawyer who runs WildlifeDirect in Kenya, says that although anti-wildlife-trade laws there have recently become tougher, most African governments have "very weak" legislation – and these countries are the source of a large proportion of trafficked species. Many wildlife authorities are underfunded and easy to bribe. "You can't just threaten people with going to jail because unless it's the very junior or middle players, they can bribe their way out of jail," she says.

XINHUA/RACHEN SAGEAMSAK/EYEVINE

AP PHOTO/DENIS FARRELL

By the time contraband is seized, it's too late. Can new methods tackle the problem at its source?

International cartels

Another problem is that over the past couple of years, it has become increasingly clear that the crime syndicates involved in wildlife trafficking are bigger and more professionally run than previously suspected. Some are international cartels that see these animals simply as large bags of money, whose trafficking is not logistically different from that of drugs or firearms.

Under this regime, improving the protection of animals in situ can lead to an unintended effect: "all you do is push the price up," says Peter Knights, executive director of WildAid.

Instead of trying to use a patchy legal system full of loopholes against powerful and entrenched international syndicates, Knights has long advocated a better way: kill the demand for wildlife products – the source of these crimes. It's an idea that is starting to pick up steam.

There are two ways to stop demand. One is to ban sales.

Supply and demand

Most rhino horn goes to Vietnam and China, where belief that it has medicinal properties drives prices up to $65,000 per kilogram (kg). These prices have motivated large numbers of professional criminals to get involved

SOURCE: WORLD WISE

That may seem obvious, but endangered animal parts are not banned everywhere, or bans are inconsistent; when African nations allowed the sale of legal ivory stockpiles, demand – and elephant poaching – soared. "You only really make progress when you actually ban sales within a country," Knights says.

But the process of corralling governments into making consistent laws can be a long one.

In the meantime, there could be a far more effective way: data and online tools are suggesting a whole new approach to tackling the problem.

For example, data collection is giving us evidence that the appetite for wildlife contraband can be dampened with the careful use of social campaigns. One Vietnamese poll suggested that, following a year-long campaign challenging the idea that rhino horn has medicinal properties, demand in the country had fallen by as much as a third.

And more figures can tell us what else works. An analysis following the Chinese government's decision in 2013 to no longer serve shark fin soup at official banquets revealed that by 2015, demand had dropped by 25 per cent. "It's not necessarily illegal to consume shark's fin," says Eric Phu, who has worked on projects to reduce demand for wildlife products, "But because it was considered opulent, that was enough to reduce the desire to be seen consuming it." The trend shows no indication of reversing: in January, Air China joined 30 other airlines in banning shark fin cargo.

Before you can contain demand for a particular species, however, you need to understand where it is most popular. Progress is happening here too. New data gathering methods employed by the United Nations Office on Drugs and Crime has resulted in demand maps that reveal surprising destinations for rhino horn (see map, above).

"The appetite for illegal wildlife can be dampened with the careful use of social campaigns"

One important destination is China, where thanks to increasing law enforcement efforts, illicit wildlife trade is shifting from physical markets to online platforms and social media. The week of Vince's killing, China's top three internet service providers publicly pledged to crack down. Their measures include apps that raise awareness among web users, and removing advertisements for illegal products.

One problem there is sorting the legal from illegal listings; doing so often requires comparing them against a vast database of endangered species and local laws. Compounding the problem is that illegal ads are scattered through the internet – listings can be unsearchable and enjoy impunity on many social networks – even Facebook, says Jennifer Jacquet, an environmental studies professor at New York University. "My students were finding live tiger cubs for sale, African grey parrots," she says.

So Jacquet and data scientist Sunandan Chakraborty developed a text analysis tool that uses machine learning to flag suspicious listings, checking them against the endangered species catalogue. Other technological tools are now being tested to track poached contraband directly to the source (see "Turning the hunters into the hunted", right).

As this new effort ramps up, a greater awareness of the syndicates responsible for much of the carnage has led to calls to see wildlife crime for what it is: organised crime. "I'm struck by how few enforcers have applied the same financial rigour to wildlife trafficking that they apply to drug trafficking," says Tom Keatinge at the Royal United Services Institute in London.

"The scale of it makes it clear – you cannot do it on your own," says Cees van Duijn at Interpol's Environmental Security Programme. Earlier this month, the agency seized 1300 illicit products. An enforcement win, perhaps, but for the animals in question, it came too late.

"They're going to wipe out species," says Kahumbu, and unless we diversify our efforts "we're going to sit here like idiots saying, 'Oh, maybe we should have acted a bit faster'." ■

TURNING THE HUNTERS INTO THE HUNTED

EVERY summer, hundreds of thousands of sea turtles – including many critically endangered species – make their way to the beaches of Nicaragua to lay their eggs. Poachers lie in wait.

Sea turtle eggs can fetch up to $100 each, making them a lucrative target. "Easily 90 per cent of nests or more are poached," says Kim Williams-Guillén of conservation NGO Paso Pacifico. Not even armed guards can protect them, and as a result some species are nearing extinction.

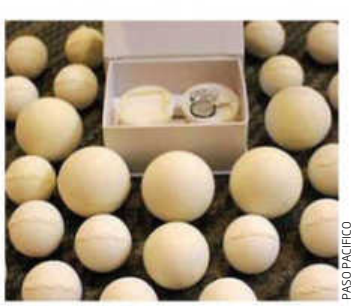
RED-HANDED

But when the poachers come collecting this summer, they might get more than they bargained for.

Williams-Guillén and her colleagues have created artificial turtle eggs, 3D printed to look and feel exactly like the real thing. "A turtle egg is kind of squishy – these squish in a very similar way," she says. But instead of a baby turtle, they contain a GPS tracker, SIM card and battery.

This summer, Paso Pacifico will smuggle 50 to 100 of the devices into real clutches on the beaches of Costa Rica and Nicaragua. When poachers loot them, they will be tracked to their paymasters. Local crime networks are deeply involved in the illegal turtle egg trade, says Williams-Guillén, but the more important information is where the eggs end up.

This would reveal the trade routes and destination markets for trafficked sea turtle eggs. Conservation scientists and law enforcement have urgently sought this over the past two years, as it has emerged that reducing demand is the crucial linchpin to stopping the illegal wildlife trade.



PASO PACIFICO

Space oddities

When it comes to astronomical mysteries, let's have a little less ET and a little more astrophysics, if you please, says **Geraint Lewis**

WHEN astronomy is faced with the unexplained, ET is sometimes invoked until we know better. There were the "canals" of Mars in 1877. And the idea of "little green men" was raised when Jocelyn Bell Burnell detected the regular "beep-beep-beep" of pulsar stars 50 years ago. Soon after, the discovery of the vast explosions of gamma ray bursts led to speculation of intergalactic war.

Last year the media was abuzz with talk of Tabby's star, a pretty unremarkable F-type star in the constellation of Cygnus in our galaxy. NASA's Kepler satellite found its light varied in a complex and unexpected way. Natural explanations were proposed, including a lumpy disc of orbiting material, the chaotic break-up of a planet, or clouds of comets. But the media latched on to one idea in particular, that the dimming could be due to "alien megastructures".

So it was not a huge surprise when the headline "Harvard Scientists Theorize That Fast Radio Bursts Come From Alien Space Travel" appeared last week.

First seen in 2007, these intense and mysterious flashes of radio waves come from the depths of space and last milliseconds. Their brevity means they must originate in cosmically tiny regions, some 100 kilometres across. Astronomers have suggested natural events that could fit the bill, such as neutron stars and black holes colliding or potent flares from extraordinary stars.

But the Harvard idea proposes that we might be catching a glimpse of beams produced by advanced civilisations to propel spaceships with immense light sails between the stars.

The focus on alien explanations is understandable: the public gets excited, newspapers are sold and

Putin's real prize?

Was US climate denial the reason Russia rooted for Trump, wonders **Owen Gaffney**

SCOTT PRUITT, US Environmental Protection Agency chief, made headlines for his recent denial that anthropogenic carbon dioxide is the primary control knob for Earth's climate.

Of course, the truth is that growth in CO_2 emissions is the main contributor to the climate change we see. Without emissions abatement it seems inevitable that pumping greenhouse gases into the atmosphere will be catastrophic for most, if not all, nations.

The question is when this catastrophe will hit, and the biggest uncertainty is whether politicians take action to reshape the economic playing field to tackle climate change.

Pruitt's appointment, part of a grander, darker geopolitical strategy, makes that reshaping less likely. This is not about the science. It is not about economic priority setting nor conflicting values. It is not about a desire for small government, the primacy of individual freedom or myopic belief in capitalism. The only fact that matters is that solving the climate issue means killing the fossil fuel industry – arguably the most influential on the planet.

"A global clean energy revolution is likely to put Russia's economy in a death spiral"

Dealing with climate change means summoning the economic "gales of creative destruction" – economist Joseph Schumpeter's phrase for how innovation kills and replaces old industries to drive economic growth.

The first gales are here. Zero-carbon technology is now cheaper and easier to install. Renewables promise individual freedom through energy self-sufficiency.

The world economy is at a crucial inflection point. The US is well placed to ride the storm and capitalise on the next economic revolution. But vested interests dominate the landscape and US

links clicked. Scientists often feed the fire with press releases and more speculation. But many roll their eyes. It is important to understand that the odds that aliens are the solution to the unexplained is vanishingly small, especially when more "mundane" astrophysics, such as colliding black holes or the smashing of planets, is much more likely.

Frustratingly, when the solution has been found, a lot of the media has moved on. And while talk of aliens is thrilling, it can be a distraction. There are researchers who worry that the thought of funding alien speculation might be seen as a waste of taxpayer funds in a world that is facing many pressing problems, while others feel that fascinating scientific results get lost in the clamour.

This is not to say that we scientists shouldn't consider the possibility of alien activity – we should be open to radical ideas. But science's role is to rule out the boring and often tedious before we seriously embrace the extraordinary. That's one message that should be beamed far and wide. ■

Geraint Lewis is a professor of astrophysics at the University of Sydney, Australia

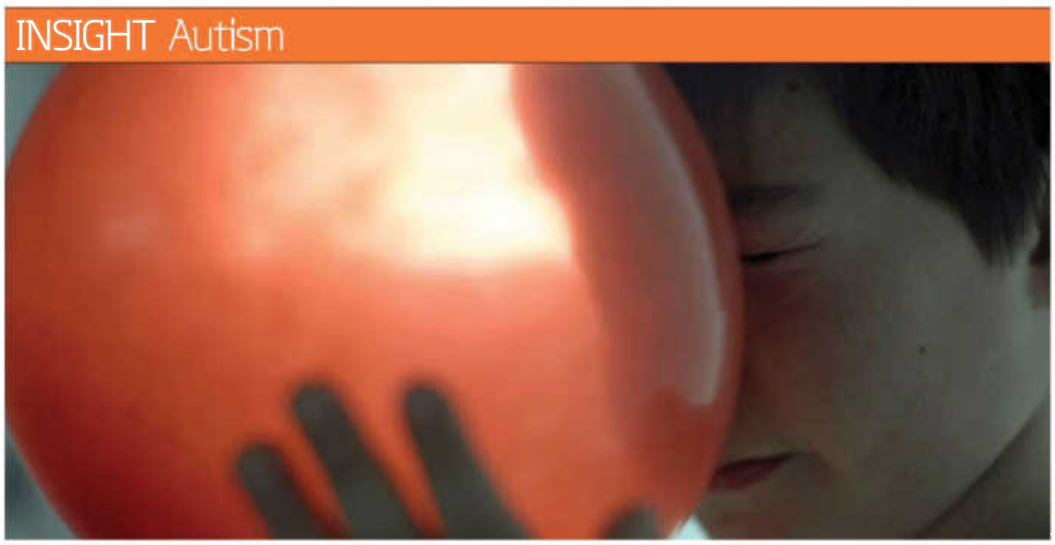
policy could delay the revolution.

In contrast, there are no Russian gales. Its economy is a basket case. Apart from oil and gas, it produces little anyone wants to buy. A clean energy revolution is likely to put its economy in a death spiral.

Serious questions have been asked about the role of Russia, the world's fifth largest greenhouse gas emitter and the largest oil producer, in the election of Donald Trump. Perhaps it's time to expend more effort asking why it wanted him in power. ■

Owen Gaffney is Anthropocene analyst and communicator at the Stockholm Resilience Centre and Future Earth

INSIGHT Autism



TIMOTHY ARCHIBALD/REDUX/EYEVINE

Why a simple autism test is unattainable

Clare Wilson

ANOTHER day, another biological test for autism is in the news – this time it's a blood test. But don't expect it to reach clinics any time soon, and not just because of the usual delays in translating research into reality. The test itself may be flawed.

Eagerness for a simple test is understandable since early diagnosis and intervention might be helpful. Autism can involve difficulties with speech and different social abilities, and the number of children diagnosed with the condition has soared in recent decades (though some believe this is down to closer attention to children's development rather than an actual rise in cases).

Some adults with autism argue it is not a disability, but a difference to be celebrated. However, some parents' groups are concerned by the apparent rise in cases.

Currently, diagnosis is made by observing a child's behaviour, but by the time all the specialists agree, most children with autism are more than 4 years old. Speech and behavioural therapies are the main forms of intervention and the hope is that they would help more if started younger.

Hence the optimism greeting the new test: not only does it promise a cheaper, faster, simpler way to detect autism, it may even offer the possibility of earlier diagnosis.

The test was developed by taking blood samples from 159 children under 10, about half of whom had autism. The researchers identified five blood biomarkers that could separate a number of autistic children from another "neurotypical", or non-autistic, group. Over 96 per cent of children in each group got a result that matched the standard behavioural diagnosis.

"Autism researchers have been here before - previous diagnostic tools have yet to bear fruit"

That may sound impressive. But there's a familiar problem affecting this – and any – potential test for autism. Because it is relatively rare – affecting about 1 per cent of the population – the number of children correctly diagnosed with autism would be outnumbered by the neurotypical children who were misdiagnosed. So a positive result would probably be wrong more often than not. That doesn't mean the test has no value. It could still be used to identify children who might benefit from behavioural testing.

There is a deeper issue: we don't yet know if this is a test for autism or, instead, a more general test for brain differences. The five blood compounds in the test aren't specific to the changes that seem to link to autism. Some are in pathways involved in helping cells resist damage from inflammatory chemicals or toxins. Others are involved in regulating how genes are turned on or off – which genes might be affected here are unclear.

So we can't be sure the test would not also lead to positive results for children with general learning disabilities or epilepsy. "It could indicate something in general going a bit awry with brain development," says Jonathan Green of the University of Manchester, UK.

It's not the first time we have been here; several earlier biological tests for autism – including a widely reported brain-scanning method – have yet to bear fruit.

In fact, it would be surprising if we ever do find a simple test for autism, says Green, because the condition is complex and multifaceted, with many different potential causes and manifestations. So like previous claims, the reality is unlikely to live up to the headlines. ■

The art of death

IF IT flies, it dies. That seems to be the motto for hunters on the Mediterranean island of Malta, currently serving as a staging post for millions of migratory birds (see page 36). Every spring, these travellers seek rest and recuperation in the island's fields after epic journeys across the Sahara, only for many to be shot down and stuffed for display.

Shooting in spring is banned throughout the European Union. Everywhere except Malta that is, where hunters are permitted to shoot a few thousand turtle doves and common quails. This year it was limited to quails alone, because the turtle dove is deemed vulnerable to extinction. But the reality is that hunters shoot and capture many other species too.

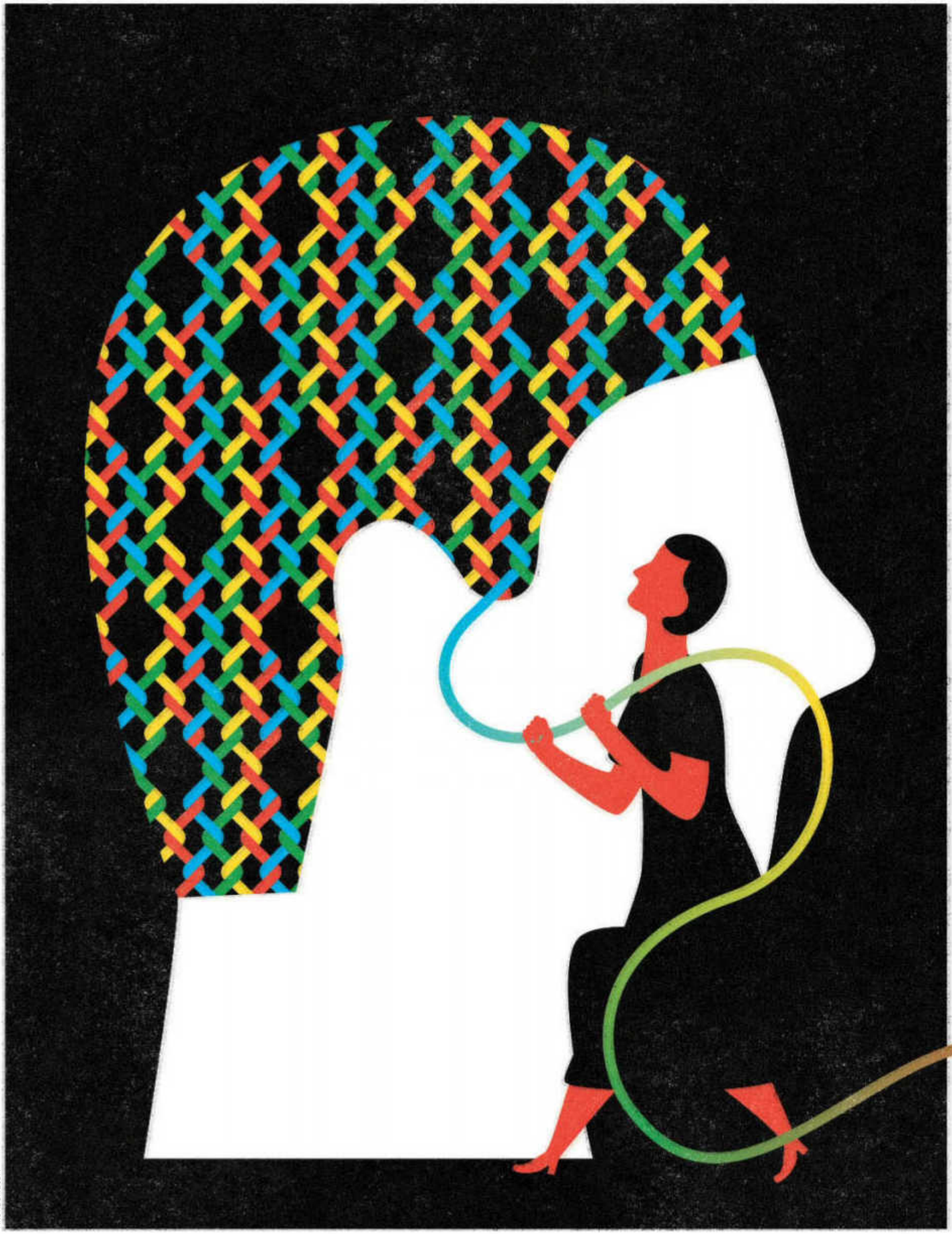
Disregard for the ban isn't limited to Malta. BirdLife International estimates that 25 million birds are unlawfully killed or captured around the Mediterranean every year. Four countries are responsible for 8 million of those: Cyprus, Egypt, Lebanon and Syria. But the slaughter is most intensive in Malta, where some 7200 birds are killed per square kilometre every year.

In April 2012, photographer Kieran Dodds joined volunteers in Malta as they tracked migrating birds and their would-be killers. When the birdwatchers retrieve birds shot illegally, they take them to a local vet – who insists on anonymity for fear of reprisals – to confirm cause of death for legal prosecutions.

It was at a veterinary practice in Valletta that Dodds captured these images of slain migrants: (clockwise from top left) a golden oriole, a bee-eater, a common swift and a hoopoe. "The vet's table was so clean and clinical, I thought it would give the photos the feeling of a still life," he says.

Is there any light at the end of the barrel? Dodds isn't filled with confidence. "Hunting is such an intrinsic part of Maltese life, and they don't take kindly to outsiders telling them to stop," he says. "The thing is, these birds are not theirs to shoot – they're passing through, they don't belong to anyone." Daniel Cossins

Photographer
Kieran Dodds
Panos



ANDRE DA LOBA

Holes in the head

The gaps in your brain's wiring might be the secret of its power, finds **Caroline Williams**

IT HAS been described as a "monstrous, beautiful mess", a "tangled web" and a "dense canopy of tropical branches". But in reality, it is nothing of the sort. The human brain is a highly organised, efficient machine, no circuit laid without good reason. If it appears tangled, that is only because we haven't managed to unravel its 100 billion wires and 100 trillion connections well enough to explain how it works.

The reward for that feat wouldn't just be a map of the most complex object in the known universe. Understanding the brain's connections would begin to teach us how its flashes of electricity add up to a fully conscious experience, one in which our senses, intuition, reasoning and memory interact to give a coherent view of the world.

That understanding has long eluded us. But a new approach is providing fresh clues by focusing not on the neural cables but the spaces between them. By applying a curious branch of mathematics more usually applied to exotic states of matter, neuroscientists are revealing a hidden dimension of the brain. It turns out that the wiring between your ears is full of holes – and you might have them to thank for your most impressive mental feats.

In the early 1900s, the Spanish anatomist Santiago Ramon y Cajal was the first to draw the neurons that make up the basic scaffolding of the brain. His sketches made it obvious that the cells form a connected network. The cell bodies make up what is known as grey matter, brain areas where particular types of processing happen. The cells also have long protrusions, called axons, which not only connect to nearby neurons but also make up white matter, the tissues containing long-range links that allow electrical signals to flow to distant areas of the brain.

Even in Cajal's day, it was easy enough to see the white matter; so called because when you slice up a brain the colour shows up obviously. These days, instruments such as MRI scanners can reveal the white matter without the need for any incisions. But we have never had a full picture of how the electrical impulses move within the wires or how these create our seamless experience of the world. It's a bit like an old-school road atlas: we can see the available routes, but not the ever-changing traffic conditions.

Except, until recently, we didn't even have a decent map. That only began to change after 2005, when cognitive neuroscientist Olaf Sporns of Indiana University in Bloomington called for a concerted effort to map every connection in living brains, to produce what he called the "connectome".

Sporns got his wish. In 2009, the US National Institutes of Health launched the Human Connectome Project, which has since received almost $40 million in funding. It carried out brain scans on thousands of volunteers and stored the resulting maps in a databank that researchers can use to test ideas about how brain structure relates to function. Last year the data helped identify 180 brain areas, 97 of which were previously unknown.

Studies of the connectome almost all have one thing in common: they use a mathematical approach called graph theory to describe the brain's wiring. This breaks networks down into a series of dots and lines – or "nodes" and "edges" in graph theory parlance. In the case of the brain, the nodes are grey matter and the edges white matter.

Graph theory was a reasonable choice. After all, it had already yielded insights into other complex networks, clarifying how ideas propagate via social media and how infectious diseases spread. Applied to the brain, it revealed that the connectome is ›

what mathematicians call a "small world network". That means that each brain area has dense internal connections, with only a few links to other nodes that act as hubs, relaying signals between areas.

All this is now established neuroscience, so much so that we have moved on to comparing people's connectomes to see what the differences might tell us. For instance, Martijn van den Heuvel, who directs the Dutch Connectome Lab at Utrecht University in the Netherlands, has found suggestions that the shorter the connections between hubs, the higher the person will score in an IQ test. The explanation could be that shorter connections make it easier for the brain to integrate information. "The brain is a network, and we can examine it with network tools as we do the internet and social networks and so on," says van den Heuvel.

Graph theory can only take us so far, however. While it has been incredibly useful for describing processing in densely connected brain regions that are also close in space, or are working on a similar problem, it doesn't explain what happens next.

Imagine, for instance, that your dog's leash breaks while you're out walking. Thinking up a solution requires you to conjure up a mental image of a substitute – something long, thin, flexible and strong – while combing your memory for what might fit the bill. An ivy stem, maybe? Or how about a belt? We know that circuits in the frontal lobe, the seat of

"The connectome has helped reveal 97 previously unknown brain areas"

logical, goal-directed thinking, assess the ideas in turn to see which will work. But graph theory is silent on how the brain shifts between processes like recalling memories, planning and visualisation. That's why, says van den Heuvel, the entire connectomics field is trying to expand its understanding of the brain as a network, to see how far it can take us.

Danielle Bassett, a neuroscientist at the University of Pennsylvania in Philadelphia, began to think we could make progress by switching to another kind of maths. The field that caught her eye was topology, a branch of maths that offers something a little different from graph theory.

We are used to thinking of shapes in terms of geometry, categorising them using the angles of their corners and lengths of their sides. But to a topologist, the distances between points in a shape are unimportant; what matters is that they remain connected in the same order. So, topologically speaking, a bagel is the same shape as a coffee cup. If the cup is made of a squishy material, allowing you to pull its handle and squash its body, you would be able to form a bagel without breaking the outline or making any new joins. In effect, topology emphasises gaps in connections; the cup handle and the centre of the bagel are the important bits, so to speak. Start with these gaps, and you can quickly see the ring-like shapes that encircle them.

Topology has long been used to explain exotic states of matter, which do things like conducting electricity with no resistance. But Bassett noticed that her colleague at the University of Pennsylvania, mathematician Robert Ghrist, had recently begun to use topology in new ways; to map dead zones in mobile phone signal coverage, for example. She wondered if it could prove rewarding to look at the connectome's dead zones, too. "If we're not looking at the holes," she says, "are we missing something important about how this thing works?"

With her colleague Ann Sizemore and others, she designed an experiment to find out. First the team scanned the brains of eight healthy adults and identified the same 83 brain areas in all of them, including sensory regions such as the visual cortex and areas deeper in the brain that are involved in memory and emotional processing. Then, they mapped the white matter pathways that linked them and analysed the network using the rules of topology.

The first things they found were those familiar, highly connected brain areas. Then they reanalysed them so that areas that were densely connected to each other were considered as single processing units: cliques, in the language of topology.

So far, so unremarkable. But when they turned their attention to the gaps that topology highlights, they saw something totally new: holes in the connectome that serve to separate cliques from each other. These "cycles" are encircled by loops of connections of assorted shapes and sizes (see diagram, left).

Bassett's team identified four of these loops that join deeper parts of the brain to the outer cortex, and one that loops around the outer cortex. Some were simple loops, while others are complex three-dimensional shapes that take in many different brain regions.

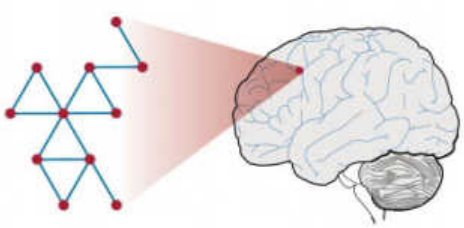
The same cycles turned up in all the volunteers, which suggests they are there for a reason, says van den Heuvel. "Previously we simply ignored those weak connections, but if you look at multiple individuals and you find the same connections across them all, then it's very likely that it has a special role in the overall structure," he says.

Bassett speculates that the reason cliques are kept separate is to avoid crosstalk between those that are carrying out different kinds of processing. A cute example, says Bassett, is that if you had too much connectivity between the brain areas that deal with taste and vision "you could get confused and start feeling that you're seeing what you are eating".

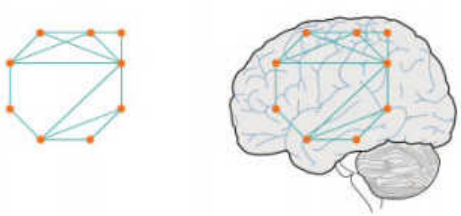
Crucially, information travelling between cliques has to flow neatly around the periphery of a cycle; it can't take a short cut

Unpicking the brain

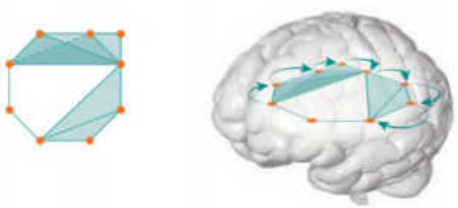
Mathematical techniques are giving us remarkable insights into how the brain is wired up



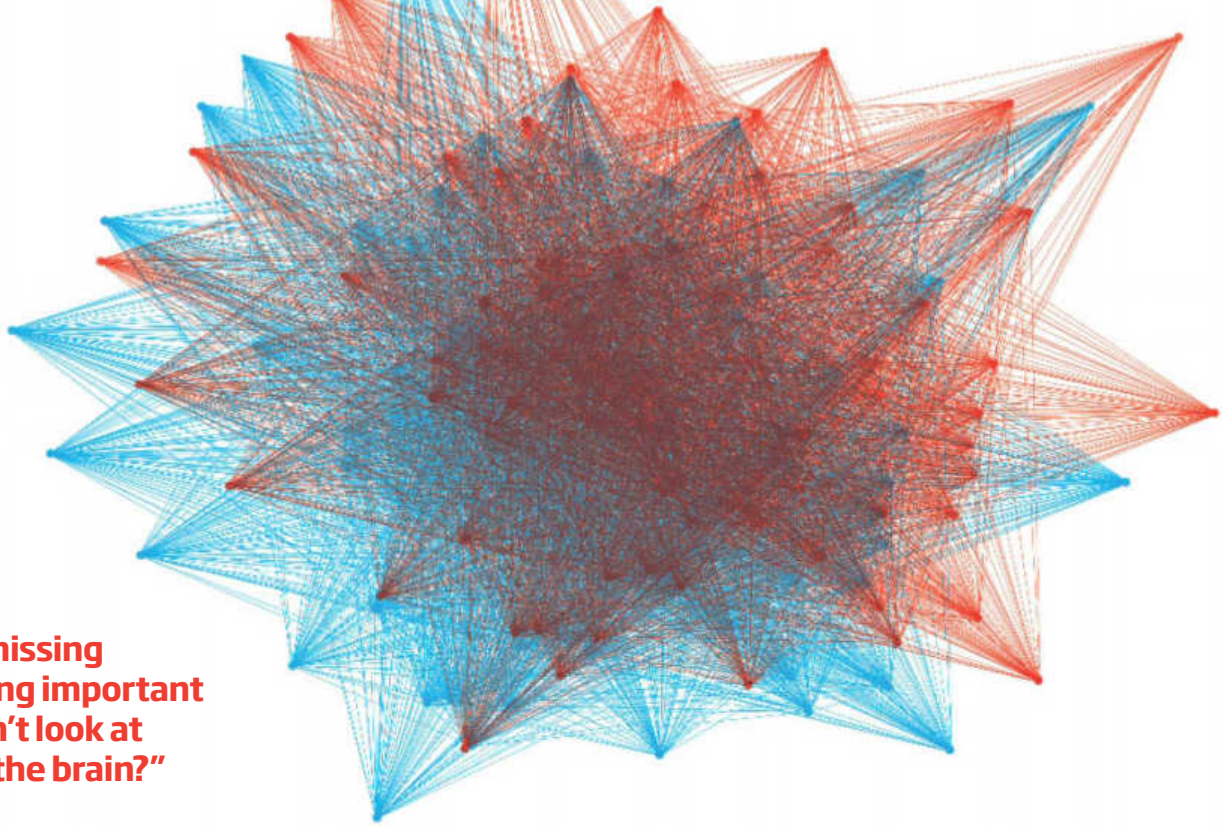
Graph theory has revealed **dense short-range connections** within brain areas, but not the way one area is linked to another



Now studies using **topology** have identified those long-range connections. They form loops with "holes" at the centre



That means **signals must travel around a hole's periphery** – no shortcuts across the gap. This might explain how the brain combines inputs from multiple senses without getting confused



"Are we missing something important if we don't look at holes in the brain?"

across the gap. Bassett thinks this might allow the brain a certain amount of control over when to integrate information and how. Think back to that broken dog leash; the cycles could explain how the brain sifts through the options to make a decision without everything getting confused.

But this is about more than unfortunate dog walking incidents. Van den Heuvel reckons the discovery of cycles might open up a whole new window on how the brain works overall.

In particular, Bassett says some of the cycles seem to connect brain areas that we know are involved in executive function. This is a collection of mental processes that allow us to plan and to control impulses, attention and fear. The old view was that each brain area worked separately, without much crosstalk between them. "This work suggests that they are not necessarily segregated, but just connected by very long loops," says Bassett.

Let's say that your peripheral vision spots a snake in the grass. Messages from the visual cortex inform the amygdala, the brain's burglar alarm, that something requires immediate attention. This snaps focus to the threat, while informing the motor cortex to move your body out of the way. Meanwhile the frontal cortex, the brain's decision-maker, comes online, consults memory and spots that what you have seen is actually a stick. Finally, it's back to the amygdala, which turns off the panic button. We know all this must happen, but not how. Bassett thinks cycles might be the answer.

That's fascinating because executive function is one of the things that makes our experience so rich and humans so smart, providing us with self-control and reasoning. And this might point to a way we can test Bassett's ideas.

We know that executive function strengthens during adolescence, which would suggest that this might be when cycles start to form. To see if we can catch them in the act, Sizemore is now analysing connectome data from 2000 people aged between 8 and 22.

Loopy minds

Similarly, if Bassett's ideas are correct, you would also expect animals lower on the evolutionary tree to have cycles that are less sophisticated. And indeed, the loops seem to link evolutionarily older and younger brain areas, says Bassett, suggesting that they might have evolved to add nuance to more basic functions like the flight response, reward seeking and learned associations. Now Bassett's team plans to train a topological lens on the few connectomes we have from other species – including fruit flies, mice and nematode worms – to check if it's possible to see cycles emerge. "Potentially, over evolution, what has changed is the length of the loops and that they are connected to the newer areas of cortex," says Bassett.

All this could have medical uses too. The existence of cycles opens up the possibility that their shape might reveal changes in connectivity that underlie problems like depressive disorders, schizophrenia and attention deficit hyperactivity disorder (ADHD). These conditions are characterised by problems in the way that the frontal areas of the brain regulate emotional processing, and it is possible that the cycles linking them are the source of the trouble. "That's an open question that we are working on," says Bassett.

Diagnosing these conditions relies on cataloguing an individual's symptoms, which can be subjective. If brain scans show that physical differences in cycles are correlated with these disorders, that might give us another mode of diagnosis, Bassett thinks. Ditto for synaesthesia, a condition in which senses are combined in unusual ways, so people might hear colours or taste sounds.

Although Bassett's work shines a powerful light on the large-scale organisation of the brain, some think topology could be revealing on smaller scales too. Experiments on mice moving through a maze have already tracked the topology of neuron firing patterns in the hippocampus, a brain region that plays a crucial role in spatial memory. Vladimir Itskov of Columbia University, New York, who led the study, found he could recreate the shape of the maze from the firing patterns alone. Some are beginning to think that whenever information is being integrated in the brain – whether on the scale of the whole brain or a few neurons – then topological rules are important.

It is still early days for this new holey view of the brain. But perhaps it is at least time we ditched our focus on pulling at its wires. If we want a better understanding of our brain, then maybe its many holes are a better place to start picking. ■

Caroline Williams is a consultant for *New Scientist*. Her book about her brain's plasticity, *Override*, is out now

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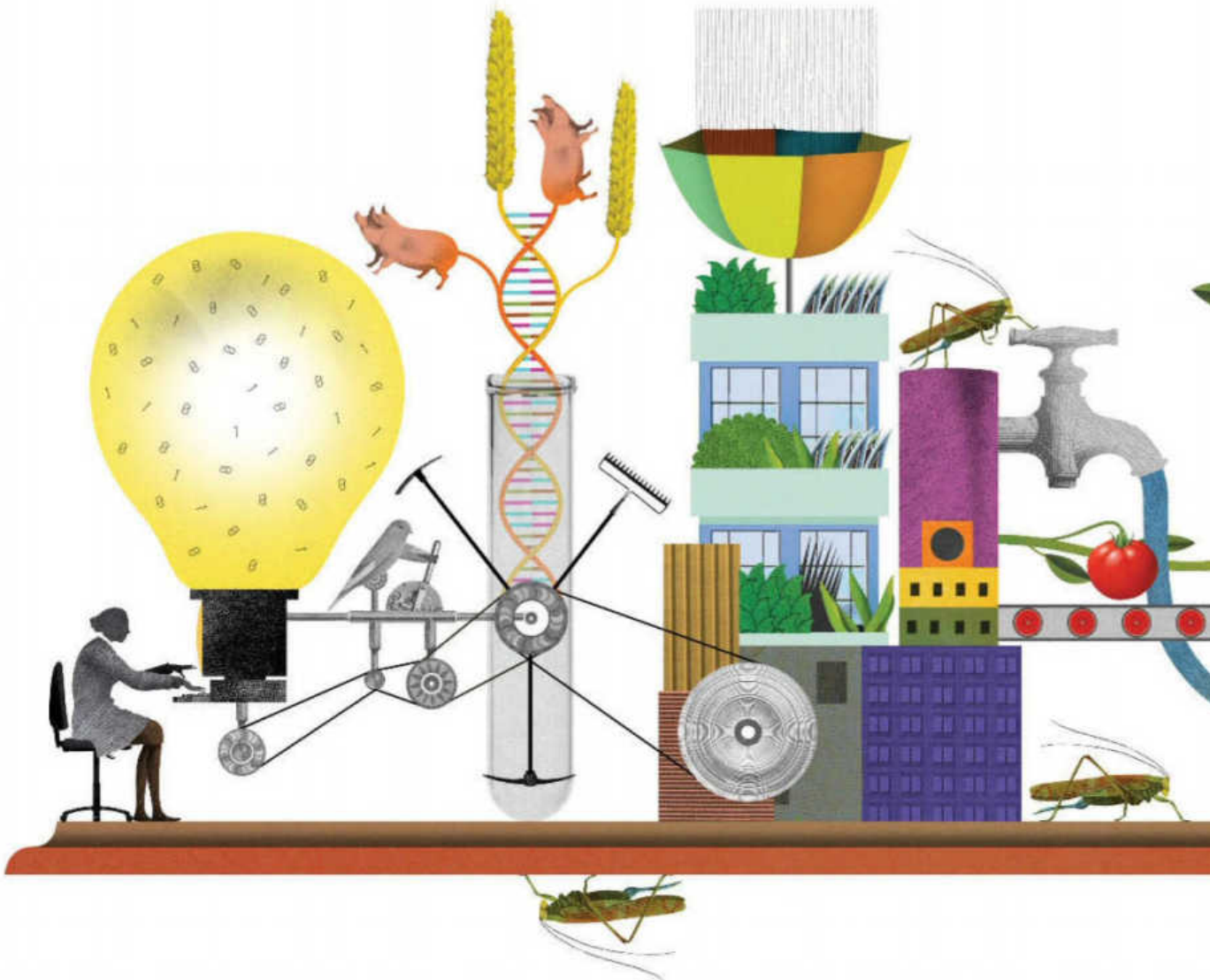


BRETT RYDER

Tomorrow's menu

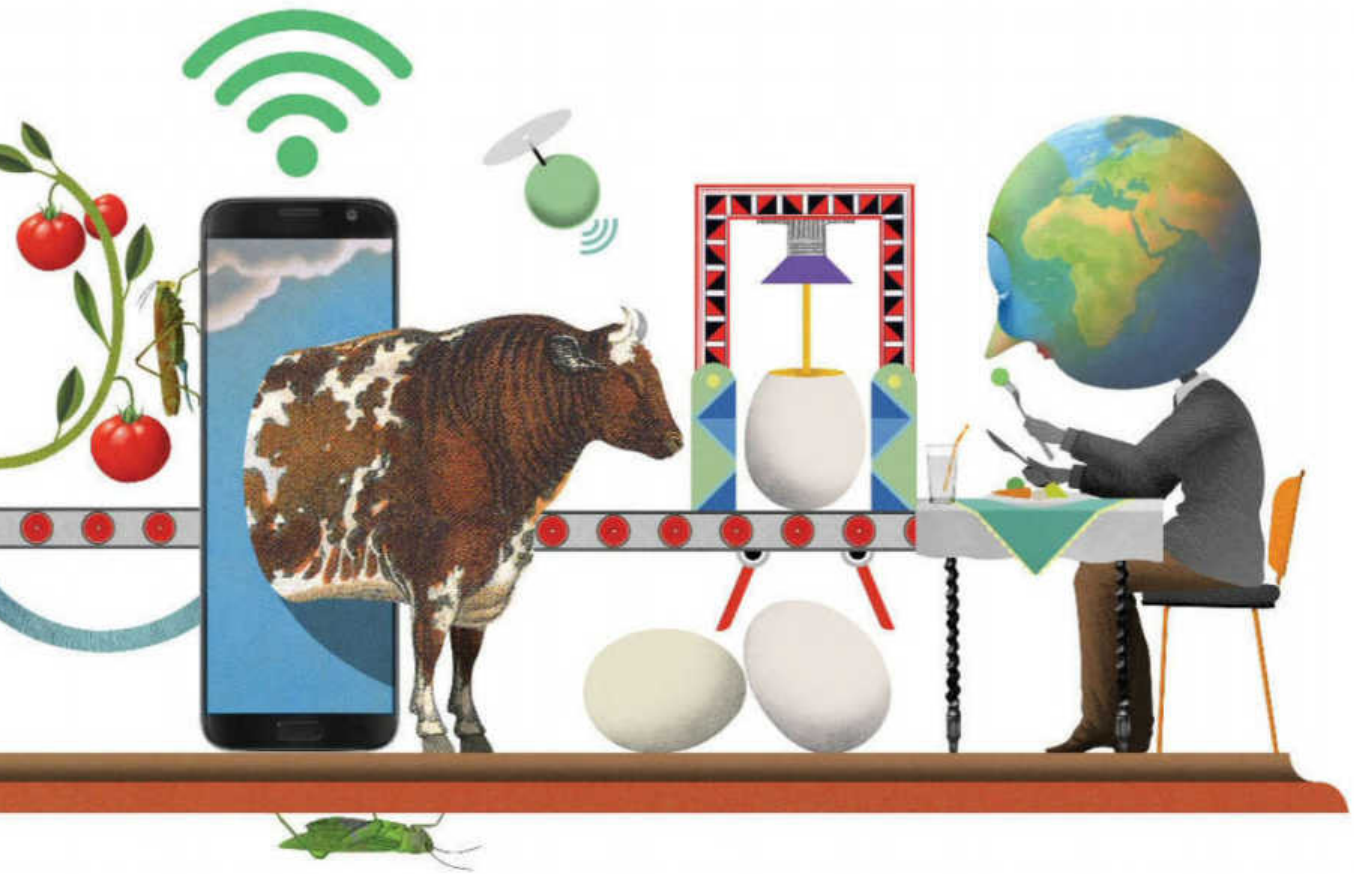
To feed billions more mouths, we will have to acquire new tech and tastes, says **Marta Zaraska**

IN 1970, US biologist Norman Borlaug won the Nobel peace prize. Dubbed the father of the green revolution, Borlaug was credited with saving over a billion people from starvation. That figure may be a guesstimate, but there's no doubting the success of the green revolution: in 25 years, it more than doubled cereal production in many parts of the world through the use of high-yielding varieties and modern farming technology.

Today, the human population is almost twice what it was then, and in 2050 it could reach 10 billion. Even now, some 800 million people go hungry. Feeding ourselves without desecrating the planet is one of the biggest challenges we face. We are running out of land, water and time. To make matters worse, as the world warms, agriculture will get harder.

Feeding the 10 billion will require some creative solutions – and unpalatable compromises. Perhaps we can learn to love algae, corn husks and crickets, but what about lab-grown meat, synthetic milk and genetic modification? How far are we prepared to go to kick-start green revolution 2.0?

It's not that the original green revolution has nothing left to give. It relied on mechanised farming, modern fertilisers, effective irrigation and better seeds to increase productivity. New technology can make existing methods more effective, while also extending the benefits to parts of the world that didn't gain so much from the original green revolution. That's Africa above all. "By 2050, the world will need to boost agricultural production by at least 70 per cent. Nowhere else is the potential to achieve this increase as great as it is in Africa," says Agnes Kalibata, president of the non-profit Alliance for a Green Revolution in Africa. Around half of the world's unused agricultural land – 4.5 million square kilometres – is in that continent. What's



more, yields from cultivated land there are much lower than in Europe or North America.

A 2013 report from the World Bank concluded that there is potential to triple the worth of Africa's agricultural output to $1 trillion a year by 2030. Traditional green-revolution approaches will play a big part, especially in sub-Saharan Africa, where two-thirds of the power used to prepare land for farming is still provided by human muscle. But according to a report by consultancy McKinsey, digital technology could provide an additional boost of $3 billion per year. In Kenya, for example, a smartphone app called iCow helps dairy farmers keep milk records, receive tips on nutrition and contact local vets. Farmers with smartphones can also benefit from satellite data providing information such as which crops need more water or fertilisers.

These types of technology underpin so-called precision agriculture – applying the optimal amount of inputs such as water, fertiliser, pesticides and labour, at the right location and time. It's an approach that can help boost yields in the West, too. "The long-term goal is to increase the level of detail in crop management to the point of single-plant management," says Alex Thomasson at Texas A&M University in College Station. Imagine tractors with infrared cameras that can measure where exactly fertilisers are needed, and drones with thermal sensors hovering over fields, collecting data on plant irrigation (those short on water appear cooler in an image). "Production optimisation can offer a great deal of help in feeding the world, and water may well be the most important aspect," says Thomasson.

It also allows us to farm in ways and places not considered feasible before. In some cities, vertical farms are taking over rooftops and abandoned buildings. They can be highly efficient, with yields up to 130 times those on an equivalent area of arable land, according to AeroFarms, one of the firms building on the concept. In Montreal, Canada, for example, a 2900-square-metre rooftop greenhouse feeds some 2000 people. As well as using 95 per cent less water than conventional cultivation, it benefits from the fact that night-time temperatures tend to be higher in urban areas than in the countryside, lowering heating costs. "Outdoors you can control nothing, indoors you can control everything," says Dickson Despommier at Columbia University in New York City. In Africa, that could also mean keeping crops safe from things like locusts or even civil unrest. What's more, urban farms are close to their customers, limiting the risk of crops spoiling in transit (see "Waste not, want not", page 34).

"How far are we prepared to go to kick-start green revolution 2.0?"

But further increases in productivity and extending the range of agriculture are not going to feed the 10 billion on their own. That's going to require a fundamental rethink of what we eat.

There are some 50,000 edible plants, yet just three – wheat, rice and maize – account for over 60 per cent of the world's calorie ›

Raising standards: vertical farms use far less energy and land

JONATHAN G CROSBY/EYEVINE

WASTE NOT, WANT NOT

Around a third of all our food ends up rotting on farms and in landfills. That could easily provide sustenance for the 800 million people who currently go hungry, with plenty spare to help feed a growing human population. Reducing waste is the "most important component" of feeding the world of the future, according to John Floros, dean of Kansas State University's College of Agriculture.

In the West, most food loss occurs late in the supply chain. UK households waste 20 per cent of groceries simply because of confusion over labels, throwing out items based on "best before" dates, for example. "Such food is still good afterwards. Maybe it will have a few less vitamins, but you can still eat it," says Floros.

One way forward is to raise awareness. Better labelling can help too – introducing "freeze by" dates, or even banning best-before dates, as France did with its equivalent in 2015. Another option is to convince consumers to buy imperfect-looking produce. Some supermarkets are already on to this, encouraged by the Ugly Fruit and Veg Campaign and others. Going even further, a store called Wefood in Copenhagen, Denmark, sells only groceries that would otherwise end up in the dump. Even restaurants are starting to use waste food. They include Freegan Pony in Paris, France, which serves vegan food made from produce recovered from local markets.

In the developing world, most food loss happens long before goods reach consumers, mainly because of shortcomings in infrastructure, processing, storage and refrigeration. No one strategy will combat these, and investment is lacking. However, in Nigeria, for example, a company called ColdHubs is building solar-powered "cold stations" to store produce close to farms and markets.

Food preservation is another solution, and not just in developing countries. Here, there are promising developments, such as sterilising foods using high pressure, short electric pulses or blue LEDs. "In Western countries, the popular position is that all processing is bad," says Floros. "We have to change that perception."

intake. Indigenous plants better suited to local conditions could offer better solutions. In Africa, these include bambara, which produces a nutritious bean and is resilient to hot and dry conditions, and marama, with its nutty-tasting seeds, protein-rich tubers and ability to thrive in the poorest of soils.

Anyone for algae?

People are also starting to recognise the nutritional potential of algae, including seaweed. Some types, when dried, contain 70 per cent protein; others are packed with essential fatty acids. Seaweeds are abundant in micronutrients, too, from iron and zinc to potassium and calcium. There are more than 100,000 species of algae, yet we currently cultivate just 20, so there's plenty of scope for expansion. A big advantage of algae is that its cultivation doesn't require agricultural land: it can be done offshore or in places where the groundwater is salty, even in the Sahara.

Other technological fixes are likely to put even stranger items on future menus. For example, Percival Zhang at Virginia Tech in Blacksburg and his colleagues have found an efficient way to turn cellulose into starch using genetically modified *E. coli* bacteria. This could be used to make food out of fibrous plant materials such as corn husks and even perennial grasses.

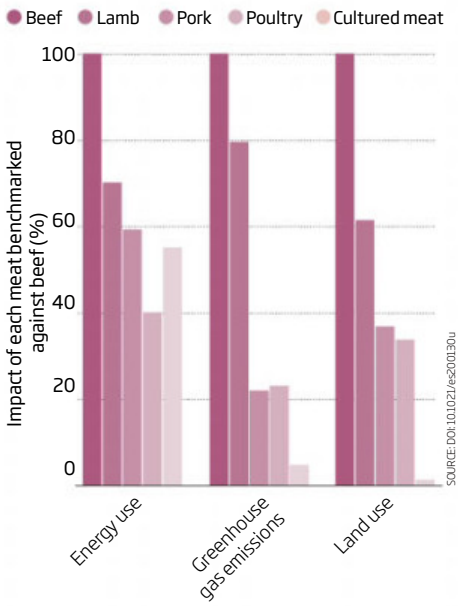
That may sound drastic, but if we are to feed 10 billion people, we have no option but to eat more plants and less meat. Currently, a third of Earth's arable land is used to grow feed for livestock. If everyone ate a US-style diet, by 2050 we would need around 4.5 times as much meat as we produce now. There simply isn't enough land to do that.

One way to fill that gap is to eat more of what 2 billion people across the globe already do: insects. It takes 25 kilograms of feed to produce 1 kg of beef, but just 2 kg to get 1 kg of crickets. Insects contain all the essential amino acids we need, and some, including termites, grasshoppers and caterpillars, are better sources of protein than beef or chicken. But insects have an image problem. It's not simply that the uninitiated find them off-putting; consumption is actually decreasing among those who traditionally eat them. "They feel that they need to eat meat to adopt a prosperous lifestyle, like people in the West," says Marcel Dicke at Wageningen University, the Netherlands. One way around this, he believes, is for insects to become part of an affluent Western diet.

An alternative is more plant-based meat

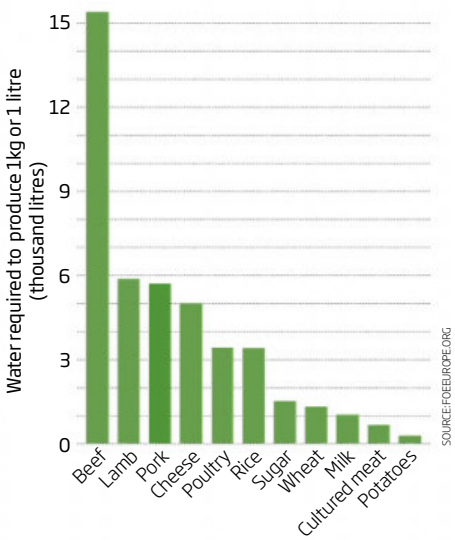
Sin of the flesh

Meat is very inefficient to produce for the nutrition we get from it. Switching to cultured meat could help



Thirsty food

If we are to feed a growing world population, we will have to use limited water resources wisely



MAKING A MEAL OF IT

Insects look too scratchy to eat? Algae too slimy? Some foods of the future can be made more palatable with 3D printing. Just convert your crickets or seaweed into powder, blend with other yummy ingredients and use a 3D printer to transform the mixture into new forms. Academics from London South Bank University have done this already – printing lace-like objects out of insect flour.

This technology can do much more than provide pretty meals for Western plates. 3D printers could easily be brought to disaster areas or remote places where malnutrition is rife. They can produce food rapidly and in the amounts required, minimising waste and costs. They also have the potential to revolutionise agriculture, allowing on-site production of herbicides or pesticides to order.

substitutes. First there was tofu, then "textured vegetable protein", and now we have "high-moisture meat analogues". These mock meats are made by breaking and reassembling plant-derived protein molecules in extruders – the same machines used to produce breakfast cereals and spaghetti. Already there are dozens of them on the market, from sausages made from lupin beans to the Impossible Burger, which takes meat mimicry to a new level using a plant-derived version of haem, a component of the blood protein haemoglobin, to create a veggie burger that bleeds.

Then there's "clean" meat grown from muscle tissue in labs, or "carneries", which also has big environmental advantages over conventional meat (see diagram, above). Four years since we saw the first lab-grown burger (cost: $330,000), the technology is gathering pace. Last year, an Israeli start-up announced that it is developing clean chicken. Meanwhile, a US company has already done tastings of "steak chips" – a cross between a potato chip and beef jerky – and says they could be on supermarket shelves within a few years.

How clean meat will go down with consumers remains to be seen. But according to Anon van Essen at Maastricht University in the Netherlands, who worked on the first clean burger, there is "nothing to fear". "These cells are dead, as in any meat. Stem cells are everywhere: in your muscles, in your regular food," he says.

Even before we are eating lab-grown meat, we could be consuming cow-free milk and chicken-free eggs. Such products are possible thanks to synthetic-biology technologies that genetically modify yeast to "brew" animal proteins. Again, there are environmental advantages over conventional production methods. Yeast-made milk uses 98 per cent less water and requires up to 91 per cent less land than a cow's milk. Synthetic products can be healthier, too: it's possible to make milk without lactose, for example.

Some consumers may see these products as "unnatural", but companies developing them liken their process to making beer. They also point out that the GM yeast doesn't make it into the end product. And if we are to meet the global food demands of 2050, some of us may have to overcome our aversion to genetic modification. GM can create crop varieties that are resistant to disease, drought and other environmental hazards that are becoming more prevalent as a result of climate change. It also has the potential to increase the overall amount of arable land by, for example, giving us crops that can thrive in salty or alkaline soils. And it could produce plants that are more efficient. For example, Australian researchers recently discovered an enzyme found in common panic grasses that if engineered into cereal crops could significantly increasing yields by making them better at taking up carbon dioxide for photosynthesis.

> "We could soon be consuming cow-free milk and chicken-free eggs"

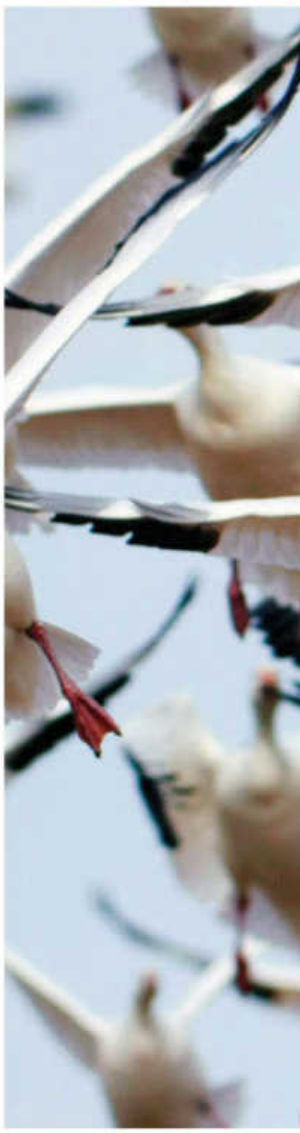
"It's easy to make GM crops sound scary, but there is really no basis to the claim that they are genetically any less safe than conventionally bred ones," says plant geneticist Ottoline Leyser at the University of Cambridge. Rather than worry about the technology itself, she says, we need to consider the consequences of particular traits introduced into plants, such as herbicide tolerance.

There's no doubt that feeding 10 billion people will require far-reaching changes both in what we eat and how we think about food. "With a problem as complex as food security, the idea that you should dismiss anything that can contribute to solving it is inappropriate," says Leyser. "We have an extensive toolbox to address food security and we need to make sure we pick the right tools for the right job, at the right time." ■

Marta Zaraska is a writer based in France and the author of *Meathooked: The history and science of our 2.5-million-year obsession with meat*

Miracles on the wing

Tiny tracking devices are unravelling the big mysteries of bird migration, says **Tim Vernimmen**



Snow geese migrate the length of North America every year

THE Arctic tern, a black-crowned seabird weighing no more than a bar of soap, flies from the top of the world to the bottom and back again every year. That's 40,000 kilometres as the crow flies. But when researchers equipped terns with satellite tracking devices, they discovered that these birds don't take the shortest path. One individual, tracked in 2015, ended up covering close to 100,000 kilometres – equivalent to more than twice around the planet.

"Bird enthusiasts have been ringing birds since the 1890s," says Anders Hedenström at Lund University in Sweden. "But ringing data only tell you where birds have been recaptured. They don't tell you what they're up to once they've disappeared over the horizon."

Thanks to lightweight trackers, we can now follow even the smallest birds on their spectacular journeys. What we're finding along the way is amazing, says Hedenström. "In just a few years, we've learned more about migration strategies than from a century of ringing." Meanwhile, mathematical modelling and molecular biology are also bringing fresh insight into why and how they do it.

There is still a lot to learn, but from where these birds really go and how they navigate to the tricks they use to prepare for such epic journeys, the story of avian migration is not standing still.

WHY BOTHER TO MIGRATE?

It's not hard to see why migratory birds leave places such as northern Europe for warmer climes like central Africa as winter draws in: why struggle through colder temperatures, shorter days and scarcer food supplies when you can be somewhere with pleasant temperatures and plentiful food. But that raises another question: why do these birds risk their lives by flying thousands of kilometres back each spring? Why not stay where it's warm?

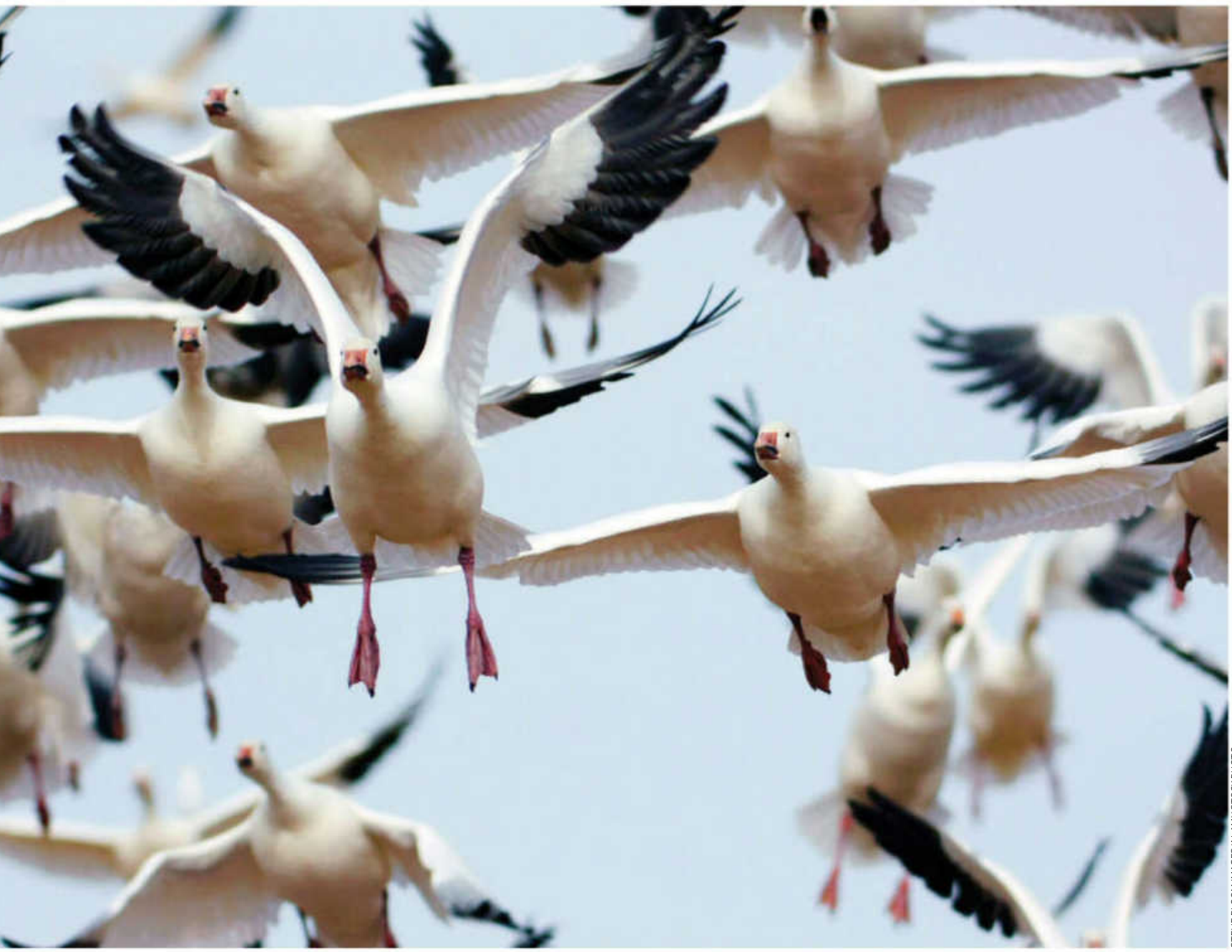
One theory is that it comes down to real estate. "In the tropics, competition for nesting space is fierce," says Hedenström. "So it may well pay to opt out of that fight and fly north, where the food supply peaks in summer and there is more room for nesting – at least if you get there in time, because the best spots may get filled fairly rapidly."

That might explain why many migratory birds are in such a hurry during their spring migration. Last year, when Hedenström and his colleagues tracked common swifts flying across the Mediterranean and the Sahara desert, they found that some birds took more than two months to complete the southern journey in autumn, while all the birds they tracked heading north in spring crossed in under two weeks.

Then again, in terms of the evolution of intercontinental migration, it's far from clear that all birds making these journeys today started out travelling north from the tropics during the summer. In 2014, Ben Winger, now at the University of Michigan in Ann Arbor, and his colleagues built a mathematical model to reconstruct the geographical ranges of the ancestors of hundreds of living species of American songbird. They found that most long-distance migrants began in the north and started flying south for winter, as opposed to being tropical birds flying north for summer.

All of which still leaves open the question of why some species fly tens of thousands of kilometres every year. Why not find somewhere closer for a winter escape? We're still a world away from a conclusive answer. One idea is that favourable winter-summer habitats slowly drifted further apart as a result of plate tectonics, forcing birds to cover just a few extra millimetres each year – but vast distances millions of years later.

Even that can't explain the curious long-haul journey of the ancient murrelet, a member of the auk family that includes puffins and guillemots. Tracking studies from 2014 showed that these birds fly almost 8000 kilometres across the north Pacific, from Canada to Japan and China, even though there is little difference in the conditions at the two destinations.



STEVE BLOOM IMAGES/ALAMY STOCK PHOTO

HOW DO BIRDS GET IN SHAPE?

Migratory birds are extraordinary endurance athletes – and their feats require some serious preparation. In the weeks before take-off, many undergo extreme physiological changes. Most obviously, they load up on fats. In many cases, that means temporarily supersizing their digestive organs to ingest as much food as possible. Then, immediately before departure, they shrink their digestive organs to reduce their flying weight.

But that's not all. At least one species indulges in what Jean-Michel Weber at the University of Ottawa, Canada, describes as "natural doping". Weber noticed that the semipalmated sandpiper, which flies non-stop from the Bay of Fundy on the east coast of Canada to South America at the end of every summer, mainlines on mud shrimp before departing. Mud shrimp are loaded with omega-3 fatty acids, and Weber suspected that these compounds boosted the efficiency of the sandpipers' muscles. To isolate their effects from other factors, he turned to a more sedentary bird. Sure enough, when he fed bobwhite quails a cocktail of fatty acids equivalent to the diet of the sandpipers, the amount of oxygen that their muscles could use shot up by 58 per cent.

Migrants' preparations don't stop there. Several species, including the red knot, are known to bulk up their heart muscles so they can pump more oxygen-rich blood around the body. The bar-tailed godwit, however, might have the most effective way to supercharge aerobic capacity. Its levels of haemoglobin, the molecule that carries oxygen around the blood, increase considerably in the weeks before migration.

That helps explain how the godwit can fly for more than 11,000 kilometres without a rest. This epic journey, revealed back in 2007 by one of the first big satellite-tracking studies, makes it the longest known non-stop journey by any bird (see "Record-breaking migrations", page 39). Another factor is that the godwit doesn't rely on fat alone. "Many birds will also break down muscle tissue along the way," says Hedenström. "Muscle proteins contain plenty of water, which helps to avoid dehydration." ›

WHAT TRIGGERS MIGRATION?

Migratory birds are punctual when it comes to departure times: all individuals in a species tend to leave at roughly the same time. But they do appear to be able to respond to shifts in conditions from year to year, so they arrive at their destination when the going is good. This suggests they respond to an external stimulus, something triggering that irresistible migratory urge known as *zugunruhe* – from the German *zug*, meaning movement, and *unruhe*, or restlessness. But what tells them to depart?

The most important indicator that the seasons are changing is probably sunlight. It's clear that shifts in the length of days are a major factor in triggering *zugunruhe*. It is far from the only thing they pay attention to, however: in studies where day length was artificially kept constant, several species of migratory birds still knew when to leave. What's more, for birds leaving from the tropics, where day length barely changes all year round, there has to be something else.

Changes in air pressure, predictive of incoming weather, seem to have an influence, as does food availability. In 2011, Peter Marra at the Smithsonian Migratory Bird Center in Washington DC demonstrated that American redstarts delay their spring departures if dry conditions in their overwintering areas mean they struggle to find enough food to prepare for the journey.

HOW DO BIRDS PICK THEIR ROUTE?

"Tracking is teaching us that different birds may follow very different routes, and they are often far from straight," says Hedenström. Take the Arctic tern, whose monster detour means it may travel 60,000 kilometres a year farther than the most direct trip. Such diversions are typically down to finding suitable rest stops, but wind has a big say too.

Because birds fly at speeds comparable to typical wind speeds, head and side winds can pose a considerable challenge. Several tracking studies have revealed that birds take hefty diversions to find favourable winds, allowing themselves to drift when it is more energy efficient than keeping to a straight line, says Hedenström. Last year, for instance, a team led by Kyle Horton at the University of Oklahoma used weather radar to track flocks of songbirds that migrated by night across North America. They found that the birds drifted sideways on crosswinds but then adjusted their course near the Atlantic coast to get back on track.

> **"This ability to navigate by Earth's magnetic fields has confounded us for decades"**

Another recent tracking study, this time following frigate birds migrating across the Indian Ocean, revealed not only that they seek out cumulus clouds so they can ride on the strong updraughts beneath them, but also that they appear to sleep as they ascend.

Bar-headed geese, which migrate over the Himalayas, have a similar appreciation for the optimal elevation. They constantly change height, descending into valleys where the air is denser and more oxygen-rich whenever they can, then climbing when necessary, using updraughts where possible. This significantly reduces the energetic cost and physiological strains of the trip.

In any case, the choice of route is critical: a 2016 study tracking cuckoos, for example, found that at least two-thirds of the birds following an eastern route through Italy or the Balkans were likely to survive, whereas animals choosing a shorter route across Spain or Portugal faced a much higher risk of dying on the trip. The researchers suspect that drought conditions in Spain, increasingly common over the years they studied, are to blame.

HOW DO BIRDS NAVIGATE?

The senses that birds rely on to find their way largely remain mysterious. This is especially true for species that travel individually, which means young birds have to figure out where to go without a flock to follow. It is safe to say that birds probably use all their senses: visual landmarks as well as the sun and the stars provide them with information on their position, as do smells for some species, especially seabirds. But there must be something else, because birds still show a clear tendency to take off in the right direction even in total darkness. That something is an ability to detect and navigate by Earth's magnetic field lines that has confounded scientists for decades.

At this point, there are two main contenders for the molecular mechanism underlying "magnetoreception" in birds. The first relies on crystals of magnetite, a form of iron oxide, found in the upper beaks of several species, including European robins and garden warblers. But it has proven maddeningly difficult to demonstrate that magnetite plays a part in magnetoreception.

Perhaps the most promising work comes from fish. In 2012, Michael Winklhofer at the Ludwig Maximilian University of Munich, Germany, took cells containing magnetite clusters from the snouts of rainbow trout and placed them under a microscope around which an artificial magnetic field was rotated. Sure enough, the cells also rotated – and their sensitivity was much greater than expected. However, it's not yet clear how those cells might send signals to the brain.

The alternative explanation involves light-sensitive proteins called cryptochromes, found in the eyes of all kinds of migratory animals. The idea is that magnetic fields alter a quantum property called spin in the electrons within these molecules, flipping them back and forth between two different states. That in turn changes the chemical behaviour of those molecules, which results in Earth's magnetic fields being superimposed on the birds' vision.

Studies have shown that these proteins are

PAUL NICKLEN/NATIONAL GEOGRAPHIC CREATIVE

2.4 MILLION KILOMETRES

Average distance travelled by an Arctic tern over its life – equivalent to three trips to the moon and back

Record-breaking migrations

Lightweight tracking devices let us plot the routes of migratory birds in astonishing detail

Longest (non-stop)

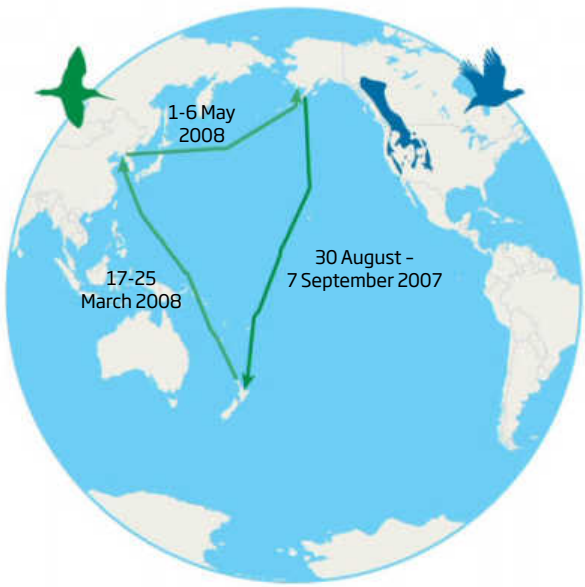
Bar-tailed godwit

One bird covered 11,500 kilometres over the Pacific in just eight days

Shortest

Blue grouse

Descends just 300 metres down pine-covered hills in North America (range shown)



SOURCE: BATTLEY ET AL. 2011/WDFW

Longest (with rests)

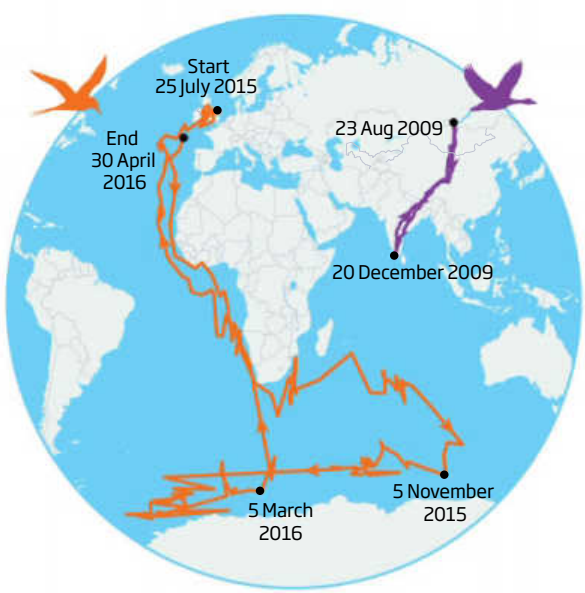
Arctic tern

An intrepid individual covered almost 96,000 kilometres in just under a year

Highest

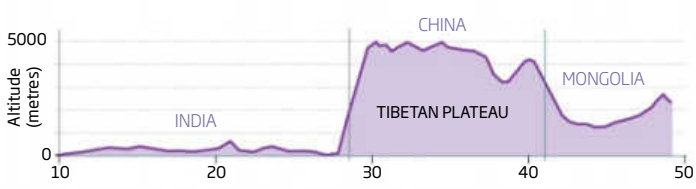
The bar-headed goose

The highest-flying individual reached almost 7300 metres above sea level when crossing the Himalayas (see below)



SOURCE: RICHARD BEVAN, CHRIS REDFERN, NEWCASTLE UNIVERSITY

On their twice-yearly migration, bar-headed geese have to cross the Tibetan plateau, some 5000 metres above sea level



Average elevation for 38 geese tracked with GPS-enabled devices

SOURCE: DOI:10.1152/physiol.00030.2014

sensitive to magnetic fields. Again, though, the task is to see the process in action in a living being and show it is connected to its brain.

One recent study suggested the two mechanisms could be part of the same system. Even if they are, that still wouldn't give you the whole story, says Hedenström. "The most complicated question is how the sounds, sights and smells the bird experiences combine with its magnetic sense and information on its own condition to create a natural tendency to do the right thing."

WHAT KILLS MIGRATORY BIRDS?

Although statistics on causes of death for migratory birds are hard to come by, there are plenty of ways to die. Storms, for starters. And yet one recent tracking study dramatically reveals how resilient some birds can be: a whimbrel caught in tropical storm Gert, off the coast of eastern Canada, was found to have endured extreme head winds for 27 hours.

By far the greatest threat comes from humans. Some of the countries in and around the Mediterranean are notorious for the annual slaughter of migratory birds. Researchers estimate that 25 million birds are illegally killed or captured in the region every year (see page 26). Some Caribbean islands have a similar reputation. Indeed, two whimbrels carrying trackers safely negotiated hurricane Irene in 2011, only to be shot in Guadeloupe a few days later.

Then there is the new threat posed by climate change. Rising temperatures are likely to cause more extreme weather events and may make the weather more unpredictable, meaning the primary cues birds use to decide when to leave may become less reliable. Higher temperatures may also shift the peak in the availability of seasonal foods in stop-over or breeding areas away from the birds' moment of arrival – a problem already documented in European pied flycatchers.

The biggest human-made problem facing migratory birds is still habitat destruction. Favourite stop-over sites may disappear from one year to the next, compelling migrants to continue without food, water or rest. You might think the ability to travel large distances would make it easier for these birds to find better places to feed and breed, but migration appears to make them vulnerable: around the world, their populations are declining faster than those of birds that don't migrate. ■

Tim Vernimmen is a science writer based in Antwerp, Belgium

IMAGES (L-R): ANNA ZIEMINSKI /GETTY; DISA ARCHIVE; GISELE WULFSOHN/SOUTH/GALLO IMAGES; DAVID TURNLEY/GETTY

Fighting for life in a time of AIDS denial

As HIV exploded in South Africa in the 1990s, **Glenda Gray** helped lead the fight against it, with President Nelson Mandela behind her. But then came a new president, and a wave of catastrophic denialism

THE 1990s brought democracy to South Africa – but also an explosion in HIV infections. More than 1.5 million of my country's 38-million population were infected with HIV when apartheid ended and Nelson Mandela came to power in 1994. By 2000, 1 in 5 pregnant women were HIV-positive, with about 70,000 infected babies born each year.

Under Mandela, I had been on the side of the government. I was drafting South Africa's plan to tackle HIV and AIDS, including the roll-out of nationwide treatment. But in 1999 the political landscape shifted. A new president, Thabo Mbeki, had prejudices about science. Mbeki's line was that poor nutrition, rather than HIV, was the cause of AIDS. I was stunned. Suddenly I found myself at loggerheads with the very officials I had been working well with for years – except now they were advocating beetroot and garlic to prevent AIDS! It was a nightmare.

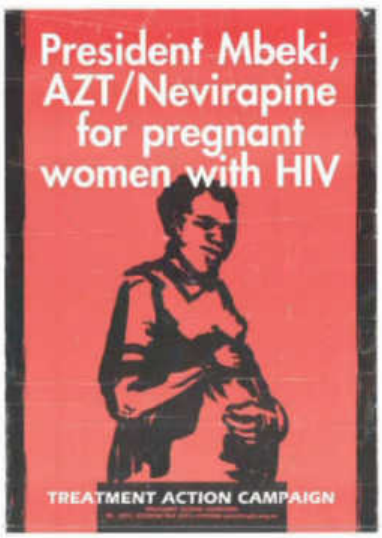
Around then, in Chris Hani Baragwanath Hospital – one of the largest in the world, in Soweto, a township of Johannesburg – virtually all the cribs were filled with terminally ill infants. AIDS was the biggest cause of death in children at the hospital. Most of them died before they turned 1. In adult wards, I watched young people waste away, their skin stretching across their skeletons before they died. As a doctor, I'd been trained to deal with death, but it was tough seeing such suffering every day, no hope in sight.

A huge problem was the transmission of HIV from mother to baby during childbirth or breastfeeding, which is preventable by giving the mother antiretroviral drugs (ARVs). But Mbeki's government would not provide ARVs. I saw the effects of this firsthand, alongside James McIntyre, when we ran the University of Witwatersrand's Perinatal HIV Research Unit at Baragwanath. We were counting the dead bodies, many of them babies.

The lack of drugs stemmed from Mbeki's AIDS plan, announced early in his presidency, which focused on prevention and not also on treatment of HIV for adults, and didn't mention mother-to-child transmission. At the event where the plan was announced, I got into a big argument in the bathrooms with the outgoing health minister Nkosazana Dlamini-Zuma, as I couldn't understand the government's stance. If you want to look good, you save babies, but here was a government that didn't want to.

Scientifically, mother-to-child transmission of HIV, and its prevention, weren't contentious. Why would anyone object to giving AZT or nevirapine – internationally approved drugs that reduce HIV's ability to replicate – to a pregnant woman to prevent her infecting her baby? Yet suddenly something unequivocal was being contested. Some so-called "AIDS dissidents" in government and society were even saying that AZT was toxic and that we were killing black women by using it.

Fortunately, because James and I were



researchers as well as doctors, we didn't have to rely on the South African government for funding. Independent grants and money from the French government's International Therapeutic Solidarity Fund meant we could carry out research into how to scale up the provision of ARVs. But despite this, we still struggled to get permission from the new health minister Manto Tshabalala-Msimang to demonstrate the use of ARV treatment in Soweto.

Administrators and civil servants kowtowed to Mbeki whether they believed in AIDS denialism or not, and so toed the party line at whatever cost. For example, I once had a call from a doctor at another hospital, who said, "I have an HIV-pregnant woman in labour. I hear you have the drugs to prevent mother-to-child transmission during childbirth. Can I send an ambulance to fetch them?" The ambulance rushed to our unit, and I gave the driver the package. When he got there, the hospital boss confiscated the drugs and phoned me, saying, "How dare you send that medicine!"

Those of us who did stand up against AIDS denialism were marginalised. But as a scientist, I didn't get to choose a side: I could only show the evidence and advocate on that basis.

In 2001, a civil society group called the Treatment Action Campaign took the South African government to court, and the court reinforced what we had been saying all along: healthcare facilities had to provide pregnant women with ARVs. But the several years between the court judgment and the wide-scale roll-out of ARV drugs to pregnant women felt very long. I was trying to keep my patients as healthy as possible, while we waited for the drugs that would keep them alive.

The Lazarus effect

When the ARVs were finally rolled out it was like Lazarus syndrome. My patients went from needing wheelchairs and oxygen tanks, from lying on stretchers, to healthy. Children I was treating went back to school. It was beautiful to see people claim back their lives. ARVs were the most amazing thing to happen to South Africa.

In 2008, the political winds changed again. Mbeki resigned and interim president Kgalema Motlanthe, on his first day in office, appointed a new health minister. It was like waking up from a nightmare. Mbeki's stance on HIV was ultimately his undoing, and with him gone South Africa began making ARVs available in all its clinics, to anyone who needed them.

We cannot bring back the 300,000 or more people who died as a result of Mbeki's denialist government, but between 2005 and 2014 the average South African life expectancy jumped by nine years. The mortality rate for children under 5 plummeted. We now have the largest ARV roll-out in the world.

But, sadly, HIV is still rampant in South Africa, with around 1000 new infections every day. We estimate that about 1 in 5 people are HIV-positive. And while we can prolong their lives, we can't yet stop the stigma they face.

Far left: while protesters took to the streets during Mbeki's presidency, and campaigned (left), Glenda Gray (above in green) cared for mothers with HIV and their babies

South Africa is an oddly conservative country: even if you were born with HIV, you are considered dirty and shameful. It's hard to tell a pregnant woman she is HIV-positive, which I have often had to do. At what should be a precious time, she is wondering if her partner gave it to her, and how to tell her family.

Back in the "bad days", people were dying and were embarrassed about their illness, so they kept quiet. It is better now there is treatment, but the stigma is still there. And that is why we need a vaccine – to stop people getting infected in the first place.

I am now part of a team beginning a vaccine trial that holds great promise for our country and the world. In November, we enrolled 5400 adults in a trial called HVTN 702 – the largest and most advanced of its kind in South Africa. It builds on a smaller clinical trial in Thailand. In that earlier trial – the most successful to date – participants who were vaccinated were 31 per cent less likely to contract HIV over a three-year follow-up than participants who didn't receive the vaccine. We aim to get the first results from our trial, using a new vaccine formulation, in 2020.

We need a vaccine that works in adults before we can give it to babies. Once we find a vaccine and give it to infants, I will have completed my journey. ■

As told to Sarah Wild

PROFILE
Glenda Gray is the president and CEO of the South African Medical Research Council, a research professor of paediatrics at the University of the Witwatersrand, and a director at the Perinatal HIV Research Unit in Soweto

War by any means

Sally Adee marvels at the story of a secretive Pentagon agency

The Imagineers of War: The untold story of DARPA, the Pentagon agency that changed the world by Sharon Weinberger, Alfred A. Knopf

SHORTLY after arriving at the Advanced Research Projects Agency (ARPA) in April 1958, the new chief scientist presented a plan to the agency's director. Four months later, nine ships set off for the (mostly) uninhabited Gough Island deep in the South Atlantic, carrying 4500 personnel and three small nuclear weapons to launch into the magnetosphere.

This was Project Argus. The idea had germinated in the panic after the launch of the Soviet Union's Sputnik satellite. In light of these surprising new capabilities, the US had a problem: how could it protect the country from an incoming nuclear warhead?

Armed with some wild physics, Nicholas Christofilos hatched an equally wild plan: turn the upper atmosphere into a force field across the US that would fry the electronics of incoming missiles. How? Explode nuclear weapons in Earth's magnetosphere to create a long-lived radiation belt that would degrade the missiles.

The first atomic detonation set off a luminous fireball, triggering a staggering blue-green aurora that captivated its audience. But beyond the pretty lights, it was a failure. The bombs did indeed produce many high-energy electrons, but it turned out that Earth's magnetic field wasn't strong enough to keep the electron shield from decaying.

Christofilos's ill-fated "death belt" is probably not what you think of when you think of DARPA ("Defense" was only added permanently in 1996). If you have heard of this Pentagon agency, you will know it as the place that brought you the internet, the laser and the stealth fighter. Sharon Weinberger's groundbreaking book *The Imagineers of War*, however, reveals how that mythology is the result of some pretty tight PR control by DARPA, exposing as much as she can of a far more uncomfortable truth.

DARPA likes to present itself as a uniquely nimble outfit. Unbound by the usual red tape, it can do the kind of "high-risk, high-reward" research way beyond the purview of other branches of government. It has been so successful in propagating this view of itself that it has spawned two other agencies in its image: ARPA-E and IARPA, specialising in energy and intelligence respectively.

But beneath lies an altogether messier story. Weinberger paints a picture of an agency that long struggled to establish its identity among competing entities – including the US army, the air force and at one point even NASA. Today, as military contracting expands inexorably into arenas that were previously civilian, the nature of war would be unrecognisable to people like

"The plan was to turn the upper atmosphere into a force field over the US to fry any incoming missile"

Christofilos. Just what sort of role is there for an organisation that aimed to win wars, when the US defence department spends more than the entire GDP of many countries on military contracting?

Weinberger is uniquely placed to ask – and to answer – that. A former defence analyst, she became editor-in-chief of leading defence magazine *Defense Technology International*, and then co-founded *Wired*'s Danger Room blog during the "war on terror" years of George W. Bush. The *Wired* blog quickly became required reading, garnering praise across the political spectrum.

Weinberger also has plenty of experience writing about military boondoggles. Her first book was an investigation of the fringe science pursued by some of the shadier wings of the defence establishment, including remote psychic viewing and antimatter bombs.

She has a long history with the right people and knows what to ask them. And, to judge by a sources and notes section that runs to 85 pages, she also seems to have dug into reams of redacted reports. Yet somehow, miraculously, Weinberger has fashioned her material into the best kind of airport thriller.

This is just as well, given all those crazy projects that keep stealing the show. Project Argus, she tells us, was far from alone. Among many more was Project Orion, a 20-storey egg-shaped starship whose escape from Earth's gravity would have been

Robot competitions are part of the image DARPA likes to project

CHIP SOMODEVILLA/GETTY IMAGES

AF ARCHIVE / ALAMY STOCK PHOTO

The game-playing computer in the film *War Games* was not all fiction

powered by about 200 nuclear explosions.

Over several decades, these kinds of comical technological projects were winnowed with deadly precision, their progeny morphing into the sleek drones that whine over US targets in the Middle East today.

Weinberger finds a congruent evolution in how war itself is theorised, and in what counts as a battlefield. DARPA's role in the Vietnam war has been hugely under-reported, and one of her book's major contributions is that it exhumes the agency's involvement in everything from Agent Orange to ill-fated counterinsurgency efforts.

During Vietnam, DARPA irritated Congress with its increased meddling in world affairs and its sponsorship of social science research. The agency had realised that beyond creating technology to kill people or protect them from being killed, you had to go further upstream if you wanted to end wars, never mind win them. You had to rethink "weapons supremacy" to include psychological weaponry.

The subsequent efforts to manipulate people were as Strangelovian as you might expect given the times, full of ham-fisted Western chauvinism. For example, the agency enlisted a psychoanalyst to help the military understand the

"War has moved from weapons to kill individuals, to weapons that manipulate relationships"

"Vietnamese psyche". He administered a Rorschach test to four Vietnamese people, and then extrapolated from the results to make recommendations about an entire nation.

This spawned the Simulmatics Corporation, which, echoing the bombast of Argus, promised to deliver, as Weinberger quotes Simulatics' precise wording, "the A-bomb of the social sciences", a way Americans could "predict and control human events in Vietnam" and thus manoeuvre the population in the way that they wanted.

The immediate results were disastrous, but again, evolution winnowed these ludicrous first steps into something fearsomely effective. "Technologies of human manipulation" based on shoddy science and incomplete thinking evolved into the kind of data mining, relationship monitoring and tactical use of the internet now in use today.

Imagineers is required reading for defence nerds. It will stock their pub conversation arsenal with finely wrought weapons. For example, there is more than you could ever want to know about the machine that inspired the game-theorising computer in the cult teen movie *War Games*. And there is an eye-popping account of the only underground nuclear test ever done in Mississippi. It took the government two years of pumping fresh air into the cavern just to get its temperature down to 150°C.

But *Imagineers* isn't just for nerds. It provides a glimpse into the history of war itself through the lens of an agency that bills itself as trying to "prevent and create surprise". Over DARPA's lifetime, war has moved from weapons to kill individuals, to weapons to manipulate individuals, to weapons that manipulate relationships.

This means that there is an important question hanging unanswered over the book: is DARPA irrelevant? That may seem like an odd question as the agency's reputation is burnished today by breathless reportage of the applications of its technologies, with driverless cars, robot challenges, advanced prostheses and even neuroscience applications that seem tailor-made to meet civilian preoccupations.

But while Weinberger paints a clear picture of how all the techie gadgetry evolved into DARPA's current projects, she offers less clarity on where all that counterinsurgency work led. Beyond a shortish few anecdotes on the growing appreciation of big data and the power of manipulating social networks, that tale seems to end abruptly around 2009.

The consequences of military dabbling can have a long tail. Gough Island might have been largely uninhabited by humans, but 50 years later, residents of nearby islands raised questions about the unusually vicious mice that now roam the island (50 per cent heavier than wild mice anywhere in the world) and devastate the bird population.

It is worth asking just what unintended consequences lie in store for today's secret counterinsurgency projects. ■

In place of disease, unease

Vaccination is unlovely but miraculous, says **Sheena Cruickshank**

The Vaccine Race: How scientists used human cells to combat killer viruses by Meredith Wadman, Doubleday

EVERY year, millions of children and adults are vaccinated against diseases that only a few decades ago were terrifying and deadly, including rubella, polio and measles. Meredith Wadman's meticulously researched book begins with the heart-rending account of a baby girl born in 1964 who survived just 16 months before succumbing to the effects of maternally transmitted rubella. She spent only nine days of her life outside hospital.

The fear and horror these diseases cause is a fading memory, and despite the fact that vaccines work, the sceptics are gaining ground, their claims given credence by a handful of Hollywood stars and now by US president Donald Trump.

Vaccination is based on the principle, developed by Edward Jenner in 1796, whereby the body's immune system, inoculated with a killed or weakened pathogen, naturally creates a protective response to the disease.

As well as describing the science, Wadman explores the motives of those involved in the vaccination story, particularly Leonard Hayflick, whose vision of a safer route to vaccination led to a long-running dispute.

Though many early vaccines worked well, side effects were always a concern, sometimes because the virus was still infectious, sometimes because proteins were present that triggered severe immune reactions. Many vaccines were tested, without consent, on prisoners, orphans and even newborn babies.

Early vaccines also used cells from other animals. Often the dead or weakened viruses were grown in monkey cells as these, it was wrongly assumed, contained no transmissible infections. Cell lines from human tumours did exist, but were considered unsafe: what if cancerous cells were transferred along with the vaccine?

Wadman describes the scandalous cover-up following the discovery that monkey cells used in vaccinations were infected with a virus, SV40, that could infect humans. Intervention from wealthy non-scientists such as the philanthropist Mary Lasker drove even deeper investment into animal-based vaccines despite growing evidence of their lack of safety and efficacy.

Step forward Hayflick. Based at the Wistar Institute in Philadelphia, he was a gifted young scientist who reasoned that fetal cells derived from a normal pregnancy would be a virus-free and safe alternative for vaccine development. In 1962, he obtained tissue from an aborted fetus, grew the lung cells and created a new cell line, WI-38.

"Many early vaccines worked well, but sometimes the virus was still infectious"

In 1968, Hayflick discovered that the institute's director had filed a patent for the WI-38 cells to be used in a rabies vaccine, but that he wasn't named on the patent. Infuriated, Hayflick left the Wistar, taking all the WI-38 cells with him. As he battled to get the cells licensed and his colleagues recognised for their work, he hid the cells in his garage.

Much has changed. Many modern vaccines use only those parts of the pathogen that stimulate the immune response, so there is no chance of infection. Still, the history of vaccines is not a romantic tale. It's a success story for grown-ups.

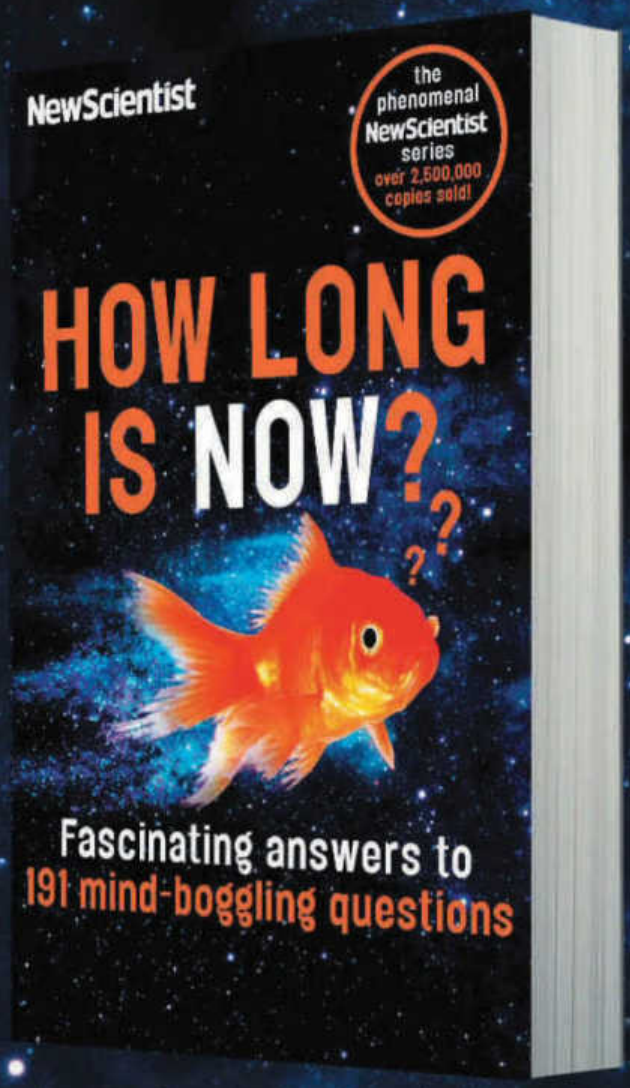
Detailed and discursive, *The Vaccine Race* isn't an easy read. But among its detailed descriptions of cell preparation, discursive descriptions of the issues around abortion, and the story of the discovery that normal cells have a finite lifespan, there is plenty of ammunition for those arguing with family or Facebook friends who have swallowed the conspiracy theories of the anti-vaccination community. ■

Sheena Cruickshank is an immunologist and parasitologist at the University of Manchester in the UK

No contest: if you fear the needle, try reading about the disease

BSIP/UIG VIA GETTY IMAGES

WHY ARE DOGS' NOSES WET?



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TRIUMF is a partner of the Canadian Particle Astrophysics Research Centre (CPARC), a program supported by the Canada First Research Excellence Fund (CFREF). TRIUMF, in partnership with Queen's University, is currently accepting applications for a joint tenure-track Research Scientist position in particle-astrophysics. We invite applications from outstanding scientists who have a proven track record in neutrino or particle-astrophysics, the desire to attract and mentor postdocs and graduate students, and the ability to establish an effective research program as a part of the CPARC program.

The successful candidate will be expected to lead a neutrino physics or particle-astrophysics program at TRIUMF and develop a scientific and technological link with the neutrino and particle-astrophysics physics programs at TRIUMF and SNOLab. TRIUMF was part of the successful SNO experiment, and is currently playing important roles in several SNOLab projects, including EXO-200/nEXO, DEAP-3600, SNO+, and HALO. TRIUMF has also been taking a leadership role in the on-going long baseline neutrino physics program in Japan, T2K, as well as in proposed projects, NuPRISM and Hyper-Kamiokande. In addition, the successful candidate is expected to contribute, develop, and strengthen collaborations between TRIUMF and Queen's University.

Applicants for this position must possess:

- A PhD in particle, particle-astrophysics, or nuclear physics
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This is a full time TRIUMF Board Appointed tenure-track appointment, and is considered equivalent to a faculty position at a Canadian university. In addition, the position is jointly held with the Department of Physics at Queen's University as an Adjunct Professor. TRIUMF offers a comprehensive benefits package and a competitive starting salary commensurate with qualifications and experience. The position is located at the TRIUMF campus in Vancouver. This appointment will be at the equivalent rank of an Assistant Professor, but in exceptional cases other levels can be considered.

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Applications should include a statement of research accomplishments and interests, and arrange for at least 3 referees to submit reference letters directly to the email contact below.

TRIUMF is an equal opportunity employer committed to diversity in the workplace, and we welcome applications from all qualified candidates.

The complete application package should be submitted by email to recruiting@triumf.ca and should include the following in one complete PDF file:

- Subject line: Competition #560
- Employment Application Form
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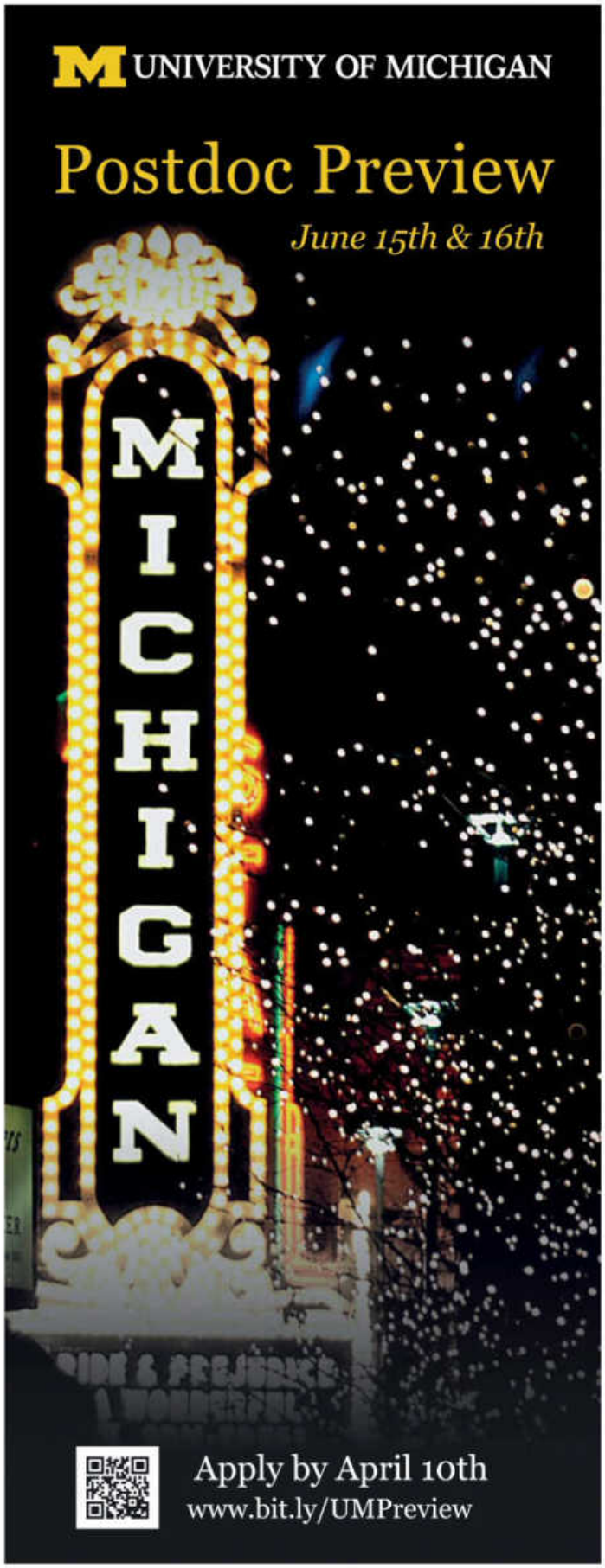
Applications will be accepted until **May 1st 2017**



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EDITOR'S PICK

Extinction is not forever: revival is perennial

From Geoffrey Cox, Rotorua, New Zealand

Sandrine Ceurstemont mentions plans to revive the extinct aurochs, a large ancestor of domestic cattle (25 February, p 37).

When I was a child, back in the 1960s, I subscribed to a magazine called *Animal Life*. In its May 1963 issue, I read (p 13) that German zoologists had, by selectively breeding existing cattle, succeeded "after many years" in recreating the aurochs. There were photos of a cow and bull.

The zoologists were Lutz Heck, Nazi-era director of the Berlin Zoo, and his brother Heinz, director of the Munich Zoo Hellabrunn. The unique features of the resurrected aurochs apparently included improved resistance to disease, especially foot and mouth, and a "wilder" disposition.

After this success the brothers turned their attention to the extinct tarpan horse, and, according to the article, had similar success.

I have since read of other scientists trying to do the same from time to time – most recently the Dutch team mentioned. Shouldn't we be awash with aurochs lookalikes?

Wherever cosmic brains arise, they're a headache

From Toby Pereira, Rayne, Essex, UK

It's interesting to see Sean Carroll using anthropic reasoning to argue that we are not in a universe destined to expand forever (18 February, p 9). Such a universe, he says, would see a proliferation of Boltzmann brains, which would outnumber us. This would make it more likely that a random conscious observer would be one of these random fluctuations than a properly evolved human being – a potentially embarrassing situation for some theories.

It is not enough to argue, as Carroll does, that we are not in such a universe. If Boltzmann brains outnumber "normal" brains, then this is a problem wherever and whenever they are: in our universe trillions of light years distant, or in another corner of the multiverse.

We need to understand exactly what might cause some logically possible universes to exist and not others, or to get a statistical grasp on what would be the case if all logically possible universes exist.

What pattern is hidden in the hidden pattern?

From Chris deSilva, Dianella, Western Australia

So the promising exploration of "hidden patterns" in boiling water has uncovered conformal symmetry (18 February, p 28). That is, features of the pattern look the same under "conformal transformations" that distort space but, within a small region, leave angles unchanged.

Back in 1915, Emmy Noether published her theorem, which states that every system that is

"I'd love to be able to hop to a new world about now"

Melinda Ayres reacts to TRAPPIST-1's planets being close enough for life to jump between them (18 March, p 14)

invariant with regard to a group of symmetries satisfies a corresponding conservation law (25 April 2015, p 33). Is there a conservation law that is the consequence of conformal symmetry? Conservation of what?

Time considered as a sequence of snapshots

From Derek Bolton, Birchgrove, New South Wales, Australia

Anil Ananthaswamy describes Julian Barbour's idea of time as "the universe constantly changing from one snapshot to another" (4 February, p 29). That would retain time as a reality.

I understand Barbour's suggestion as defining time by the small differences between snapshots. Given a collection of detailed snapshots of a system, such that a continuous path can be constructed by placing those with the smallest differences adjacent, we would have a good chance of putting them in an order which we call chronological.

But why should weakly connected parts of the system result in the same order? If I watch an hourglass emptying, snapshots of it can be placed in an order, as can the snapshots of my memory (as a whole, not just of the hourglass), but why should the orders match?

A case for cold dark antigravity antimatter

From Derek Hacking, Ely, Cambridgeshire, UK

I have long wondered whether antimatter would have the same effect on the curvature of space as normal matter, and was delighted to see that this is going to be tested in the next couple of years (7 January, p 28). In the unlikely event that it does turn out that antimatter has a negative gravitational mass, I wonder what this would say about dark matter.

Cold dark matter is now central to our understanding of the evolution of the universe. It provides the scaffolding for the aggregation of normal matter and the formation of galaxies and stars. Could there be cold dark antimatter with a negative gravitational mass? Could aggregations of this explain the normal matter voids that seem to be associated with dark energy, invoked to explain the accelerating expansion of the universe? In other words, could dark energy be explained by cold dark antimatter?

The editor writes:

■ Such a scenario would work if dark antimatter does not gravitationally attract normal antimatter: normal antimatter gives out light just like matter does, and so would not appear to be a void.

Give us this day our carbon-efficient bread

From Peter Cutforth, St Albans, Hertfordshire, UK

Michael Le Page explains that each loaf of bread represents half a kilo of carbon dioxide (4 March, p 14). But without some context, this does not answer the question of whether an intelligent UK consumer should be buying less bread or something else instead.

Bread is actually very efficient in terms of carbon emissions and land use. About 3.5 million tonnes are sold in the UK each year, which is about 150 grams per person per day and about 11 per cent of our daily food intake, allowing for waste. ›

As Le Page says, this causes 0.5 per cent of UK carbon emissions. Growing the wheat used takes only about a third of a million hectares.

So we can take a crumb of comfort: bread is a small problem. Meat and dairy are a different kettle of fish.

Maybe what you don't eat makes veg healthy

From Roger Leitch, Bath, Somerset, UK

Should we be eating 10 portions of fruit and veg a day (4 March, p 19)? I am suspicious of this research and the recommendation coming out of it.

The 10 portions would amount to 800 grams in total. That's a lot.

Analysis should be able to tease out the effects of the quantity of fruit eaten versus those associated with varying amounts of meat, fat, carbohydrates and so forth. My gut feeling is that people who eat a lot of fruit and veg benefit partly because they are also likely to eat less meat than average, and probably a lot less fat.

Thinking about what is impossible to think

From Bernard Mulholland, Belfast, UK

Your Leader proposing that to advance science we must think about the impossible (4 March, p 5) left me wondering whether what we think is constrained by the physical and biochemical construction of the human brain.

What thoughts, visions or dreams might emanate from a brain made of other materials? What effect may communicating these have?

We know that altering the chemistry of the brain can alter its output, don't we? Perhaps we need to experiment more with other aspects of such thoughts, and probe the nature of thoughts.

What do brain scans really tell us?

From Lucy Roberts, Wantage, Oxfordshire, UK

Imagine a study finding that people who report feeling hungry have empty stomachs, followed by the finding that MRI scans of their brains show the "paying attention" part lighting up when you wave a bun in front of them. I don't think this would be widely followed up.

So I don't understand the excitement underlying your article on why some people hate chewing noises (11 February, p 14). All the story appears to say is that MRI scans of people who report feeling angry at certain noises show their brain is responding angrily to these sounds.

In the same issue you interview Daniel Dennett (p 42). If, like him, you do not believe that the mind is a mystical object separate from the brain, then it is not surprising that people's reported experience matches their brain's activity. I believe that our experiences form our brain, and our brain activity forms our experiences, in a complicated dance. What would be interesting is how such an unusual feedback loop arose in the first place.

The editor writes:

■ A first step to understanding a newly recognised condition is detecting brain activity associated with it. We are learning that some people have a physiological reaction to chewing sounds that makes their lives very difficult. Finding that their brains for some reason devote more attention to these sounds weakens other hypotheses, such as the condition being caused by a preoccupation with polite behaviour.

Was echolocation once found in all mammals?

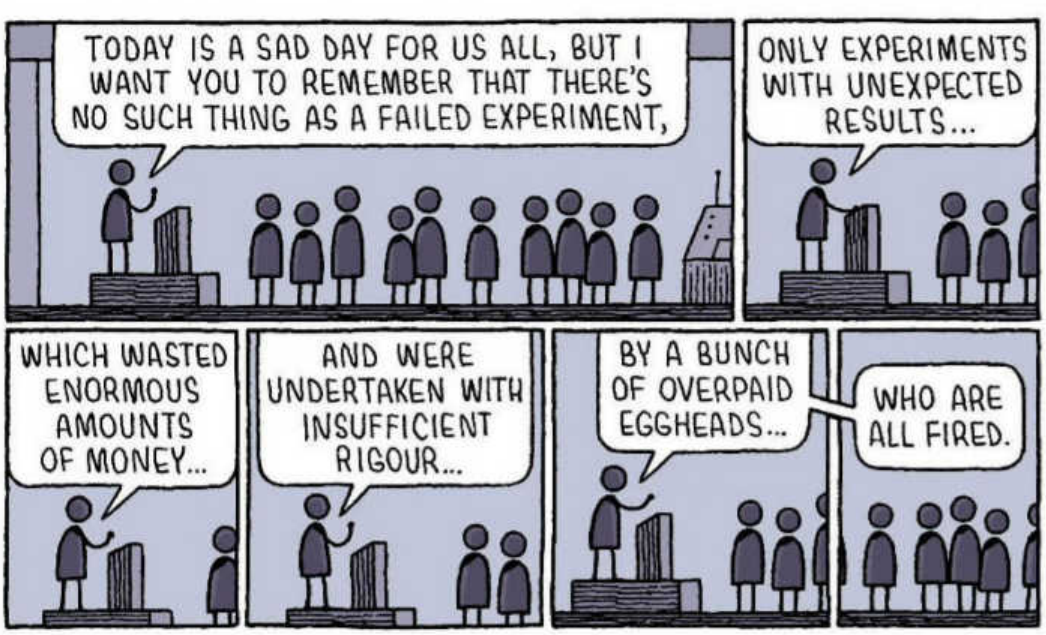
From Gwydion Williams, Coventry, West Midlands, UK

I was interested to learn that the dormouse also has echolocation (25 February, p 20). Echolocation is famously well developed in two groups of mammals, the bats and the dolphins and whales. Now it has been found in rodents as well, which are only distantly related to the others.

The conventional belief would be that these were three separate evolutions of the same unusual system. But I wonder whether it could be a hangover from primitive mammals, who all used it before the various orders of mammals separated. And maybe it was lost in most of them when mammals diversified after the extinction of the dinosaurs.

Mammalian predators might have been using the signals to track prey. They would lose it when there was no longer a strong advantage in keeping it. Life in the ocean, in the air or up trees might mean it retained an advantage.

TOM GAULD



For the record

■ **Water chlorination helps prevent diseases such as dysentery, cholera and typhoid (11 March, p 32).**

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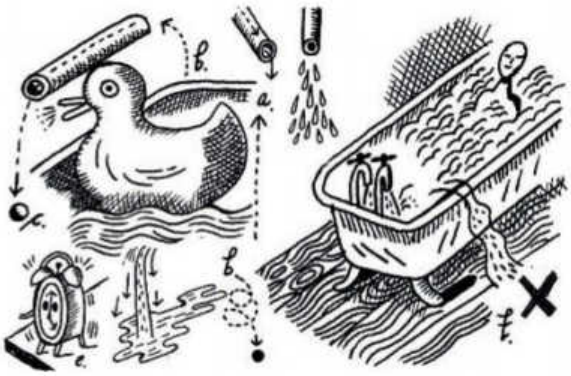

Thrills and spills

Here's a quacking idea for a stress-free soak in the tub. All you need is a rubber ducky, plastic tubing, an alarm system, a ball bearing, a hacksaw...

TAKING a bath is relaxing – but running one isn't. You end up hovering impatiently over the tub as the water level inches up, else risk soggy disaster by not checking on it. I knew there had to be a better way.

My first idea was to point a smartphone camera at the bath's rim. A rubber duck peeking into frame could trigger a motion-detection app and sound an alert. But the bath would be perilously full before Ducky's head reached the brim. Besides, if the handset slipped, I'd ruin my bath and my phone.

My next design involved a siphon, which would drive a waterwheel fitted with a bell once the water reached a certain level. But I didn't fancy putting anything in the bath that I wouldn't normally, and neither did my housemate. We couldn't decide how it would affect the cleaning rota.

Back to the rubber duck. Perhaps I could attach a hollow tube to its head, hinged to a downpipe. As the bath filled, the angle of the tube would change, causing a tinfoil ball inside to roll into the downpipe and land on electrical contacts at the bottom. That would complete a circuit and trigger an alarm. I outlined the idea to my mother. She asked: "Does the alarm quack?" Sadly not.

This design could be tweaked too, by way of Lego bricks glued to Ducky's head and the end of the tube. On days I want room for a layer of foamy bubble bath, I could just add bricks for a shallower bath. And this way, Ducky would be fully detachable, and could join me for a soak afterwards.

One quick visit to the plumbing shop later, I was armed with materials that were both cheap and bathroom-proof. Though small, the buzzer was loud enough for my apartment. The most expensive component was the rubber duck. But sometimes it's worth paying for quality.

Confident in my design, I ran a bath and sat back to watch TV, nearly flooding the bathroom when the foil ball got jammed. At least it was an easy fix: use a ball bearing instead.

It was a tricky build, but at least I got to end it with a relaxing bath. Though maybe next time I'll just use a timer.

Hannah Joshua ■

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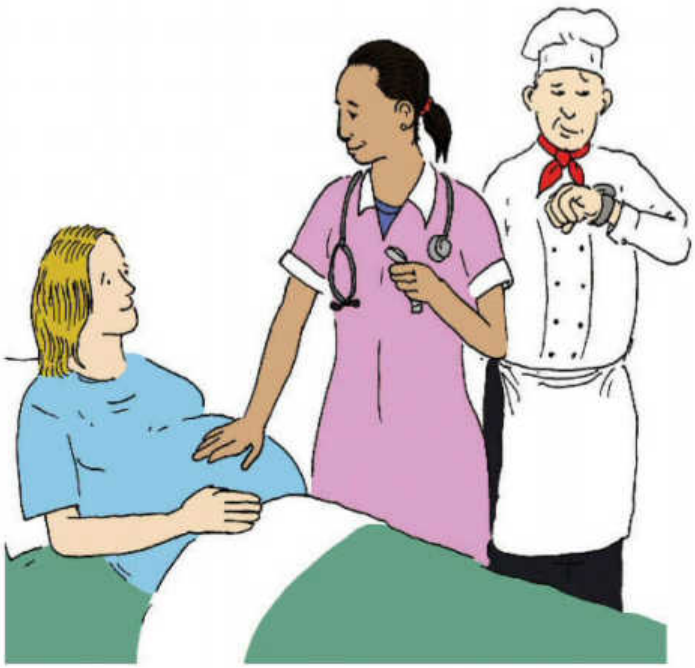

PAUL MCDEVITT

KEEPING up on his celebrity gossip, Michael Zehse discovers that Bo Bruce, star of TV talent show *The Voice*, has made her placenta into edible pills. Bruce (known to her parents as Lady Catherine Anna Brudenell-Bruce), posted a photo on Instagram of a jar containing "raw dried placenta capsules" following the birth of her first child.

Although placentophagy has become fashionable of late, US researchers last year concluded this human offal offers no evident health benefits, even when the placenta is prepared to look like vitamin pills.

There's nothing new in celebrity endorsements of nutritional supplements with questionable health benefits, of course, although a rather queasy Feedback hopes that Lady Bruce's latest product is strictly for personal consumption.

FROM celebrity ruses to celebrity cruises. Our colleagues are currently hard at work developing exciting travel experiences for globetrotting readers. But even they might struggle to compete with the offer spotted in Toronto's *Globe and Mail* by Richard Van de Wetering.

Travel firm Celebrity Cruises offers a 12-day voyage from Southampton to Iceland and back (Feedback is not sure if this involves sailing with celebrities, or in hot pursuit of their luxury yachts). Richard notes that in the itinerary given, "day two makes the trip special, and worth the $4100 per person cost, as the ship is scheduled to call at Sydney, Australia".

Feedback is aware the new Northwest Passage promises to slash seafaring travel times, but this is still a remarkable overnight journey from Dublin.

PREVIOUSLY Feedback reported on hue and cry in the art world, after Anish Kapoor monopolised the supply of Vantablack, the world's darkest paint. This led Stuart Semple to release a series of intense pigments that are available to everyone except Kapoor (4 March).

Chris Barrett recalls shades of grey in a classroom description of black body radiation many years ago. "Those of your readers who learned their physics in the 60s and 70s may remember *Advanced Level Physics* by M. Nelkon & P. Parker," he writes. "I was always amused by their description of the black body: 'The effect of multiple reflections is then to convert the body from nearly black to very nearly black indeed'."

MEANWHILE, Neil Dale writes to point out that "many painters, including myself, never use any kind of black pigment. Instead we use a mix of alizarin crimson and phthalo green. It makes the blackest black."

Both of these are molecular dyes, he explains, not particulate pigments. "If you want a black 'pigment' you have already gone wrong before you even start, as particulate pigments always scatter some light." That's another black mark on our report card.

AND lastly, James O'Neill is getting into the spirit of the affray after dreaming up a new shade of green for last week's St Patrick's Day celebrations.

"I thought I'd succeeded," he says, "but it turned out to be a pigment of my imagination."

WHILE driving through Kent recently, Roy Brown was surprised to see a van marked "Kent Police: Crime Support Unit". He says: "I knew that police corruption was a problem in some parts of the UK, but was not aware that it had become quite so blatant."

ON THE subject of automatically truncated text: perhaps craving more exciting messages, Peter Duffel's email software is making its feeling known on the contents of his inbox.

A recent email had its subject shortened to "Reforming European VAT: Boo".

COMBINING two of our favourite things, Howard Bobry points out that "the Centre for Homeopathic Education (4 March) is an example of nominative determinism at an organisational level." This institution, he says, "appears to be a practice administering minute doses of knowledge, which would be symptomatic of acute fruitloopery if administered in larger amounts."

BROWSING *New Scientist* over breakfast, Lindsay Write spies the headline "Ceres serves up an organic feast on its surface" (25 February, p 12), while dining on Ceres brand organic toasted muesli. A dwarf planet covered in breakfast cereal could tempt her, spoon in hand, to the nearest rocket launch pad, says Lindsay, "but the tarry substance described doesn't sound at all appetising".

THOSE who settle down with John Scalzi's new audiobook *The Collapsing Empire* are likely to finish it before their tea goes cold, says Kim Caulfield. She noticed the running time advertised in a promotional email clocks in at a succinct 0 hours and 0 minutes.

"It is unabridged," Kim writes, "though I'm not really sure how you could abridge a book of this length."

A valet machine tells Colin MacLeod "This machine accepts £1 coins only. Please note that this machine does not contain cash." "Where does the money go?" wonders Colin.

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Spider shroud

I went on holiday for two weeks and returned to find this ghostly impression of a spider on our toilet roll (see photo), but no spider or spider body anywhere around. How did the spider cause this pattern?

■ A fossil is the remains or trace of an ancient organism preserved in a substrate, usually sedimentary rock. This spider impression could be a modern-day equivalent, perhaps captured during the manufacture of the toilet paper.

In the production process, wet, fibrous pulp is spread on a flat screen that runs through a very hot dryer, which almost immediately converts the pulp to thin paper. This is then embossed, rolled, cut and packaged. If the spider had fallen onto the pulp, it could have been cooked and vaporised, leaving just its ghost behind.

Alternatively, the spider could have been trapped during the embossing (which you can see just under the mark), with its remains falling from the paper in the course of the rolling process. If the arachnid had been trapped during rolling, your questioner would have had more than just an imprint on his toilet paper.
David Muir
Edinburgh, UK

■ The spider is not guilty. It was taking a statutory mid-morning tea break (note the colour of the image) when the mill machinery started rolling and it was then destined to become part of The Last Word history. Your correspondent should not reproach himself for missing this before his holiday: loo-roll study ranks several orders of interest below watching paint dry.
Philip Leonard
Tidenham Chase, Gloucestershire, UK

■ Does this means that someone has a roll with the ends of the other four legs showing?
Dan Trinder, aged 10
London, UK

■ Although the image looks like a spider, I don't think that it is of animal origin. It is more likely to be a stain on the paper caused by plant juice, aftershave lotion or even white wine.

It is significant that your correspondent was away for two weeks, because many initially clear plant juices or organic materials will oxidise on paper or fabric over a period of weeks to produce a deep brown stain, similar to that in the picture.
J. A. Crofts
Sherwood, Nottinghamshire, UK

Solar panel supernova

What effect would a coronal mass ejection or a solar flare have, if any, on a typical photovoltaic solar panel system found on a house?

■ Solar events should not affect photovoltaic panels much more than they do most other electrical equipment.

Flares and ejections deliver charged particles and associated electric and magnetic field fluctuations that induce current surges in conductors. Surges powerful enough to destroy solar panels would probably incapacitate so much infrastructure nationwide that damage to local panels would be a peripheral concern.

"Earth's magnetic field steers charged particles such as electrons and protons into polar auroras"

As for direct impact from the charged particles – mainly electrons and protons – Earth's magnetic field largely steers them into polar auroras, but even if the planet's magnetic shielding were to fail completely, hardly any charged particles could penetrate our atmosphere to affect the panels.

Any increase in the intensity of light from plausible solar events would be negligible compared with the amount that the photovoltaic cells and their panels could absorb and process in their generation of power.

Hypothetical increases in the intensity of incoming visible or ultraviolet light sufficient to harm the equipment would be so deadly for living creatures that the fate of solar panels would not be a primary concern.
Jon Richfield
Somerset West, South Africa

This week's questions

TOUCH OF FROST

If I park my car overnight on an open driveway in cold weather, I have to scrape frost from all of its windows in the morning. But if I park it under the adjacent carport, which is open on all sides but has a roof, no frost forms. Why does a roof make such a difference?
Judy Murfitt
Coulsdon, Surrey, UK

POINT OF IMPACT

Why can I only see round craters on the moon and on other bodies in the solar system? Surely not all of the impacts can be at right angles to the surface. What am I missing?
Chris Exley
By email, no address supplied

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